WHAT IS A SPORTS CAR?

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ABSTRACT

Principal component analysis is employed to construct a new formula defining 'sports cars', a classification variable commonly used by Belgian insurers in motor insurance. Five hundred and eighty-one different car models were used in the design of the formula. It is based solely on the cars' technical characteristics and hence does not rely on the subjective opinion of experts; the resulting classification is independent of units of measurement employed. Thus the definition is suitable for application world-wide.

KEYWORDS

Principal component analysis, establishment of motor insurance tariffs, sports cars.

1. INTRODUCTION

The Belgian automobile market is wide open to competition. There is no 'Belgian car', and the country is small and boasts an excellent network of motorways. It is not difficult for a foreign car manufacturer to enter the Belgian market. The cost of establishing a chain of dealers and workshops is modest. Moreover, foreigners do not have to confront established domestic manufacturers as would be the case in, say, France or the US. As a result, Belgian consumers have the privilege of being able to choose among no less than 581 different models.

For the insurers, there is a marked drawback in having so many different car models in such a small market, shared by over 100 companies: claim statistics for car models are unreliable. Until a few months ago, companies were not even required to provide statistics by car model to the Automobile Statistics Commission of the Professional Union of Insurance Companies. Hence such data are for the moment totally unavailable, and other variables than 'car model' need to be used for tariff purposes.

In establishing their rates, Belgian insurers have always used a variable called 'vehicles of a sporting nature', i.e. sports cars. The statutory tariff for third-party liability penalizes sports cars brought on to the road before 1 July 1971 by a supplement of 40% on top of the basic premium for business use. In other lines (fire, theft, collision, etc.) there is no statutory tariff. Nevertheless, most companies treat sports cars in a special fashion. For instance, the underwriting standards for sports cars in one large company are as follows:

in collision coverage, to require the largest available deductible and apply a surcharge of 40%, and
in theft insurance, to require an electronic security system.

By definition, a vehicle is said to be of a sporting nature iff

$$\frac{W}{P}\sqrt[3]{S}\sqrt[4]{cc} < 17,$$

where

W is the weight of the car, in kilograms,
P is the power of the engine, in DIN horse-power,
S is the number of seats, and
cc is the engine cubic capacity, in litres.

This formula was devised in 1971 by a well-known Belgian Grand Prix driver (it is also used in rally and endurance racing, to subdivide the competitors into classes). Clearly, it is not exempt from criticisms:

(i) it is extremely sensitive to the number of seats, a variable which is not well defined;
(ii) it does not take into account the recent technological evolution in the construction of engines (introduction of turbos, improvement in diesel engines, LPG, ...);
(iii) the use of third and fourth roots has no physical justification;
(iv) as the formula classifies all vehicles into two categories only, awkward border-line cases were bound to arise. For instance, a BMW 528I is of a sporting nature, while the more expensive and slightly heavier BMW 728I is not. Yet both cars have identical engines! This lead to bittersweet discussions with the importer, who claimed that his customers could avoid the surcharge by always carrying a heavy bag in their trunks!

In an article entitled 'Fraud', a leading specialized automobile journal presented six car models (Audi 80 GTE, VW Golf GTI two and four doors, VW Jetta GT two and four doors, VW Scirocco GTX), with the same engine, power, cubic capacity and number of seats. Due to slight weight differences, four of the models are of a sporting nature, two are not. A VW JETTA with two doors is a sports car, while the four door version is not!

It is obvious that the formula has its flaws. Moreover, the classification 'sports car' is itself a questionable notion. After all, sports cars are not dangerous *per se*; those who buy and drive them are the risks. Thus 'sports car' is at best a proxy variable for 'driver who behaves aggressively'. In fact, the objective is to characterize the 'sports car driver' by the vehicle s/he is likely to buy. In spite of all of this, the claim statistics presented in Table 1 show that 'vehicle of a sporting nature' remains a highly significant variable.

