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RELATIONS BETWEEN MANUFACTURING COSTS AND VOLUMES OF PRODUCTION IN THE AUTOMOBILE INDUSTRY

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- C O N T E N T S -

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Chapter 1

General Data on the Automobile Industry

1.1 The importance of the automobile industry in the national economy

1.1.1 Its effect on the national product - example of an industrialized country

A) The automobile industry is a factor of prime importance in the economy of an industrialized country. This is why a vast majority of the industrializing countries are interested in the development of a "national" automobile industry. Such an industry may very well play a leading role in local industrial development. In fact, not only will the automobile industry have an important effect on the national product of those countries, it will also generate growth and development in many related industries.

Thus, in order to give an example of a developed country, France produced 2'075,000 private and commercial automobiles in 1968. This represents total sales amounting to 25 billion French francs, all taxes included; that is, 3% of the total amount of sales of all French industrial and commercial enterprises.

B) The automobile industry may be considered a basic industry: an analysis of the intersectorial exchanges of this branch shows that it constitutes an important customer for the iron and steel industry, the glass industry, the rubber industry, etc.

In France, for example, the automobile industry consumes:

12% of the iron and steel industry production,
50% of the alloy steels production,
32% of the thin steel sheets production,
8% of the aluminum production (thus, it is (its first customer),
52% of the rubber manufactures,
7% of the glass production,
5% of the textile production.

Moreover, it represents approximately 20% of the national machine-tool park.

Aside of the very important position it occupies among the manufacturing industries, automobile construction generates the development of foundries (iron, steel, non-ferrous alloys) and forges which may also serve other markets: forges and foundries are basic and necessary activities in industrializing countries.

1.1.2 Its role in employment and labor development

A) The automobile industry requires a high amount of labor. In France, it employed approximately

300,000 prersons in 1968, as follows:

. 200,000 in the manufacture of automobiles;

. 90,000 in the manufacture of equipment and and parts for automobiles and garages.

But, if these figures are added to the number of all those employed in related activities (commerce, repair services, gas stations, road transportation, etc.) it may very well be estimated that approximately 1'500,000 persons gain a living from the automobile, that is 6% of the total active population.

B) From a qualitative point of view, as far as employment is concerned, the automobile industry offers the following advantages:

- it contributes to the training of qualified labor in specialties which are not specific to the industry. For example: lathe operators, fitters, boilermakers, machine tool operators, set-up men, electricians, etc.
- it introduces a spirit of "quality" conducive to a new mentality. This is a precious factor of progress in an industrializing country.

1.1.3 <u>The automobile industry is typical of a mass production industry</u>

A) Considering its mechanical complexity, an automobile is a remarkably cheap product if compared to machine-tools, public works machinery or handling equipment.

Of course, this is possible due to the use of special manufacturing procedures for large series. In other words, the price of an automobile reflects the advantages of mass production specially well. Therefore, any experience in automobile manufacture on a small scale, will result in an immediate high increase of production costs. At times it may be possible to offset this increase with a lower labor cost but, at the same time, most frequently a lower productivity will result, at least initially.

B) Cost-volume ratios are most helpful in pointing out the necessary relationships that exist between the volume of automobile production and production costs, thus bringing out the notion of critical mass for each technique used.

We can define this notion as follows: in a given economic space, the critical mass of production corresponds to the production level or minimum rate of production which must be reached in order that the cost price may compete with the cost price of the main world market manufacturers.

What this means is that for a given set of production techniques, any enterprise attaining the critical mass level will not be in a disadvan tageous position as far as production costs are concerned; on the contrary, an automobile builder surpasses the critical mass level will gain no significant advantage over his competitors.

1.1.4 Problems arising from the setting-up of an automobil industry in an industrializing country

The development of a "national" automobile industry in an industrializing country offers the significant advantage of providing a rich source of foreign exchange savings, as the importation of automobile vehicles frequently amounts to 10% of total imports. The governments of such countries face great problen in this connection and are therefore anxious to set up a national automobile industry. However, very frequently their objectives are contradictory:

- to offer consumers the most complete range of vehicles at the lowest possible price;
- to build locally the most modern vehicles and introduce every year the new vehicles marketed the world manufacturers;
- to create an automobile industry capable of supplying the local market in the shortest poss time;
- to reach the highest possible rate of local integration.

Quite obviously, some factors will have to offset others.

It is well known that cost-volume ratios are very important in the automobile industry, therefore if the number of models is increased the market for each model is consequently reduced and manufacturing costs are increased.

On the other hand, it can be easily proven that in a reduced market, each locally manufactured part replacing an imported part produced in large series, usually pushes up the unit's cost price. Thus, as local integration rises, the manufacturing cost of the unit also rises.

Finally, a very rapid industrialization will be equally instrumental in increasing costs.

Governments in industrializing countries must then reconcile all these different imperatives, a by no means easy task:

- they do not always have the necessary information to make the necessary choices;
- they are under pressure from customers from their own country who are always adverse to any narrowing of their scope of choice;
- they are also subjected to external pressure the main world manufacturers who wish to ha t of share in these markets which are at the h sible development and naturally in the best conditions.

It thus emerges that cost-volume ratios for the different techniques used in the automobile industry constitute important technical and economical laws in the evaluation of development projects for this industry. They should, in particular, provide basic guidelines for the developing countries and give them a clearer insight into the problem of setting-up a "national" automobile industry.

1.2 General data on automobile manufacturing plants

An automobile is made up of about 20,000 primary components. These must first be manufactured separately and then assembled. Many of these parts are identical and are used by sets of 2, 4, or 8 units and even by the dozen when screws, washers, rings, etc. are concerned.

According to this second approach the number of different parts to be manufactured is only about 3,000 or 4,000 for each unit.

1.2.1 The manufacturing phases in automobile construction

The assembly of such a high number of components must necessarily proceed step by step.

A) Basic elements: these are for example, the carburator, the door locks, the spark plugs, the bumpers, and especially the body elements known as "units".

In the case of a "completely knocked down" vehicle (C.K.D.), these elements are already assembled when delivered.

Thus, a medium size vehicle will consist of only about 1,500 basic components intead of the 20,000 basic parts mentioned above,

B) Sub-assemblies: these are doors, hoods, dashboard, seats, gearboxes, engines, etc. Sub-assemblies are made up of several basic parts. The most complex sub-assembly is, obviously, the engine. Because of the very thorough checks the engine must undergo once assembled, it is usually delivered completely assembled, or more exactly "stripped down", this means partially disassembled for packing and transportation convenience, after being completely assembled and checked.

C) Final assembly: the different sub-assemblies and a great number of basic components are finally fitted together in the final assembly line. This operation is carried out in a very strict order to facilitate the operations and insure the quality and safety of the new completed vehicle.

N.B. Sometimes the whole vehicle may be delivered partly assembled for transportation convenience. Gearbox, motor, wheels, etc. will be delivered separately, Such a vehicle is said to be "semi-knocked down" (S.K.D.). This method is frequently used in the transportation of heavy trucks,but generally speaking it is not very economical for private cars, In the jargon of the automobile industry a completely assembled vehicle is known as a "built up" (B.U.) vehicle as opposed to the "completely knocked down" (C.K.D.) vehicles defined previously.

1.2.2 Purchases made by the automobile industry

A) Extent of purchases

The majority of the parts and sub-assemblies which make up a unit are the result of very detailed studies and require very complex manufacturing techniques. Under these conditions, an automobile manufacturer will frequently decide to buy these parts from a specialized supplier. In the case of a medium size vehicle, the components bought from a specialized supplier represent approximately 40% of the total cost price of the unit. This percentage does not include raw material purchases (iron, steel, steel sheets, aluminum,etc.).

A) Manufacturing done by the automobile plant

This is done in the manufacturer's shop. On the whole, this covers essential parts that the manufacturer wishes to manufacture himself in order to keep the vehicle under his control on quality or safety grounds. This applies to the engine and the gearbox and in general to safety parts.

He may also do this for cost and investment reasons.

The car body is also included, since because of the technique used for this, investment in machinery and buildings is considerably high, especially in the case of big body parts which are difficult to sub-contract.

In an extreme case, the manufacturer could confine himself to the assembly of the vehicle, but this is seldom the case.

B) Sub-contracting

For certain selected parts, manufacturing may be entirely or partially sub-contracted.

Complete manufacturing and more frequently, partial manufacturing is farmed out to other smaller manufacturers selected according to their technical skills in a very specific and restricted field. Sub-contractors thus sell a service or working time in their special branch to the car manufacturer.

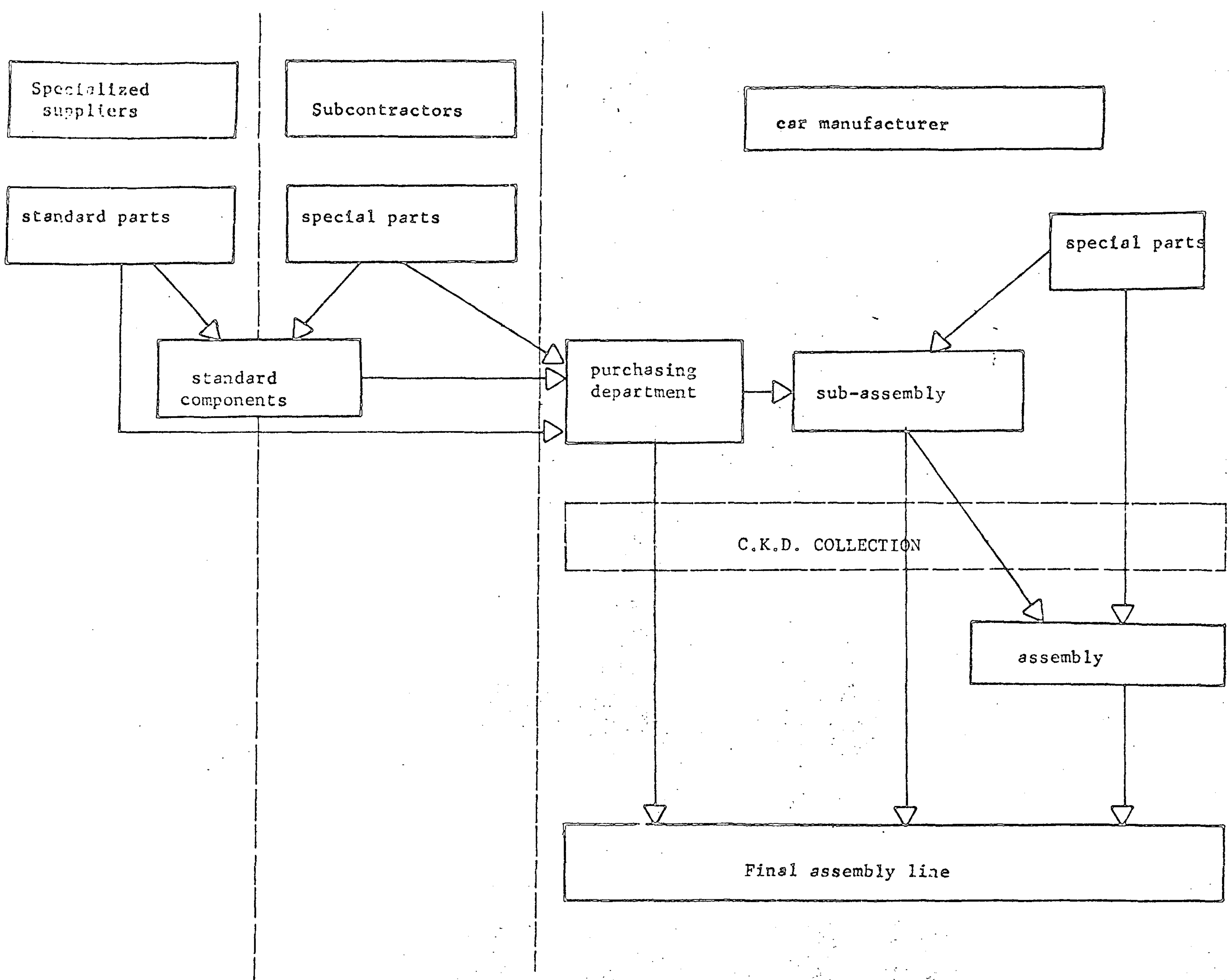
The automobile constructor thus maintains strict control over the manufacturing technique used and the cost price of the parts. At some time he may resume manufacturing on his own, that is, he may do in his own shops a certain job which he previously sub-contracted.