These statistics persuaded the Automobile Technical Commission of the Professional Union of Insurance Companies to appoint a study group, composed of actuaries, engineers and practitioners, to establish a new formula. The initial conclusions of the study group were as follows:

1. The formula should be of the multiplicative type, for technical reasons (e.g. the engineers of the group felt that the variable 'weight/power' makes more sense than any linear combination of 'weight' and 'power');
2. It should only include well-defined parameters. This requirement led to the deletion of variables like 'top speed' or 'minimum time to reach 100 km/h', for which there is no international standard of measure: the values provided by the manufacturers depend on weather and road conditions, on the type of tyres, ... The selected parameters were

   the power of the engine, in kw din;
   the weight of the car, in kg;
   the cubic capacity of the engine, in cc;
   the maximum torque (couple), in Nm din;
   the maximum engine speed, in rounds per minute.

3. The construction of the formula should if possible be 'expert-free'; in other words, the classification of a given vehicle should only depend on objectively measurable performance standards, and not on a necessarily subjective evaluation by an expert. One consequence is that the new

TABLE 1

CLAIM STATISTICS FOR ORDINARY AND SPORTS CARS FROM A MAJOR COMPANY

Ordinary cars			Sports cars	
Claim frequency	Average claim amount (BF)	Year	Claim frequency	Average claim amount (BF)
0.124	42,352	1976	0.134	228,057
0.127	46,841	1977	0.157	32,252
0.121	48,328	1978	0.127	420,430
0.119	54,375	1979	0.142	280,216
0.109	63,026	1980	0.106	44,594
0.105	73,141	1981	0.141	36,094
0.098	79,299	1982	0.132	39,412
0.096	93,349	1983	0.132	1,990,334
0.098	105,280	1984	0.144	30,346
0.111	92,796	1985	0.170	230,777
0.102	88,662	Average 1981/1985	0.143	440,952
0.111	69,980	Average 1976/1985	0.139	312,600

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definition will consider only technical characteristics of car; no attempt is made to consider manufacturers' 'images' on consumers' minds.

All the models registered on 1 January 1986, 581 in total, were compiled in a data base (where several slightly differing variants of a model are marketed, only one was considered). Five models (the three Bentleys and the two Rolls Royces) had to be eliminated, since the importer did not disclose the values taken by several variables. Since there are only 96 Bentleys and 221 Rolls Royces in Belgium, these deletions are insignificant. Noteworthy is the near-absence of American models: the high US dollar, near its peak in January 1986, priced US-manufactured cars out of reach of most Belgian motorists. It should also be noted that all car models received an equal weighting in the statistical analysis: a technical formula defining sports cars should of course not depend on market shares. Analyses performed on sub-groups of cars led essentially to the same formula, which appears to be extremely robust as regards the models in the data base.

2. STATISTICAL RESULTS

The statistical method used was principal component analysis, performed on the logarithms of the variables so as to linearize multiplicative formulae.

Principal component analysis is a multivariate technique whose main purpose is to derive a small number of linear combinations (principal components) of a set of variables that retain as much of the information in the original variables as possible. It aims at reducing the number of variables necessary to describe the data, while losing the smallest possible amount of information: very often a small number of principal components can be used in place of the original variables. Given a data set with p numeric variables, p principal components may be computed; each one is a linear combination of the original variables with coefficients equal to the eigenvectors (customarily taken with unit norm) of the correlation matrix. The principal components are sorted by descending order of the eigenvalues, which are equal to the variances of the components. Principal components have a variety of useful properties:

The eigenvectors are orthogonal; so the principal components represent jointly perpendicular directions through the space of the original variables.

The principal component scores are jointly uncorrelated.

The first principal component has the largest variance of any unit-length linear combination of the observed variables. The jth principal component has the largest variance of any unit-length linear combination orthogonal to the first $j-1$ principal components. The last principal component has the smallest variance of any linear combination of the original variables.

The first j principal components are the best linear predictors of the original variables among all possible sets of j variables.

The five following variables were used in the analysis, after standardization in order to eliminate the influence of measurement units.

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$x_1 = \log(\text{weight/power})$,
$x_2 = \log(\text{power/cubic capacity})$,
$x_3 = \log(\text{maximum torque})$,
$x_4 = \log(\text{maximum engine speed})$,
$x_5 = \log(\text{cubic capacity})$.

Table 2 shows the high correlations between the variables.

The main results of the principal component analysis are summarized in Table 3.

Thus, 92.86% of the total variance is explained by the first two components, whose interpretation can easily be obtained by their correlation with the original variables, top speed and minimum time to reach 100 km/h.

The correlations with the first principal component (see Table 4) indicate that, the higher the score of a car model on the axis, the faster it can go (correlation: 0.96), the shorter the time necessary to reach 100 km/h (−0.96), the lower its weight/power ratio (−0.97), the higher its maximum torque (0.88) and its specific power (power/cubic capacity; 0.80).

The correlations with the second principal component indicate that the higher the score of a car model on this axis, the higher its engine speed (correlation: 0.78) and its specific power (0.51) but the smaller its cubic capacity (−0.68) and its maximum torque (−0.46). This axis is roughly orthogonal to the time to reach 100 km/h (−0.06), the weight-power ratio (−0.08) and the top speed (−0.16).

Clearly, the first principal component characterizes the sporting nature of a model, while the second component describes the technical characteristics that lead to it; for instance, small, fast, 'nervous' cars (Golf GTI, Peugeot 205

TABLE 2

CORRELATIONS BETWEEN VARIABLES

	x_1	x_2	x_3	x_4	x_5
x_1		−0.8165	−0.7960	−0.5146	−0.6090
x_2			0.4779	0.6911	0.1545
x_3				0.0835	0.9200
x_4					0.1007

TABLE 3

PRINCIPAL COMPONENT ANALYSIS — MAIN RESULTS

Principal components	Eigenvalues	Variances (proportion)	Cumulative variances (proportion)
1	3.0960	0.6192	0.6192
2	1.5468	0.3094	0.9286
3	0.2766	0.0553	0.9839
4	0.0675	0.0135	0.9974
5	0.0132	0.0026	1.0000

TABLE 4

Correlations Between Principal Components and Variables

Variables	Axis 1	Axis 2
x_1	−0.9714	−0.0800
x_2	0.7962	0.5136
x_3	0.8789	−0.4569
x_4	0.5022	0.7796
x_5	0.7026	−0.6783
x_6 (= log(top speed))	0.9561	−0.1597
x_7 (= log(time 0–100 km/h))	−0.9567	−0.0610

GTI, ...) score high on both axes, while large, powerful cars (Mercedes 560 SEL, Citroën CX GTI Turbo, ...) score high on the first axis but low on the second. Most of the lower performing cars and the majority of diesels score low on both axes.

Since the first principal component characterizes the sporting nature of any car, it is only natural to define the new formula along the axis, using the eigenvector coefficients.

The formula is

$$F = -1.7326x_1 + 1.8671x_2 + 1.1889x_3 + 2.7410x_4 + 1.1164x_5.$$

As intuitively expected, there does not exist a clear-cut separation between sports cars and ordinary cars, but rather a continuum of models. It was then decided to partition the models into 10 classes, according to the deciles of the distribution. Class boundaries are as follows

Class		$F \leqslant$		
1		$F \leqslant$	24.6786	(least sporting nature:
		$F \leqslant$		αιτϱοεν 2αΘ, Ρεναυλτ P4, ...)
2	24.6786 <	$F \leqslant$	25.4644	
3	25.4644 <	$F \leqslant$	25.9273	
4	25.9273 <	$F \leqslant$	26.4425	
5	26.4425 <	$F \leqslant$	26.8888	
6	26.8888 <	$F \leqslant$	27.3174	
7	27.3174 <	$F \leqslant$	27.8669	
8	27.8669 <	$F \leqslant$	28.5168	
9	28.5168 <	$F \leqslant$	29.3679	
10	29.3679 <	$F \leqslant$		(most sporting cars: Ferraris, Πορsϑηε 911 ααϱϱεϱα, ...)

The classification does not depend on the units of measurement; if, for instance, HP din are used instead of kW din, the class boundaries will need to be modified, but each model will remain in the same class.

Part of the classification is to be found in the Appendix.