In this manufacturing group the sub-assemblies of the preceding group will be fitted together by the manufacturer during final assembly.

C) Outside manufacturing

This includes certain components which can be purchased as finished products, often sold by catalogue. These are real purchases. In these conditions prices are fixed by free competition among suppliers.

The majority of these components are mechanical and electrical assemblies (dynamos, starters, carburators, windshield wipers, etc.).


Specialized suppliers
Subcontractors
car manufacturer
standard parts
special parts
special parts
standard components
purchasing department
sub-assembly
C.K.D. COLLECTION
assembly
Final assembly line

1.2.4 Choice between sub-contracting and in-the-shop manufacturing

The fact is that the manufacturer is practically forced to install a foundry, a forge, and a pressing and welding shop, if he wishes to manufacture basic parts. Moreover, he is already playing an important part in machining (engine parts, gearbox, differential, front and rear axle mechanisms, etc.). All this demands heavy investment and a sufficiently large production to be able to depreciate the investment over an important number of units. This is why the idea of critical mass in an automobile construction plant is of such importance for the establishment of competitive cost prices.

However, it could be possible to sub-contract the forging operations which concern a relatively small number of parts in spite of the fact that these parts are fundamental to the safety of the vehicle.

Foundry operations could also be partially sub-contracted.

The boundary between the parts manufactured by the constructor himself and those sub-contracted is thus quite flexible. It is always possible to increse the latter, if the industrial potential of the country so permits. The engine is a good example: many of its components may be sub-contracted. On the contrary, sub-contracting is less feasible in the case of a gearbox which needs very accurate manufacturing and high investment levels (gear cutters). It is also quite difficult to sub-contract pressing operations on a large scale for body parts, all of which require important resources. Only the small cutting and pressing of parts constituting a whole may be easily sub-contracted.

In a plant which only does the final assembly of units, assembly operations are carried out with C.K.D. collections. This term refers to all the sub-assemblies and parts which constitute a "completely knocked down" vehicle. C.K.D.'s are gathered together at the main manufacturer's shops, the different parts are packed and dispatched to the plant or, more generally, to the country in which final assembly will take place.

Diagram No. 1 in Chapter 2 briefly describes the manufacturing and assembly operations of a vehicle.

1.3 Classification of techniques used in the automobile industry

The techniques used are quite varied and rely on the majority of manufacturing procedures utilized by industry in a developed country.

Diagram No. 1 is a classification of the different techniques used in the manufacturing of components for the automobile industry.

Each technique is followed by a list of the main components that may be produced by it, and the name of the usual producer in industrialized countries. The manufacturer may be:

- the manufacturer himself;
- a sub-contractor;
- a specialized supplier.

For the sake of clarity, both techniques and procedures have been divided as follows:

- processing of mass metals: mass products are obtained generally by casting or compacting (foundry, sintering, forging);

- processing of sheet metal, that is, the forming of sheets (cutting, pressing);

- metal machining: conventional procedures by removing part of the material (chips, cuttings, particles);

- treatments: these are of two types: heat treatments where an improvement of mechanical qualities is sought, and surface treatments where protection against atmospherical agents is desired;

- processing of plastics or rubbers, which is equivalent to casting techniques except that the variety of possible shapes is much greater;

- assemblies: these may be permanent (welding) or can be taken to pieces (screwing, clipping);

- components or accesories: these include those elements which are completely produced by a supplier; the product constitutes an assembly which is used as delivered. The supplier, of course, uses several basic techniques.

Table No. 1

<u>Classification of the techniques used by the automobile industry</u>

		Technique	Main Components	plant	sub-contracting	supplier
			1) Processing of mass metals			
CASTING	ferrous	Sand	engine block, crankshaft camshaft, steering wheel exhaust manifold, brake drum	x	x	
CASTING	ferrous		piston rings		x	x
CASTING	ferrous	Precision	rocker arm		x	
CASTING	ferrous	Centrifugation	cylinder lining	x	x	
CASTING	non-ferrous	Die-casting	cylinder head	x	x	
CASTING	non-ferrous	Pressure die-casting	housing (clutch (gearbox (steering (water pump (oil pump	x	x	
POWDER METALLURGY		Sintering	oil pump gears, shock absorber, piston, self-oiling ring, locksmith parts, polar parts of electric motors			x

FORGING	Drop-forging (multiple die)	connecting rod, crank-shaft, rocker arm, gears stub-axle, wheel shaft, steering rod	x	x	
	Upset forging	wheel shaft	x	x	
	Shock extrusion	swivel, pulley hub, shock absorber body	x	x	
	Continuous extrusion	seamless tube, sections			x
	Hot upset forging	valve	x	x	
	Cold upset forging	rocker arm tappet, spark plug socket,	x	x	
		thread-rolled screws			x
	Hot cambering	helicoidal suspension springs, tension rod	x	x	
	Cold cambering	(on wire) valve spring, all general purpose springs		x	x
		(on tube) seat framework body parts, brake circuit	x	x	x

2) Processing of sheet metal

	Technique	Main Components	plant	sub-contracting	supplier
FORMING	Folding (cold	body parts	x	x	
	Bending (hot	chassis parts (trucks)		x	
	Continuous profiling	all body sections and metal trimmings			x
		welded tubes for seat and body frameworks			x
	Punching	punched decoration plates washers			x
	Stamping	clipping accessories			x
	Precision stamping	electric motor rotor and stator			x
	Stamping (progressive die)	electric contact, small mechanical heads		x	x
	Forming (transfer)	pulley, steel sheet, wheel, headlight		x	x
	Conventional pressing	(small parts) tops, brackets, locks		x	
		(big parts) body, "skin" and big surface parts	x		

3) Machining of mass metals

	Technique	Main components	plant	sub-contracting	supplier
REMOVING OF CHIPS	Drilling, Automatic lathing	small mechanical parts diameter < 50 mm.		x	x
	Lathing, boring, milling, planing, transfer machine	medium and heavy mechanical parts diameter > 50 mm.	x		
	broaching	rack	x		
	Gear cutting	pinions	x	x	
REMOVING PARTICLES	Grinding and honing	cylinders, bearings, mechanical parts with close tolerances	x		

4) Heat treatments

Hardening, annealing, carburizing, sulphurizing, nitriding	on fatigue or safety parts	x		

5) Surface treatments

	Technique	Main Components	plant	sub-contracting	supplier
BATH	Chemical (phosphatation)	sheet metal treatment before painting	x		
	Electrolytic (galvanization, brassing)	anti-rust protection of parts (nuts & bolts)	x	x	
	(decorative chromium-plating)	outer trimmings bumpers	x	x	
	(hard chromium-plating)	wear resistant parts	x		
PAINTING	immersion	small pressings, internal covers	x	x	
	electrophoresis	primers, body	x		
	electrostatic	protection of mechanical parts	x		
	compressed air	body lacquer	x		

6) Processing of plastics

	Technique	Main Components	plant	sub-contracting	supplier
THERMOPLASTICS	Injection	sun visor, dashboard, headlight switches, knobs name-plate, steering wheel, gear lever, head and tail lights, parking light, handles, crank, ventilator, heating hose, seals, rings, clips, caps radiator grille, carburator parts, air filter, gasoline pump, water pump locks, temperature control housing, horn			x
	Extrusion	inside trimmings, gasoline pump, electric wire insulating material			x
	Blowing	brake fluid and windshield wiper water containers, gasoline tank			x
	Calendering coating	floor mat, seats, doors and roof cover			x
	Thermoforming	elbow rest, dashboard, parts, glove box, door panel			x
	Foam processing	seat, elbow rest and dashboard stuffing			x

	Technique	Main components	plant	sub-contracting	supplier
THERMOSETTING	Compression transfer	ignition distributor and coil cap, distributor, fuse box, commutator			x
	Reinforced plastic	body parts (sports car) various housings	x	x	x

7) Rubber processing

Moulding	tires, joints, stops seals			x
Overmoulding	belt			x
Extrusion	tire inner tube, pipes, sections			x

8) Permanent assembly

WELDING	Soldering-brazing	Body outer parts	x		
	High-frequency induction	seal-proofed massive parts	x	x	
	Arc (MIG specially)	seat framework chassis (trucks esp.)	x	x	
	Resistance spot welding	body in general	x		

Technique	Main components	plant	sub-contracting	supplier
Boss welding	small pressings	x	x	
Roll welding	gasoline tank muffler	x	x	
Riveting, crimping, gluing	components of body units	x	x	
9) Detachable assembly				
Screwing, Clipping, clamping	mechanical parts	x	x	
	bodyparts, soft and hard trimmings	x	x	

10) Components or units

Industry	Components
Iron casting	piston ring
Non-ferrous casting	piston, gasoline pump, carburator
Forging, tooling	tool kit
locksmithing	lock hinge
Small mechanics	windshield wiper
Hydraulic mechanics	brake (mechanism brake (hydraulic
Seal-proofing	shock absorber flat joint revolving and ball joint
Transmission	chain belt gear pulley bearing ball-bearing rings (metal rings (plastic joint
Heat exchange	radiator air regulator air filter oil filter
Glassware	windshield windows rear mirror
Electricity electric motor	(starter (generator (windshield wiper (horn

Industry	Components
Electric transformer	(ignition distributor (ignition coil (voltage regulator
Electric conductor	wire
Electric insulation	spark plug
Permanent lighting	storage battery headlights lamp
Industrial clockwork	dashboard
Iron and steel works	sheets bars
Drawing and extrusion	massive section seamless tube
Profiling	sheet section welded tube
Wiredrawing	wiring
Bolt and nut works	bolts and nuts
Cutting and stamping	clipping
Thread cambering	ring, spring

N.B.: Practically all accessories under item 10 are purchased from a special supplier: this is also the case of some other articles (plastic and rubber, in particular).