TABLE 5

CLASSIFICATION OF ALL MODELS: OLD AND NEW FORMULA

Class (new formula)	1	2	3	4	5	6	7	8	9	10	Total
Sports (old formula)	0 0%	0 0%	0 0%	0 0%	0 0%	1 1.72%	7 12.28%	24 41.38%	34 58.62%	50 87.72%	116 20.14%
Ordinary (old formula)	57 100%	58 100%	58 100%	57 100%	58 100%	57 98.28%	50 87.72%	34 58.62%	24 41.38%	7 12.28%	460 79.86%

3. COMPARISON WITH OLD FORMULA

Table 5 compares the results given by the old and new formulae; for instance, the first sports car (as defined by the old formula) appears in class 6 of the new definition. Seven models which were formerly not considered as sports cars are now assigned to class 10.

Figure 1 shows the position of all models along the two axes. Sports cars (according to the old formula) are indicated by a '+', ordinary cars are shown by a '○'. Thus the old formula provided some degree of consistency in that it selected the upper-right part of the figure: most of the sports cars, according to the old formula, are to be found above a diagonal straight line. Clearly the deviser of the 1971 formula sought to combine technical characteristics with the external aspect of the car: small, 'zippy' cars were classified as sports cars; on the other hand large, powerful cars (with the same power but a less 'appealing look') were not.

4. SHOULD ENGINEERS BE TRUSTED?

The old formula selects as sports cars the models which fall into the upper-right part of Figure 1, above the diagonal. The new formula proceeds by horizontal lines. This difference results from the study group's decision to use only the technical characteristics of the models in the definition: this is the major assumption behind the entire analysis.

Yet the people who buy fast cars are not necessarily engineers. Are they influenced purely by technical considerations in their selection process, or do they also base their decision on external aspects of the cars?

To provide a tentative answer to this key question, four people (two experts and the two top executives of the automobile department of a large company) were independently asked to classify all 581 models according to their own feelings. They were provided with photographs and characteristics of all cars, but with no other instructions than to classify the models into seven (for experts) or four (for executives) categories. Their decisions were then plotted on Figure 1 to check whether horizontal or diagonal lines would emerge. The results are presented in Figure 2 (where for reasons of legibility models are subdivided into three categories only).

With few inconsistencies, they clearly favour the new formula, as class boundaries tend to form horizontals rather than diagonals.

Note: The problem of classifying car models for insurance tariff purposes is of course not new. In the recent past, authors have used cluster analysis and credibility theory to improve the quality of the experts' subjective decisions: the most relevant references are CAMPBELL (1986) and SUNDT (1987). It seems worthwhile to stress again the main difference between most approaches and the one used here: we only use the models' technical characteristics; no use is made of claim statistics, for the simple reason that they are not available in our country.