1.4 Basic technical and economical data of a vehicle

In order to make the part played by the different manufacturing techniques clearer and to show the importance of the necessary investment, the following tables show the different technical and economical constants that characterize an ordinary model of a vehicle.

Furthermore, in order to give a general idea of the problems arising from automobile construction, Table No. 2 shows the percentage of the total cost price corresponding to each main unit.

All of these figures have been calculated on the basis of a medium size automobile of the European or Japanese type, built in large series; the main characteristics of which would be approximately as follows:

Power:	50 to 60 HP
Cylinders:	1000 to 1200 cm 3
Seats:	4 to 6
Weight:	800 to 1000 kg.

Annual production: approx. 300,000 vehicles.

N.B. Weight is generally heavier in the case of a USA built vehicle but the other characteristics mentioned are usually similar,

The technical and economic characteristics mentioned have been classified as follows:

1.4.1 <u>Breakdown of the cost price of a vehicle according to the main techniques used</u> (Table No. 2)

The following points have been specially shown:

- outside purchases which correspond to raw materials, on the one hand, and to units, on the other.
- value added by the constructor according to the main techniques used.

For the model chosen, the percentages are:

Purchases :	55%
Value added:	45%

1.4.2 <u>Breakdown of the cost price of a vehicle according to its main units</u> (Tables Nos. 3 and 4)

Tables Nos. 3 and 4 show the cost price of the main parts, and point out to possible outlets for processing industries that may supply automobile plants (components and possible sub-contracting).

1.4.3 <u>Production time breakdown according to the main manufacturing techniques</u> (Table No. 5)

This table shows that the total manufacturing time of a medium size car is approximately 55 to

59 hours; out of this total time nearly half of the time (46.5%) is required for the various assembly operations: assembly of the elementary body parts (the "units"), mechanical assembly, and final assembly; all these operations can be considered as labor-intensive manufacturing techniques.

Machining operations are often viewed as labor-intensive, but here, they account for 14% of the total production time only. This can only be obtained through the extensive use of semi-automatic machine-tools and transfer machines.

This latter remark also applies for the sheet-metal working operations (pressing, stamping, spot welding) which account for 14.9% altogether. Such a relatively short time results from the use of highly expensive equipment (like automatic handling features between presses) and sophisticated welding equipment which are specific to the model of car manufactured (multiple head spot welding machines).

1.4.4 <u>Production time breakdown according to the main components</u> (Table No. 6)

Table No. 2

Breakdown of the cost price according to the main techniques used

Groups of purchases or techniques	Purchases %	Value added %	Total %	
Sub-assemblies	30		30 (3)	Purchase of products
Components	10		10 (3)	
Miscellaneous	2		2	
Foundry	1.5	3.5	5	Processed materials
Forge	1 (Forge and Machining)	1.5	2.5	
Machining		12	12	
Sheet working - welding	10.5	8.5	19	
Assembly of sub-assemblies (1)		8.5	8.5	Assembly
Final assembly (2)		11	11	
TOTAL	55	45	100	

(1) including engine, gearbox, suspension, "units", seats, etc.

(2) chain assembly and painting

(3) with an increasing proportion of plastics

Table No. 3

Breakdown of the cost price according to the main units

Units	%
Motor	15
Clutch - gearbox	10
Steering	2
Front and rear axle mechanisms	9
Wheels, tires, suspension	7.5
Radiator, muffler, gasoline tank	2.5
Electricity and controls	8.5
Body	20
Upholstery and equipment	14.5
Assembly and painting	11
TOTAL	100

Table No. 4

Breakdown of the cost price of an engine
(additional equipment and accesories not included)

Units	%
Crankshaft	24
Connecting rod	6
Pistons	3.5
Cylinder head	19
Valve control	2
Camshaft	2.5
Engine block	35
Oil sump base	8
TOTAL	100

N.B.: These cost prices correspond usually to the units manufactured by the constructor.

Table No. 5

Breakdown of the production time of a vehicle according to the techniques used

Technique	Average time (hours)	% average
Foundry	3	5.3
Forge	1	1.8
Machining	8	14
Gear cutting	2.5	4.4
Heat treatments	1.5	2.6
Stamping - pressing	4	7
Welding	4 to 5	7.9
Painting	6	10.5
Assembly of "units" and final assembly	25 to 28	46.5
TOTAL TIME	55 to 59	100

Table No. 6

Breakdown of the production time according to the main units

Unit	Average time (hours)	% Average
Engine	7.5	13.10
Gearbox and clutch	6	10.50
Steering	1.4	2.45
Front axle mechanism	1.6	2.80
Rear axle mechanism	2	3.50
Front and rear suspension	0.5	0.87
Chassis - floor	6	10.50
Electricity and controls	2.1	3.67
Radiator and tank	0.3	0.52
Muffler	0.2	0.35
Tooling	0.1	o.17
Body	11	19.20
Upholstery	6	10.50
Equipment	12	20.90
Wheels	0.5	0.87
TOTAL	57.2	100.00

1.5 General presentation of the study

1.5.1 Method of analysis used

Cost-volume ratios will be studied in the context of industrialized countries on the basis of the information furnished by the large European manufacturers. This method involves homogeneous and meaningful investigations of the phenomena studied thus making it possible to screen out some of the rather complex problems connected with the detailed analysis of the cost price of a vehicle.

Reference was given to this method, rather than to a direct study of cost prices according to production levels in different countries having attained a varying degree of industrialization; it is known that in this case, local production conditions and fiscal and customs laws may create considerable distorsions in manufacturing costs and thus mask cost-volume effects.

This disadvantage was all the more serious as it was virtually impossible to obtain direct access to precise information on production costs, so that the figures obtained could have been compared only with great difficulty.

Since most of the non-meaningful factors were thus eliminated, the results obtained are also applicable to the developing countries, allowing, of course, for certain corrective factors. Therefore, the conclusions reached may be modified in less industrialized countries by the effect of the following parameters:

- cost, productivity, and skills of local labor;
- general industrial development level, that is, the industrial environment of the country under consideration;
- automobile production volume in relation to the number of models;
- manufacturing techniques used: they must be adjusted to production volumes and local manufacturing conditions.

1.5.2 Plan of the study

The automobile industry relies on very different production techniques (machining, forging, foundry, welding, assembly) and at the same time a constructor uses quite freely the services of related industries by sub-contracting part of his products and especially by purchasing many components from supply industries.

Consequently, a similar breakdown has been adopted for this study. In the first place, the techniques used by the constructor will be studied, that is, the value added by the assembly plant itself; then, the group of raw materials and supplies purchases will be examined, ending up with a cost-volume ratio analysis of a complete manufacturing plant.

A) <u>Value added by the constructor</u>

We have chosen the following subdivision:

- Final assembly : Chapter 2
- Machining and Assembly of Mechanical parts: Chapter 3
- Pressing and Assembly of "Units" : Chapter 4
- Foundry : Chapter 5
- Forge : Chapter 6

The final assembly shop heads the list because it is the activity which most interests industrializing countries: it is the first step in the development of a "national" automobile industry.

The other main techniques are presented in decreasing order of importance according to their contribution to the value added by the constructor.

For each shop or technique used, the following information will be given:

a) a brief summary of manufacturing procedures and a short description of the production operations;

b) the investment required for such a shop in relation to the production capacity desired; the effect of the degree of mechanization and a great number of models on the level of investment has been shown whenever possible;

c) the manufacturing overprice for the technique under consideration in relation to the volume of automobile production. An effort has been made to indicate as far as possible how this production cost is broken down according to the main units concerned and according to the production factors (labor, production expenses, general overhead, depreciation). When accurate information was available, production overprice for certain parts selected because of their importance in a vehicle's cost price was shown in relation to production.

It must be noted that the calculations are sometimes theoretical, so that the results obtained are quite approximative. However,

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the curves plotted in the charts furnish valuable indications on the general shape of the variation of the overprice of production in relation to the volume. The critical mass required to obtain a price comparable to that of large manufacturers is also shown.

B) Purchases (Chapter 7)

The study of purchases of raw material has been separated from that of the components produced by specialized industries.

It is not possible, in this brief study, to calculate the investment level for the basic industries concerned (iron and steel, glass, rubber, etc.) and only certain typical ratios will be indicated to show an order of magnitude.

In particular, in reference to purchases, the critical mass needed by each one of the industries under consideration to be able to supply economically a national automobile industry has been indicated.

Finally, an indication is given of the overprices expected to occur in relation to the volume of automobile production in the purchase of raw materials and components.

C) <u>Complete automobile manufacturing plant</u>
(Chapter 9)

On the basis of the results obtained for the different shops and the analysis of a constructor's purchases, it is also possible to study the cost-volume relationship for a complete automobile manufacturing plant.

Total investment has been calculated as a function of the production volume for <u>complete manufacturing such as is done by the main European manufacturers</u>. The manufacturing overprice of a complete vehicle in relation to production volume (the aforementioned techniques being in this case integrated by the constructor at his own shops) has also been studied.

It must be noted that in these conditions, the value added by the constructor represents only 45% of the vehicle's cost price, since raw materials and supplies cover approximately 55% of the cost price.

Finally, the local supply of raw materials has been studied in order to show, in developing countries, the incidence of the percentage of local integration on the manufacturing costs for various production volumes.

D) New techniques in the automobile industry
(Chapter 8)

This chapter is an effort to present certain prospective elements in the automobile industry, The following observations show the development of the main techniques used in automobile manufacturing together with the future trends. In particular, we will look at those fields where new techniques still relatively unknown today will bring significant changes in the future, both in the design and in the manufacturing of a vehicle, assuming that the present difficulties will be eliminated eventually.

A good part of this chapter is devoted to an examination of the new possibilities offered by the use of plastics. This branch is at the height of development and should lead, in the coming years, to important changes in the design and manufacture of vehicles and is of great interest for industrializing countries where automobiles must be manufactured in small series.

Chapter 1 - Annex 1

Definition of the "scale-up factor"

The scale-up factor α is defined as follows:

$$\frac{I_1}{I_0} = \left(\frac{C_1}{C_0}\right)^{\alpha}$$

α : scale-up factor

I_1 : investment necessary for capacity C_1

I_0 : investment necessary for capacity C_0

When investment rises more than proportionately to capacity, α is greater than 1.

When investment rises proportionately to capacity, α is equal to 1.

When investment rises less than proportionately to capacity, α is less than 1.

In this study the scale-up factor is usually calculated on the assumption that production capacity is doubled, therefore:

$$\alpha = \frac{\log \frac{I_1}{I_0}}{\log 2}$$

Chapter 1 - Annex 2

Definition of the percentage of local integration

There are many definitions for the percentage of local integration, we may mention the following in particular:

A) Definition based on the weight of parts: according to this notion local integration is defined as a percentage of the weight of locally produced parts in relation to total vehicle weight. This is a poor definition as it leads to an unwarranted increase in a vehicle's total weight during the first stages of local integration.

B) Definition based on the price of parts: the ratio between the price of locally produced parts at local prices and the initial value of C.K.D. collections. This definition should be rejected because it masks reality: the fact is that the higher the price of locally produced parts the higher the local content will appear to be.

A second method which apparently is more correct, would consist in measuring the amount of local integration by establishing a ratio between the value of locally produced parts at C.K.D. prices and the total value of the collection, also at C.K.D. prices. This latter definition is the one we shall use in this report.

Chapter 2

Final Assembly

A study of assembly costs is of particular interest insofar as each country, whatever the solutions adopted elsewhere for the manufacture of parts or units, has decided to install one or more assembly plants on its territory.

In the main industrialized countries there is an increasing number of assembly plants engaged in the final assembly of parts and units each of which is produced in separate plants.

Therefore, in this field there is a large number of different types of plants whose design and organization vary according to the levels of production. Assembly plants operating throughout the world today range from the small unit producing only a few vehicles a day (3 to 5 for the smallest ones) up to the highly mechanized plants manufacturing in very large series (100,000 vehicles a year and more).

The reason for the large number of assembly plants throughout the world is that CKD transportation is more economical than "built up" transportation. Transportation costs vary considerably according to the volume transported. Another reason is that in the developing countries interested in being industrialized, an assembly plant paves the way for industrialization: locally manufactured parts and units are assembled along with parts and units imported from abroad, to make up the complete vehicle to be delivered to the consumer.

This chapter thus first describes the final assembly operations and explains how installations are modified as the rate of production increases. It will then examine how the investment varies in relation to production levels and will finally consider how cost and volume effects interact.

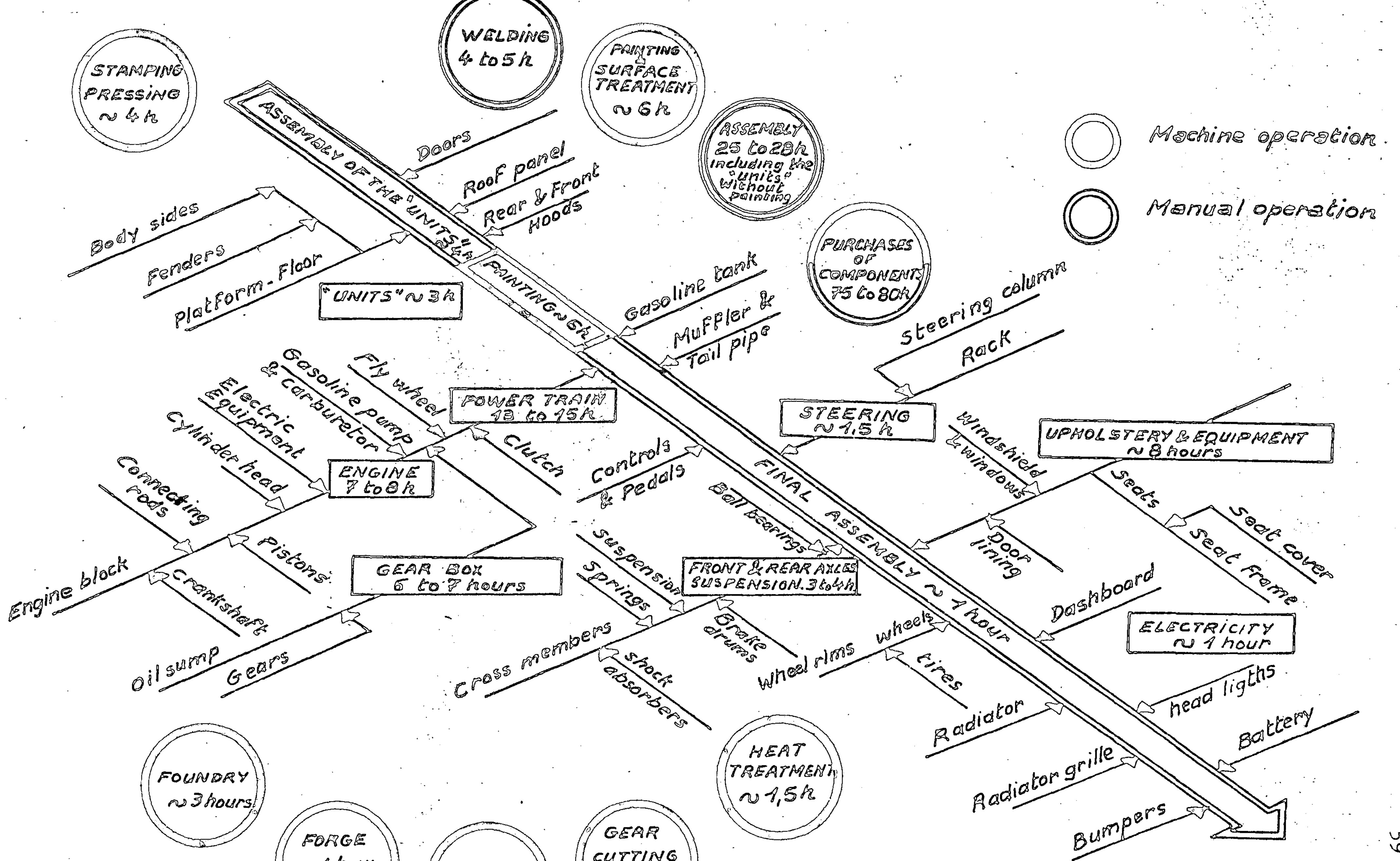
2.1 Brief description of final assembly operations

These operations involve the assembly of the different parts, of varying complexity, of a vehicle from a CKD collection.

It should be noted, however, that certain parts will have already been assembled in previous operations (these operations are described in the chapter on the machining and assembly of mechanical units and in the chapter on pressing and assembly of units). The purpose of the final assembly operations is to assemble a complete vehicle, in working order and ready to be delivered.

Diagram No. 1 shows the connection between the different operations involved in final assembly, in other words, the logical sequence of operations leading to the final finished product.

DIAGRAM N°1



Manufacturing diagram of a motor vehicle

Final assembly operations may be grouped as follows:

- reception of CKD collections - unpacking - storage
- assembly of body starting from "units"
- painting
- upholstery and trimming line
- mechanical assembly - fitting line
- touching up and tuning - delivery

2.1.1 CKD reception - unpacking - storage

Before assembly, the first operations are unpacking and quantity and quality control of the vehicle's components, whether imported or locally produced.

The collection of assemblies, sub-assemblies, parts and miscellaneous accessories is packed in a number of boxes and containers, grouped according to the nature of the components:

- body parts
- mechanical parts
- upholstery parts
- seat framework
- miscellaneous

The containers are sent to the different assembly stations in the assembly line according to requirements.

2.1.2 Body assembly - spot welding

By the term "unit" is meant a body sub-assembly made up of different steel sheet parts.

A) The first section will complete certain units which for reasons of transport were stripped of part of their components or completely knocked down.

B) The second section will carry out the general assembly of the body with the units placed on specific assembly frameworks, either fix or movable called assembly jigs. This section has at its disposal electric resistance welding machines (spot welding tongs) which may be either grouped on an independent gantry, or directly fixed on the building's framework.

C) Once the frame is assembled, it is placed on a special trolley and then enters another spot-welding line where it receives:

- supplementary weldings ensuring either complete rigidity or the watertightness of the assembly;

- the removable units such as: doors, hoods, fenders, etc.

2.1.3 Painting line

Once through the spot welding line, the unpainted frame enters the painting shop where a conveyor system will take it through the different sections. The main painting operations are carried out in the following order:

- degreasing, phosphatating, rinsing
- drying
- anti-corrosive coating of the part beneath body
- two coats of primer
- baking of primers
- application of lacquer
- baking of lacquer
- finishing touches

2.1.4 Upholstery line

Upholstery preparation: this section is mentioned here only as a reminder because usually all all upholstery items, including the seats arrive ready-made from local plants.

The inner upholstery parts must be cut and sewn; if plastics are used high frequency welding is necessary.

B) Upholstery in the strictest sense or furnishing line: the vehicle is equipped with the following elements: inner accessories, doors, windows, windshield, electric wiring, steering column, door and roof trimmings, weather strips, dashboard, headlights, outer trimmings, etc.

2.1.5 Mechanical assembly - fitting line

Outside the assembly line itself, certain amount of preparation is necessary; this is carried out in parallel sections:

- engine and gearbox fitting
- equipment of floor panel chassis with suspens brake, and steering units,

On this mechanical fitting line, the body is plac on the mechanical assemblies. The coupling and the adjustment of the different elements are done all along the line, and the last check-up takes place at the final pit. Once it is through this line, the vehicle which is now in working order, goes to be checked and tested.

2.1.6 Touching up and tuning - delivery line

After road testing, various checks are made and also mechanical adjustments and last touches of paint are given in a special cabin; the vehicle is checked for watertightness and then undergoes cleaning and shining operations.

2.2 Calculation of the investment required by a final assembly shop

In order to give some idea of the share of a final assembly shop in a complete manufacturing plant, the order of magnitude would be as follows: the investment required for a final assembly shop amounts to 10 to 15% of the total investment necessary for a complete manufacturing plant producing 100,000 vehicles a year, with a rate of integration of 95%.

2.2.1 Classification of investment

The requisite investment may be broken down into four groups:

- land, land grading
- buildings
- equipment, machinery, tooling
- general services, utilities, office buildings

In general each of these categories roughly accounts for the following share of total investment:

- land, land grading, roads	5%
- buildings	35% to 45%
- equipment, machinery, tooling	45% to 35%
- general services, utilities	15%
TOTAL INVESTMENT	100%

A) It should be noted that the land and building surfaces needed in this case are much greater than those needed for a machining and pressing shop. On the contrary, investment in equipment and tools is considerably less than in the case of a machining and pressing shop.