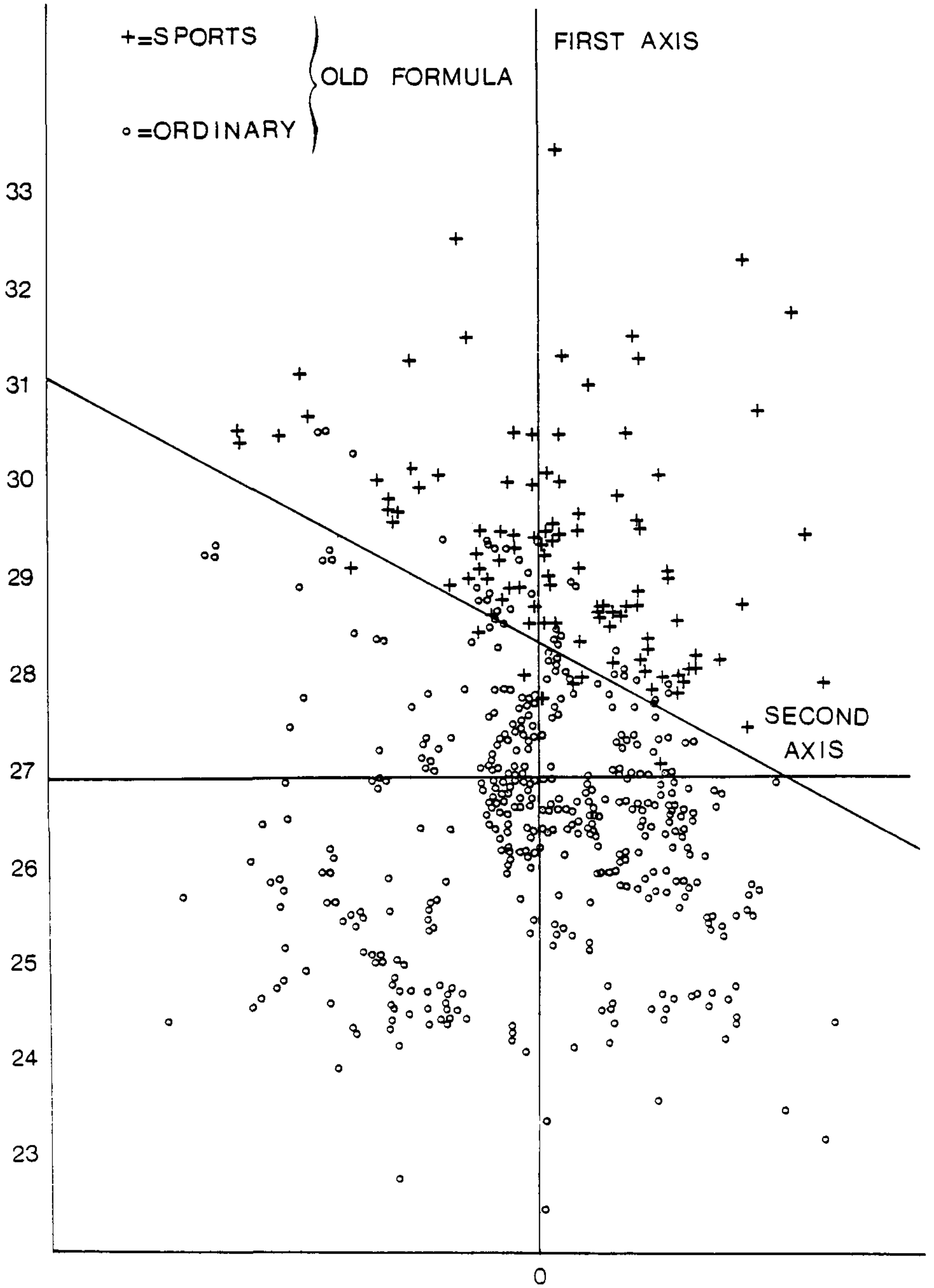

FIGURE 1. Representation of all cars in main plane

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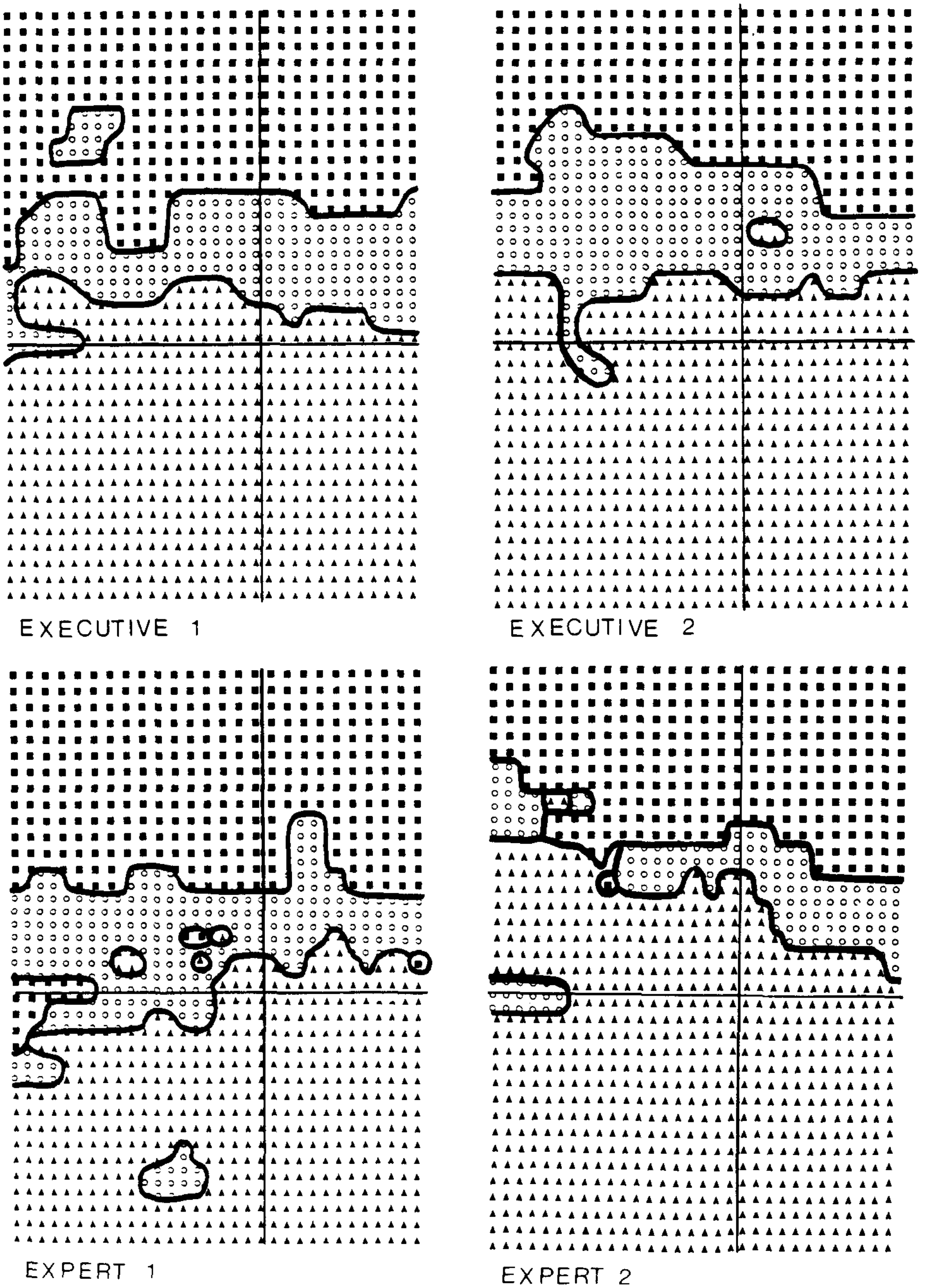

FIGURE 2. Classification by four people

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APPENDIX: A SELECTION OF CAR MODELS

For the sake of brevity, only 100 car models are listed. They are subdivided according to the new formula, 10 in each class. The table is to read as follows.

Column 1: manufacturer,
2: car type,
3: car model,
4: cubic capacity (cc),
5: maximum power (kW din),
6: maximum torque (Nm din),
7: number of seats,
8: car weight (kg),
9: maximum engine speed (r/min),
10: time taken to reach 100 km/ (seconds),
11: top speed (km/h)
12: classification according to the old formula
(0 = ordinary; 1 = sports).

	1	2	3	4	5	6	7	8	9	10	11	12
C	Austin	Rovermini	Ehlemayair	998	31	67	4	620	5000	19.5	129	0
L	Citroën	Visa	Baseclub	652	25	49	5	755	5500	26.2	125	0
A	Citroën	2CV	Specialton	602	21	39	4	585	5750	.	115	0
S	Fiat	Panda	34	850	25	60	5	680	5250	32.3	125	0
S	Opel	Ascona2	LS1.6D	1598	41	96	5	1015	4600	21.0	143	0
	Renault	R4	Berlinetl	845	21	56	4	695	4500	.	115	0
1	Renault	R5	C	956	31	65	5	695	5750	19.3	137	0
	Volkswagen	Golfdiesel	C/CL/GL	1588	40	100	5	900	4500	18.7	148	0
	Volvo	300	340Basesel	1596	40	100	5	1030	4800	20.0	140	0
	Wartburg	Berline	WWLSSL	992	37	98	5	920	4250	.	130	0

(*Table Continued*)