B) Furthermore, the amount of investment in buildings will depend on the climate of the country where the assembly plant is located.

The price of land per square meter in a tropical country may be twice or three times as much as in a country close to the polar circle, as is indicated in the following table:

Country	Venezuela	France	Finland
Price per m2 (FF/m2)	200	450-500	650

C) Also, a high degree of mechanization or automation in the assembly and painting lines may push up considerably the investment in necessary equipment.

The painting line is extremely important in this respect because it may itself amount to more than 20% of total investment in the case of a highly mechanized assembly plant.

The painting line also needs careful attention as in a great many cases it has proven to be a bottleneck in the assembly line.

The capacity of a painting line cannot be increased without heavy investment. It is therefore essential to allow for adequate spacing when it is set up to be able to face an eventual increase of total assembly capacity at a later stage.

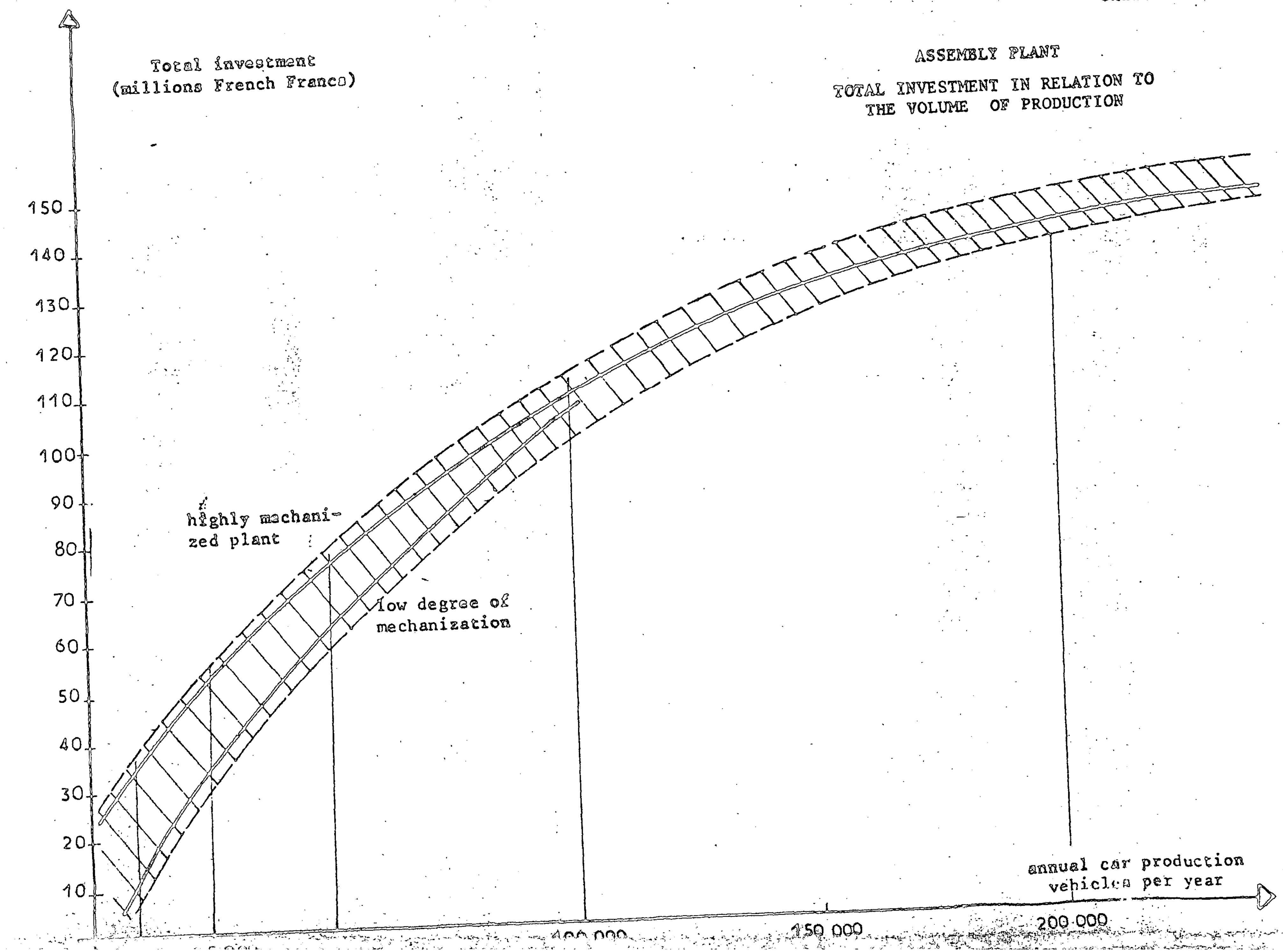
2.2.2 Ratio between total investment and annual production

The investment needed for different assembly capacities resulting from the analysis of existing plants is indicated on Chart N0. 1, where annual vehicle production appears on the abscissa and the average level of total investment on the ordinate.

- chart n° 1 -

ASSEMBLY PLANT

TOTAL INVESTMENT IN RELATION TO THE VOLUME OF PRODUCTION



N.B.: The price of land has not been taken into consideration; the amounts shown indicate the expenditure on:

- buildings and roads;
- equipment, machinery, tooling;
- general services, utilities, offices.

The studies we did in reference to low assembly rates, led us to examine plants with identical capacities but with different degrees of mechanization. This is shown by two different curves in the low production side of the chart: the upper curve represents a highly mechanized plant and the lower curve a plant with a low level of mechanization.

For assembly capacities above 100,000 vehicles a year, the curves no longer follow different paths because at this level, assembly plants are always highly mechanized.

Furthermore, the figures mentioned refer to assembly plants located in temperate climate countries.

A) <u>Effects of economy of scale</u>

Three regions may be detected on the total investment curve:

a) From 0 to 25,000 vehicles a year, the scale-up factor would be around 0.70. This means that in order to multiply capacity by 5, passing from 5,000 to 25,000 vehicles a year, investment should be multiplied by 3.

In addition, it may be observed that in the case of a plant which is not very mechanized, investment increases slightly more than proportionately to capacity; whereas in the case of a highly mechanized plant, investment increases much less than proportionately to capacity. This seems logical as in the latter case the decision was taken to set up large scale equipment since the very beginning.

b) From 25,000 to 100,000 vehicles a year, the scale-up factor is about 0.6; investment rises from 45 to slightly over 100 million francs, but production is multiplied by 4.,

c) Where the assembly rate is more than 100,000 vehicles a year, the curve drops sharply and the scale-up factor is only 0.4;

investment is considerably less than proportional to capacity. Thus, in order to push up production from 100,00 to 200,000 vehicles a year, investment should be roughly multiplied by 1.3. This is normal as at this level of production a plant is always highly mechanized.

B) <u>Effect of mechanization on investment</u>

Chart No. 1 shows that the effect of mechanization on investment is especially marked for low assembly capacities. On the contrary, as the plant becomes more mechanized and as the capacity increases, the mechanization factor will be less and less important as large series are produced.

As investment may be doubled in the case of a highly mechanized plant producing less than 25,000 vehicles a year, it will be interesting to see how mechanization can be incorporated in the assembly line.

a) Though a fixed assembly line may be used for a very small rate of production of about 15 vehicles a day (3,750 vehicles a year), it is absolutely necessary to mechanize the line as soon as about 6,000 vehicles a year are produced. The mechanization threshold of the line corresponds to about 3 vehicles an hour. Mechanization involves heavy investment and requires overhead and ground conveyors.

b) Furthermore, the organization of the paint shop is quite different when different production capacities are considered.

For very low assembly capacities, less than 2 vehicles an hour (that is 4,000 vehicles a year), the painting may be done in a cabin, the vehicle does not move and the workers use paint spray guns.

For more than 2 to 3 vehicles an hour, mechanization becomes necessary. However, investment may be limited by using the paint dipping method. For more than 4 vehicl an hour, it is preferable to replace this system and use an automatic chain. Electro-phoresis is generally used at this level, but the cost is then very high.

c) These considerations explain why investment spirals for low rhythms of production; it should be noted, however, that intense mechanization may be decided on for the assembly shop even where a small rate of assembly work does not really warrant this. This may occur when an important increse is expected; another reason may be the desire to reduce the amount of labor in assembly operations when labor costs are high.

C) <u>The effect of the variety of models on investment</u>

a) <u>The assembly line</u>

i - If there is a large number of models, costs will only be slightly higher; the additional expenses will mainly be incurred in respect of the assembly jigs needed for a particular model and control jigs. It will be necessary, for example, to have the same number of control jigs as models. In order to give some idea of the orders of magnitude, the figures below show the additional investment that would be required for the introduction of another model:

- main assembly jig:
  - average cost for a small vehicle 100,000 FF
  - approximate cost for a vehicle with medium cylinder capacity 300,000 FF
- control jig:

. body shell used to check periodically the accuracy of the main assembly jig, approximate cost for a small vehicle:

10,000 FF

- secondary assembly jigs:
  - . floor jig
  - . side panel jig
  - . door jig, etc.

  which are manufactured locally and are therefore less expensive.

ii - According to the degree of mechanization of the spot welding line it may be advisable to make some complementary investment in spot welding equipment.

In the case of low mechanization, a welding gantry with simple welding tongs is used; these are used for different models and no supplementary investment is necessary if different models are assembled.

If mechanization is more advanced, multiple head welding machines are used, this equipment is generally specific to a model.

If an additional model is introduced further investment in resistance welding will be required, This may amount to between 150,000 and 500,000 FF for a medium size vehicle.

However the cost of welding equipment may be as much as 1'000,000 FF if all body assembly operations are included.

b) Painting line

However much the plant is mechanized, the introduction of an additional model will not require new investment in this shop.

c) Upholstery line

A large number of models will not make it necessary to invest additional sums. On the other hand, the upholstery manufacturing shop will have a bigger workload, although additional costs will be small.

d) Warehousing of CKD collections

The more models there are, obviously, the more storage space will be required as the collections must be grouped in separate containers for each model. It will be necessary to invest in covered areas or warehouses, or in land, if the climate of the country under consideration is such as to allow storage in the open air.

D) Amount of investment for different production volumes

Table No. 1 shows the investment classified according to the main categories for different production volumes. In the case of small scale production, a highly mechanized plant in a temperate climate and a less mechanized plant in a hot climate have been considered.

The indicated amounts are necessarily rough figures and are useful only as a reference to orders of magnitude. The figures are based on average values; the fluctuation range goes up to 20% in the case of low production and up to 10% for high production.

The basic purpose of this table is to show the relative importance of the different investment categories and to clarify the effect of the scale-up factor.