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	1	2	3	4	5	6	7	8	9	10	11	12
C	Daihatsu	Charade	TSDT	993	37	91	5	705	4800	.	150	0
L	Ford	Escort	Custom	1117	37	83	5	790	5000	17.2	144	0
A	Innocenti	S	SLSE	993	38	75	5	670	5600	17.4	145	0
S	Lada	1200	Economyn	1198	44	87	5	970	5600	.	140	0
S	Peugeot	205	XE1.0	954	33	69	5	785	6000	18.8	134	0
	Skoda	Type 130	LLXGLS	1289	43	103	5	885	5000	15.0	150	0
2	Talbot	Samba	Lssympahia	1124	37	82	4	740	4800	18.2	143	0
	Volkswagen	Jetta	C/C/GL	1595	55	125	5	900	5000	17.2	149	0
	Volkswagen	Passatvant	C/CL	1297	44	100	5	985	5600	17.5	148	0
	Volkswagen	Polo	CoachC/CL	1043	33	74	5	730	5600	19.5	142	0
C	Audi	80	Base	1588	40	100	5	980	4800	15.5	151	0
L	Ford	Sierra	Berline	1593	55	121	5	1030	4900	14.1	165	0
A	Mercedes	SerieW124	D250	2437	66	154	5	1320	4600	16.2	175	0
S	Mitsubishi	Lancer	Break18GLD	1796	60	108	5	1025	4500	.	145	0
S	Nissan	Cherry	1.3DX1.SAR	1270	44	100	5	785	5600	14.4	155	0
	Opel	Record	LSGLGLS3TD	2260	63	189	5	1245	4200	15.0	168	0
3	Rover	SD2	2400S	2393	68	193	5	1475	4200	16.1	165	0
	Seat	Ibiza	1.2L	1193	46	88	5	900	5800	16.0	155	0
	Toyota	Starlet	1000L	999	40	75	5	780	6000	.	150	0
	Zastava	Yugo	55L55GLS	1116	40	80	4	790	6000	.	145	0
C	Fiat	Regata	70C	1301	50	100	5	890	5700	13.5	155	0
L	Lada	2105	GL	1452	55	106	5	1030	5600	.	148	0
A	Lancia	Prisma	Turbodisel	1929	59	172	5	1015	4200	16.0	158	0
S	Mazda	323	1300LX	1296	50	95	5	865	6000	12.4	147	0
S	Opel	Corsa2	GLS1.3SB	1297	51	101	5	805	5800	13.0	163	0
	Subaru	Coupe	1.6GL	1595	54	137	5	990	5200	.	160	0
4	Suzuki	Swift	1.3GA1.3GL	1324	50	104	5	700	5300	11.7	163	0
	Toyota	Cressida	StationLTD	2466	63	188	5	1370	5600	14.2	155	0
	Toyota	Tercel	Station4WD	1452	52	108	5	1000	5600	15.5	155	0
	Volkswagen	Scirocco	GT	1595	55	125	5	875	5000	12.2	167	0
C	Alfa Romeo	33	1.3L	1350	58	111	5	890	6000	.	167	0
L	Ford	Fiesta	SGHIA	1296	51	100	5	775	6000	12.2	163	0
A	Ford	Sierra	BerlineL	1796	66	137	5	1060	5400	11.8	178	0
S	Honda	Civic	1.3DX	1342	52	105	5	777	6000	11.5	157	0
S	Mazda	929	2000Estate	1970	66	154	6	1185	5000	11.4	157	0
	Mercedes	SerieW124	300D	2996	80	185	5	1370	4600	13.7	190	0
5	Mitsubishi	Colt	1500GLX	1468	55	118	5	820	5500	12.7	160	0
	Peugeot	305	GL	1472	54	116	5	995	6000	13.2	156	0
	Toyota	Corolladan	Stop	1295	55	107	5	965	6000	14.1	160	0
	Volvo	760	GLEDT	2383	80	190	5	1375	4800	12.5	175	0
C	BMW	Serie3	316	1766	66	140	5	990	5500	12.2	175	0
L	Citroën	CXBerlines	20RE	1995	77	163	5	1235	5500	12.1	177	0
A	Honda	Accord	1.6LX	1588	65	122	5	1028	6000	11.9	176	0
S	Mercedes	SerieW124	200T	1997	80	170	5	1390	5200	13.6	180	0
S	Peugeot	205	GT	1360	59	110	5	820	5800	11.6	170	0
	SAAB	90	GL	1985	73	162	5	1115	5200	14.0	165	0
6	Seat	Malaga	1.5GLGLXS	1461	67	116	5	975	5600	13.0	165	0
	Volvo	240	DL	1986	74	160	5	1230	5400	13.3	165	0
	Volvo	740	BreakGLETD	2383	80	205	7	1390	4800	13.5	175	0
	Bertone	X1/9	1.5	1498	63	118	2	920	6000	11.7	180	1