Table n° 1

DETAIL OF THE INVESTMENTS IN AN ASSEMBLY PLANT

IN RELATION TO THE VOLUME OF PRODUCTION (x)

	Production rate vehicles/year	Land		Buildings		Investments machines & tools				Utilities & annexes	Total of the investments without land
		Surface m2	Investment FF	Surface m2	Investment FF	Welding line	Painting	Upholstery and equipment	Mechanical line & finishing line		
Highly mechanized plant mild climate country	10.000	60.000		17.000	7.650.000	10.000.000	8.000.000	1.000.000	1.350.000	6.000.000	34.000.000
	25.000	110.000		30.000	13.500.000	15.000.000	11.000.000	1.500.000	2.000.000	10.000.000	53.000.000
	100.000	150.000	to be taken accordingly	70.000	31.500.000	30.000.000	20.000.000	3.000.000	4.500.000	16.000.000	105.000.000
	200.000			100.000	45.000.000	40.000.000	30.000.000	5.000.000	8.000.000	22.000.000	150.000.000
Low mechanization Hot climate country	10.000	60.000		17.000	4.300.000	4.300.000	4.000.000	800.000	700.000	3.000.000	16.800.000
	25.000	110.000		30.000	7.500.000	10.000.000	8.000.000	1.000.000	1.350.000	7.000.000	34.850.000

(x) These are only approximate figures, given here in order to show the average level for the amount of investments.

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It is necessary to stress that the amounts given have only a comparative value since absolute figures are not of any real importance in this study.

2.3 Study of assembly costs

The assembly cost price of a vehicle will now be examined by isolating the various parameters and by studying their evolution in relation to the expected production. This operation will bring out the over-prices corresponding to different production levels in a complete assembly operation.

The effect of the degree of mechanization on assembly costs as well as the effect of the number of models to be produced in the same line will also be studied.

2.3.1 Parameters of the cost of assembling a vehicle

On the whole, the cost of assembling a vehicle may be divided into four main items:

- direct labor
- production costs
- general overhead
- depreciation.

The assembly cost is the value added by the assembly plant.

A) Direct labor

It is not always easy to draw the line between direct and general labor costs in a shop. It will be assumed that direct labor includes those workers directly in charge of assembly operations, the workers in charge of unpacking and classifying the CKD collections and the handling personnel.

These are generally unskilled workers (OS1 - OS2) paid at hourly rates.

Labor costs include direct wages, social benefits, vacation pay, productivity incentives and miscellaneous charges (bonuses for work in unhealthy conditions, travel allowances, etc.)

B) Production costs

These include costs directly related to assembly operations and therefore directly affected by the level of production.

It is customary to classify them into three groups:

a) variable production costs which grow proportionately to the production volume; this refers in particular to:
   - supplies: paint, oil, cloth, etc.
   - small tools
   - energy and fluid expenses: electricity, gas, compressed air, water.

b) semi-variable production costs which do not vary in relation to production but change in successive stages; they include:
   - indirect labor costs (supervisory personnel and shop technicians)
   - maintenance costs.

C) <u>General overhead</u>

These expenses are not directly related to production. They are caused by the mere existence of the plant; they are frequently known as management costs or structural expenses.

Under this heading are to be found:

- salaries of management executives
- travel expenses
- vocational training
- miscellaneous overheads: office supplies administration expenses

- financial costs

N.B. The overheads of a plant of a given size may be taken as a barometer of the general efficiency of a plant and the skill with which it is managed.

D) Depreciation

These are charges due to the depreciation of the investment needed to ensure the plant's production capacity.

In general three groups of investment are considered according to depreciation periods:

- buildings
- equipment and machinery
- tools

For each investment group the laws in force in the country concerned lay down a maximum rate of annual depreciation.

Depreciation costs are the expression of the inevitable effect of depreciation; the sums are placed in a special account and this amount should allow for the replacement of the initial production capacity once the corresponding investments are totally depreciat

Depreciation charges are therefore directly related to the investment necessary for a certain given production level.

2.3.2 Analysis of the variations of assembly cost components

For each of the parameters of the unit cost of assembly, so defined, variations will be studied according to the following three main sectors:

- production level
- amount of mechanization of the assembly plant
- number of models of vehicles

A) Direct labor expenses per vehicle

According to the definition of direct labor stated before, the cost of direct labor increases proportionately with production, or more specifically:

direct labor cost = hourly rate x assembly time per vehicle.

The hourly rate factor is constant in relation to the production volume, so that it is only necessary to study the variation of the assembly tiem in relation to the production volume.

It would be fair to say that assembly time decreases with an increase in production but the real cause of this is the increasing mechanization of the assembly line as production goes up. In other words, as the daily rate increases, the organization of the assembly shop is modified.

a) <u>Effect of mechanization</u>

As soon as the production rate is more than 3 vehicles an hour, the assembly line becomes mobile: the vehicles are moved by overhead and ground conveyors to the different assembly stations and each worker does a few simple operations (2 to 4 operations, for example).

Thus, as production increases instead of having several workers doing many very different operations (more than 10 different ones) on a fixed vehicle, each worker becomes increasingly specialized. The worker thus acquires such an automatism that the few operations he has to do are done in a very short time. Furthermore, assembly mistakes or omissions are also reduced.

It is quite evident that specialization accordingly creates more work stations.
The problem of the organization of an assembly line is quite complex and requires ample experience to find an economic compromise between an increase in the number of assembly personnel and an increase in the time needed for assembly.

The result of the above considerations on the organization of an assembly line, may be more clearly seen on Chart No. 2.

The abscissa shows the annual production volume, and the ordinate, the corresponding assembly time.

N.B. This chart refers to a medium sized vehicle of about 1000 cm3 cylinder capacity.

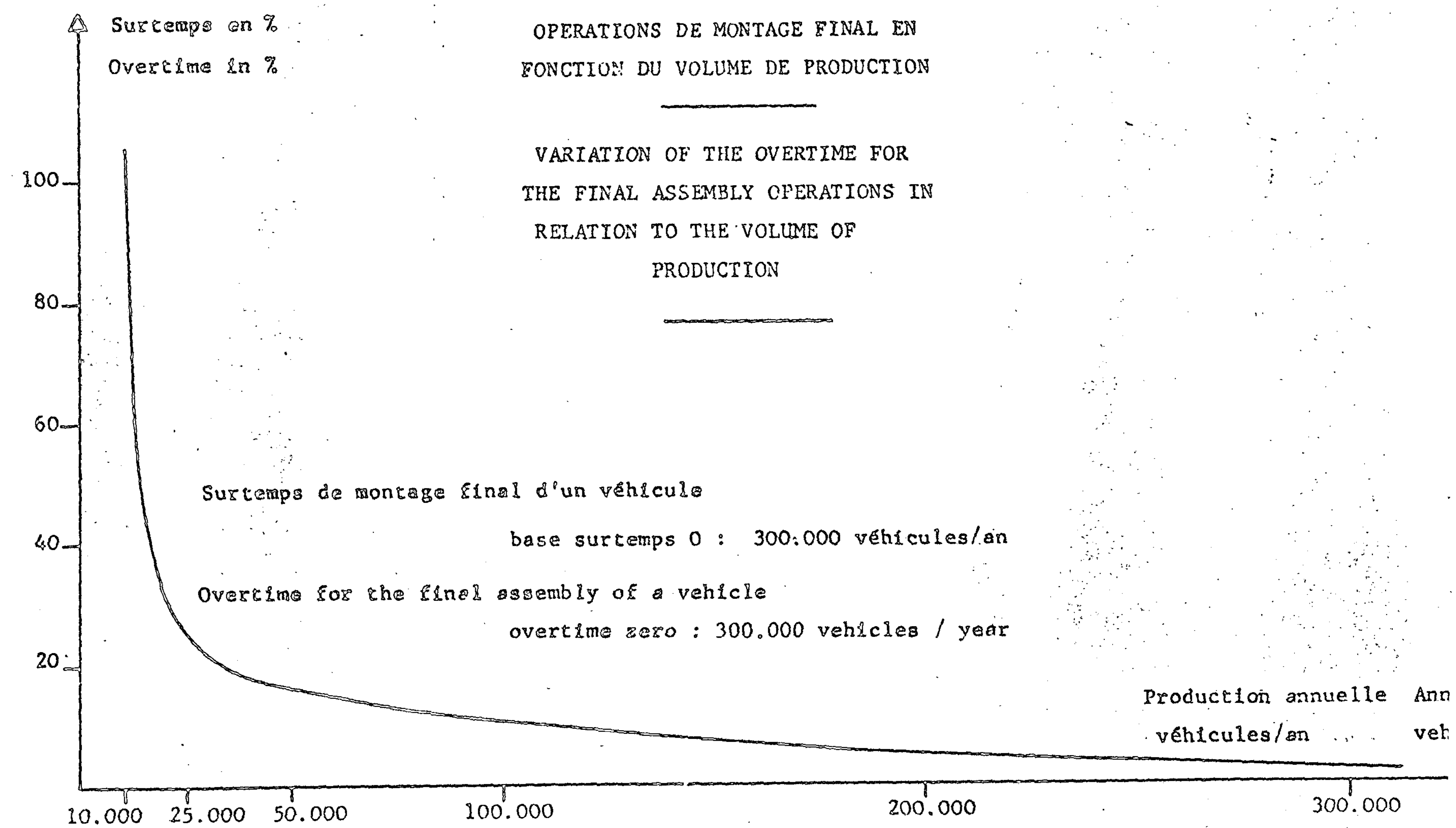
"Zero" overtime is the assembly time for a European car manufacturer building 300,000 vehicles a year.

As may be seen, the overtime assembly curve drops very sharply as production increases in the case of low production rates of

Graphique n° 2

VARIATION DU SURTEMPS POUR LES OPERATIONS DE MONTAGE FINAL EN FONCTION DU VOLUME DE PRODUCTION

VARIATION OF THE OVERTIME FOR THE FINAL ASSEMBLY OPERATIONS IN RELATION TO THE VOLUME OF PRODUCTION



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about 10,000 vehicles a year; this decrease levels out while remaining very regular, as the production volume increases. It may be observed that assembly overtime becomes almost negligeable as from 150,000 vehicles a year.

As direct labor hour rates are assumed to be constant, it may be concluded that the direct labor cost curve is identical with the assembly time curve, with a scale unit adjustment.

Together with a difference in the organization of the final assembly line itself, it should be noted that growing mechanization also affects the spot-welding line, and the painting line, as was indicated in the paragraph on investment. This change in technique also makes it possible to reduce assembly time, thus reducing labor costs.

b) The effects of a great number of models

The purpose here is to study the incidence of a great number of models of assembled vehicles on the three groups of main operations:

- spot-welding operations: assembly, welding.
- painting line
- assembly line

i - <u>The spot-welding line</u>

A distinction must be made between a scarcely mechanized spot-welding line and a highly mechanized steel sheet parts assembly line.

In the first case, welding tools are not specific (simple welding tongs), and may therefore be used indiscriminately, whatever the model. But, since the worker is no longer guided by an assembly jig specific to a model, he will undoubtedly be more hesitant; there will be a greater chance of mistakes, and assembly and welding time will be longer usually.

When the spot-welding line is more mechanized, assembly tools and jigs are specific to each model. The worker, because he is well guided by the assembly jig, uses multiple head welding machines and can work faster. Thus, assembly time is not affected by the number of models.

Consequently, it may be concluded that a variety of models increases the assembly-welding time more markedly when mechanization is low. In other words, a variety of models requires an increase in operation time which is higher for lower production rates, as an increase in the assembly rate is generally accompanied by an increase in mechanization.

ii - The painting line

In general a great variety of models does not cause an overtime in the painting operations since whatever the degree of mechanization painting equipment is never specific to a model.

iii - The assembly line

A large variety of models may be an unfavorable factor especially if the models are very different; for example, a popular low cylinder capacity car and an "American" car, or a private vehicle and an industrial vehicle.

A distinction should be made between high and low production rates:

High volumes of production:
In the case of high assembly rates, it is preferable to alternate the models on the same assembly line.

In this case, the worker must only perform a few operations on each vehicle and finds no difficulty in going from one type of vehicle to another. As a result there is no waste of time due to hesitation.

The number of different parts for each vehicle is not very high and, therefore. it is easy to organize the work stations.

Small scales of production:
In the case of small scales, it may be either preferable to work by batches, that is, by series of identical vehicles, or to work alternately. In this matter, each

case must be considered as specific depending on the degree of mechanization of the assembly. Low mechanization forces a worker to do a series of operations on each vehicle and it may not always be advisable to alternate the models; more so, it is more difficult to organize the work stations, because of the many available parts that must be stocked around the line.

iv - It may then be concluded that the variety of models means assembly overtime, which is particularly marked when output is low. However, for high production scales, the number of models has practically no influence on assembly time, as in this case mechanization is such that as far as possible specific equipment is used for each model. This makes it possible to do different assembly operations in a minimum amount of time. Also, the organization of the assembly linein the strictest sense is such that each worker does a very small number of operations and there is no waste of time.

c) Conclusions on the paragraph concerning direct labor costs

Direct labor costs decrease as output increases. This is due to the effect of a greater amount of mechanization which accompanies an increase of the assembly rate.

On the other hand, a large number of models may lead to an increase in assembly time and therefore an increase in the assembly costs. This remark, however, is only valid for low output, less than 10,000 units a year, because in this case there may still be very little mechanization,

It must be noted, on the other hand, that this general reduction in assembly costs which accompanies higher production necessarily implies higher investment, particularly when there are a great number of models, the effect of which on assembly costs is expressed in the form of depreciation.

B) Manufacturing expenses

In the *first place*, trends in total *manufacturing* costs will be studied for the whole assembly shop, and the unit value per vehicle will be deducted as well as its variation according to production volume.

a) Study of total manufacturing expenses

As previously indicated, two different categories of manufacturing expenses may be distinguished:

i - variable costs:
which increase proportionately with production: paint, oil, energy, etc.

ii - semi-variable costs:
which increase in stages as production rises; the main causes for this increase are:

. Supervisory personnel

For low production rates (3,000 vehicles a year) assembly operations, as has been seen, are scarcely mechanized. The vehicles are assembled at fixed stations and each worker performs numerous operations. In such cases, important supervisory personnel is frequently needed, because assembly errors and omissions are most frequent.

As output increases and the line becomes more mechanized, supervisory staff becomes proportionately less numerous. Total manufacturing expenses will thus increase proportionately to the output in an assembly shop with low production volumes.

. Maintenance expenses

These are rather low when the plant is not highly mechanized, which is in general the case of low production, As soon as mechanization starts, maintenance expenses increase rapdidly, but for a high rate of production, maintenance expenses rise relatively slowly.

Thus, it may be concluded that, in general, total manufacturing expenses have a tendency to grow less than proportionately to the pace of production,

The general characteristics of the phenomenon appear in Chart No. 3

b) Unit manufacturing costs

If manufacturing expenses are considered as a part of the assembly cost of a vehicle, it will be observed that these expenses decrease rapidly as the output goes up, in the case of low production; this decrease is not as marked in the case of high assembly rates.

This is clearly seen on Chart No. 4 which shows the unit manufacturing costs, for different assembly rates.

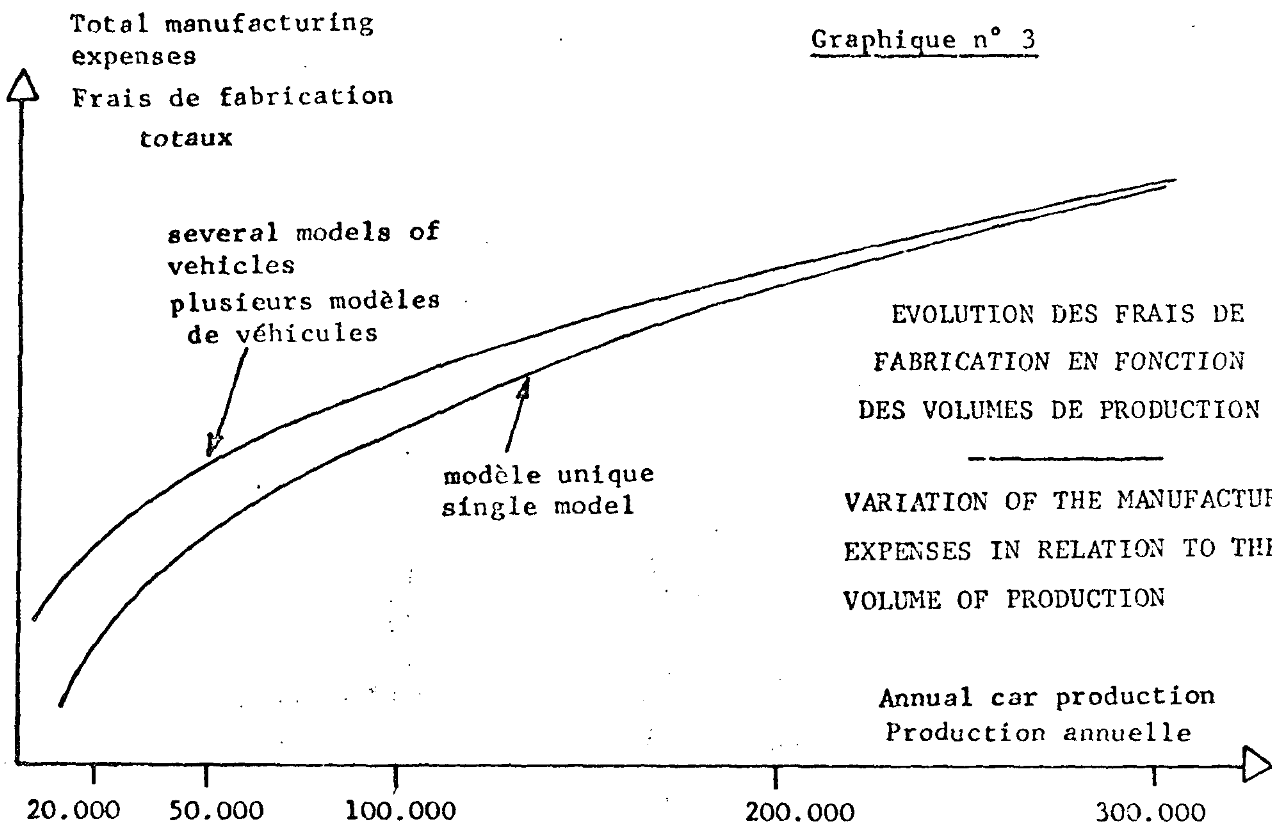
N.B. A great variety of models will always cause an increase in unit manufacturing costs, this overprice is specially marked in the case of low rates of production.

c) Effect of the number of models

In general, it may be said that a great number of models requires an increase of and floor-level personnel because planning operations are more complex when there is a wide variety of different models. On the other hand, tool costs increase and more boxes are necessary to classify the

Chart n° 3

Graphique n° 3

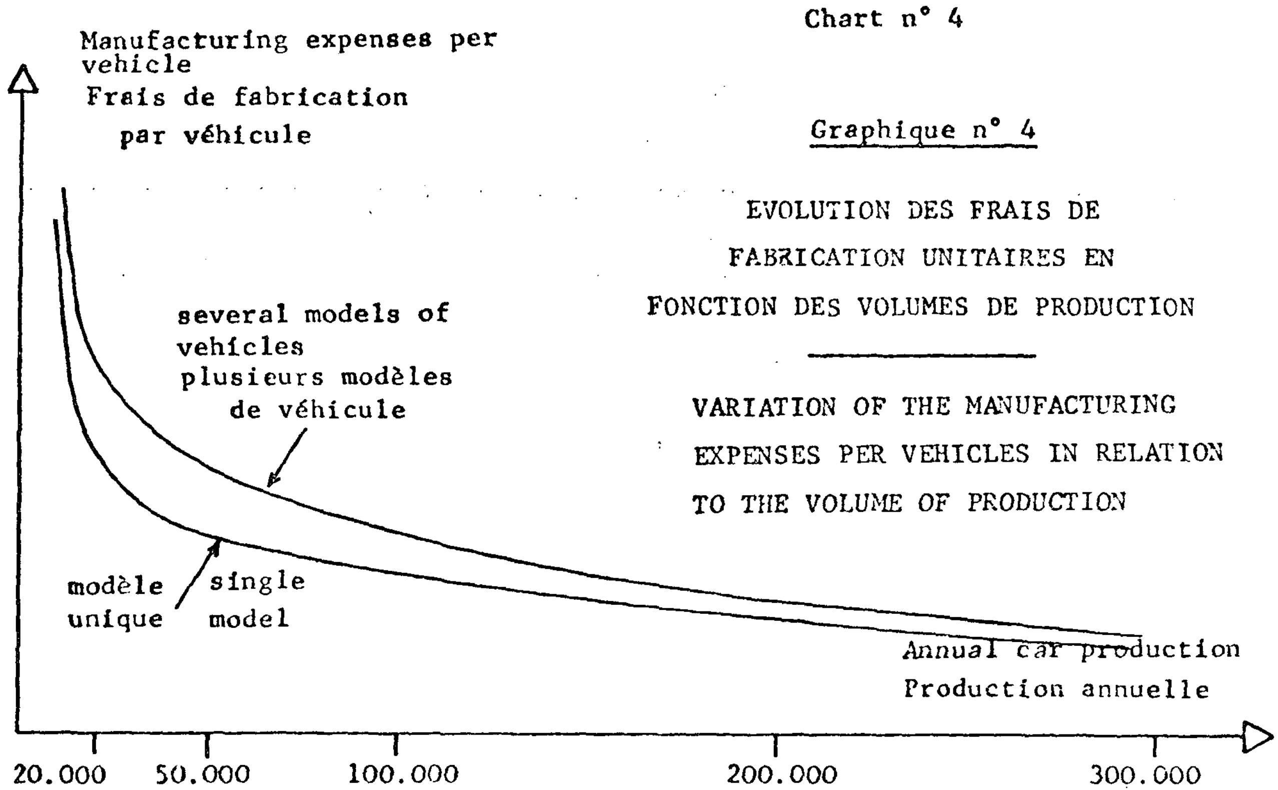


EVOLUTION DES FRAIS DE FABRICATION EN FONCTION DES VOLUMES DE PRODUCTION

VARIATION OF THE MANUFACTURING EXPENSES IN RELATION TO THE VOLUME OF PRODUCTION

Chart n° 4

Graphique n° 4



EVOLUTION DES FRAIS DE FABRICATION UNITAIRES EN FONCTION DES VOLUMES DE PRODUCTION

VARIATION OF THE MANUFACTURING EXPENSES PER VEHICLES IN RELATION TO THE VOLUME OF PRODUCTION different parts, accessories and assemblies; control costs will be higher and the expenses for the maintenance of specific equipment will also be more important.