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	1	2	3	4	5	6	7	8	9	10	11	12
C	Audi	100	Base	1994	85	170	5	1250	5200	10.7	190	0
L	BMW	Serie5	518I	1766	77	145	5	1140	5800	12.6	175	0
A	Mercedes	SerieW201	190	1997	77	170	5	1080	5500	12.4	185	0
S	Opel	Manta	GSI	1979	81	162	5	1065	5400	10.0	192	0
S	Renault	R25	GTX	2165	90	181	5	1285	5250	10.3	195	0
	Saab	900	GLI	1985	87	167	5	1140	5250	12.0	175	0
7	Volkswagen	Passatvant	GT	1994	85	165	5	1105	5400	10.8	182	0
	Ford	Fiesta	XR2	1597	71	132	5	850	6000	9.9	180	1
	Lancia	Y10	Turbo	1049	62	123	5	790	5750	9.6	180	1
	Volkswagen	Sicrocco	GT-GTX	1781	82	153	5	920	5200	9.1	191	1
C	Alfa Romeo	75	1.8	1779	88	167	5	1060	5300	9.5	190	0
L	Jaguar	Serie3	X163.4	3442	129	255	5	1770	5250	9.8	188	0
A	Mercedes	SerieW124	230E	2299	100	205	5	1280	5100	10.4	203	0
S	Mercedes	SerieW201	190E	1997	90	178	5	1100	5100	10.5	195	0
S	Peugeot	505Berlines	GTI	2165	90	189	5	1280	5750	10.0	183	0
	Volvo	740	BreakGLE	2316	96	190	5	1360	5400	10.5	182	0
8	Citroën	Visa	GTI	1580	76	134	5	870	6250	9.1	188	1
	Fiat	Ritmo	105TC	1585	77	133	5	905	6100	9.5	180	1
	Fiat	Uno	Turbo	1301	77	147	5	845	5750	8.3	200	1
	Peugeot	205	GTI	1580	76	132	5	855	6250	9.5	190	1
C	Bitter	SC	Coupe	2968	132	248	4	1560	5800	9.6	215	0
L	BMW	Serie7	728I	2788	135	240	5	1510	5800	9.5	201	0
A	Citroën	CXBerlines	25GTITurbo	2500	122	290	5	1385	5000	8.0	220	0
S	Volvo	760	Gleautoque	2849	115	235	5	1305	5700	10.5	185	0
S	Morgan	Plus8	2.0LCarbu	3528	116	267	2	940	5250	.	200	1
	Porsche	924	S	2479	110	195	4	1190	5800	8.5	215	1
9	Porsche	944	B	2479	116	205	4	1210	5800	8.4	220	1
	Renault	Alpine	V6	2849	118	221	4	1140	5750	8.0	235	1
	TVR	280I	Convertible	2792	110	221	2	1130	5700	7.8	214	1
	Volkswagen	Golfbernes	GTI16V	1781	102	168	5	960	6100	8.5	208	1
C	Maserati	Quattro	Porte	4930	205	392	5	1940	5600	.	230	0
L	BMW	Serie5	528I	2788	135	240	5	1300	5800	8.4	215	1
A	De Tomaso	Longchamps		5763	206	441	5	1700	5600	7.0	240	1
S	Ferrari	328GTD	3186	3186	199	304	2	1375	7000	.	260	1
S	Jaguar	Serie3	XJSV12Cupe	5345	217	432	4	1755	5500	7.6	241	1
	Lamborghini	Countachs	Quattroole	4754	335	500	2	1490	7000	4.8	298	1
10	Lotus	Esprit	S3	2174	115	217	2	1100	6500	7.2	222	1
	Mercedes	Classe	560SEL	5547	220	455	5	1810	5000	7.2	245	1
	Porsche	911Carrera	Turbo	3299	211	430	4	1335	5500	5.4	260	1
	Renault	Alpine	V6Turbo	2458	147	285	4	1210	5750	7.0	250	1

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