It may, therefore, be concluded that where there is a large number of models, total manufacturing costs inevitably increase.

C) Overhead expenses

For a plant of a given capacity, these have no connection with output fluctuations.

However, it is readily understandable that in the case of a high capacity plant, with a large number of workers working on the production side, it will be necessary to reinforce managerial and administrative personnel to allow the assembly plant to be run properly.

On the other hand, certain social costs (cafeteria, vocational training courses) become more necessary as production increases. All this constitutes a rise in related expenses (travel, office supplies, mail).

Furthermore, financial expenses rise when the assembly capacity increases.

Thus, it may be stated that total overheads have a tendency to increase with the output of the assembly plant. This increase is, however, less than proportional to the increase of assembly rates.

a) Effect of the number of models

The assembly of a great number of models means that many more administrative personnel will be needed in an assembly plant. The control of supplies and purchases requires more personnel; the same goes for the control of the assignment and reception of CKD collections, which is particularly complex when there are more models. On the other hand, control of cost prices is a more complicated procedure.

It is thus true to say that a wide variety of models necessarily entails, for a given assembly capacity, a rise in overheads.

b) Share of overheads in the assembly unit cost

It has been stated that the mass of overheads is not constant, and that it increases slowly with the volume of production.

This variation is shown on Chart No. 5

Chart n° 5

Graphique n° 5

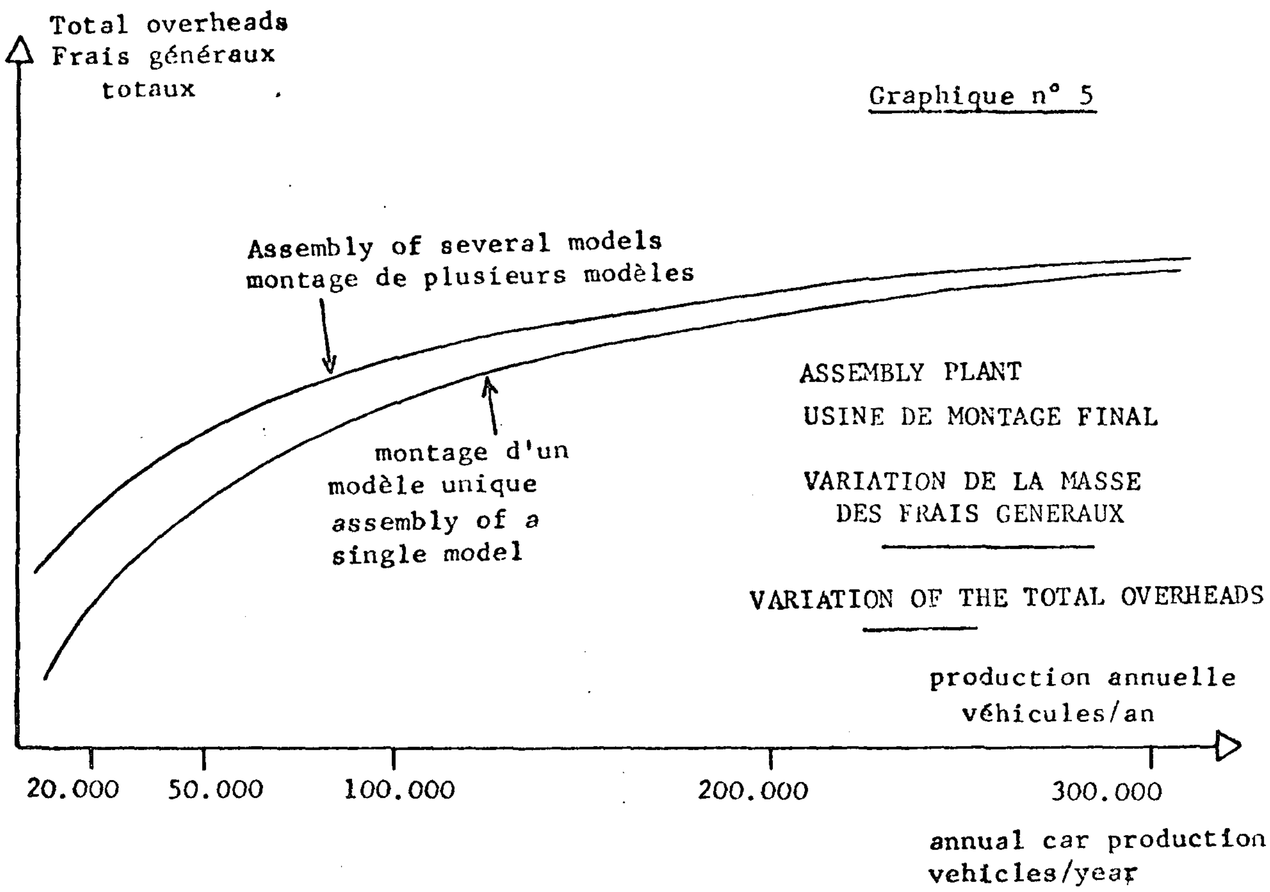
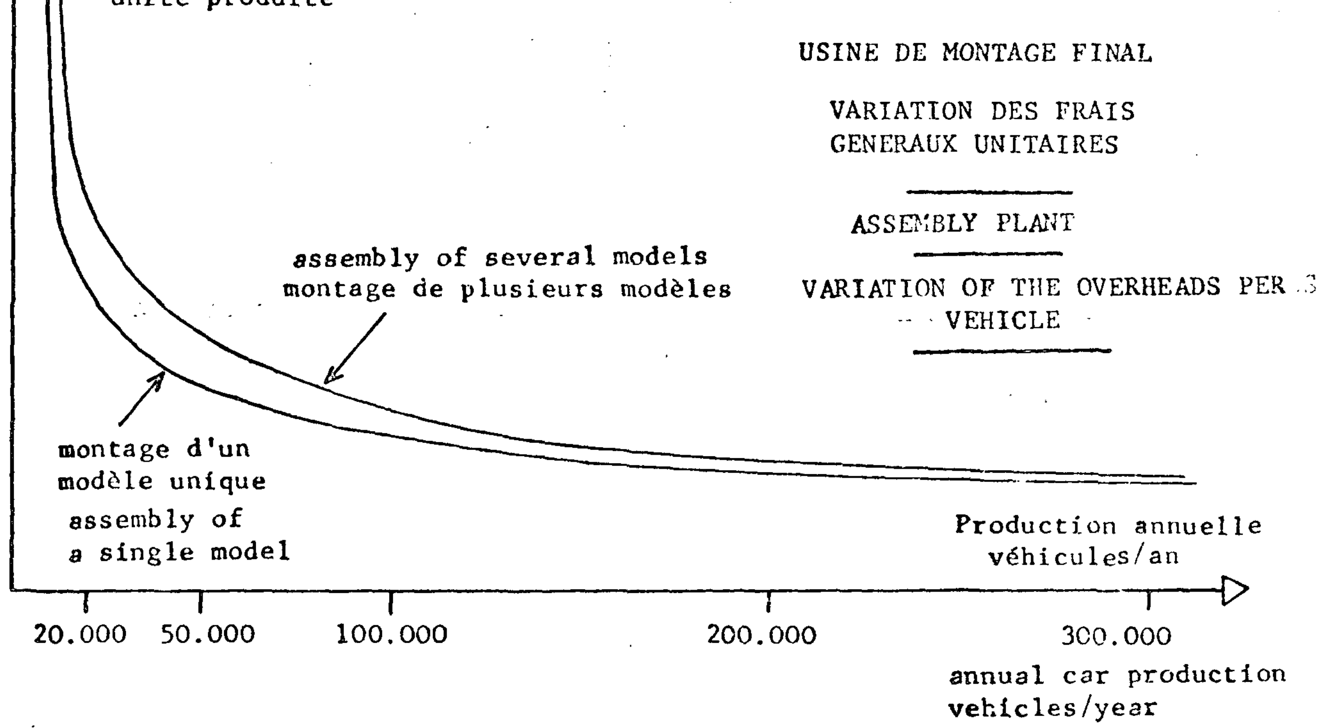


Chart n° 6

Graphique n° 6



The increase of total overheads in relation to production is quite fast for low rates but it obviously tends to slow down in the case of high assembly rates.

This is one difference in comparison with the manufacturing costs.

As to the share of overheads in the unit assembly cost of a vehicle, a decreasing curve is observed with higher production.

Overheads have a big share for very low assembly rates but falls quite rapidly as the assembly capacity increases. For a higher annual output, the share of overheads in the unit cost diminishes very slowly, and has a tendency to level off.

This development may be seen on Chart No. 6 where the variation of overheads in the unit assembly cost has been indicated in relation to the capacity of the assembly plant.

It is worth noting that a large number of models causes an appreciable expansion in overheads as indicated in the chart.

D) Depreciation

Depreciation is directly tied to investment: total depreciation charges increase therefore, with the capacity of the plant, and are higher in a highly mechanized plant.

For total depreciation allowances, one will obtain a rapidly rising curve which will then increase more slowly; this is shown on Chart No. 7.

a) Depreciation trends

Depreciation charges per vehicle fall sharply as the production increases, in the case of low rates. The higher the output, the slower the decrease, in case of high rates. This may be seen on Chart No. 8

b) Influence of the life span of a model: interest in "freezing" the models of vehicles

Depreciation for a given amount of investment will be affected by two factors:

- category of investment concerned;
- depreciation period allowed.

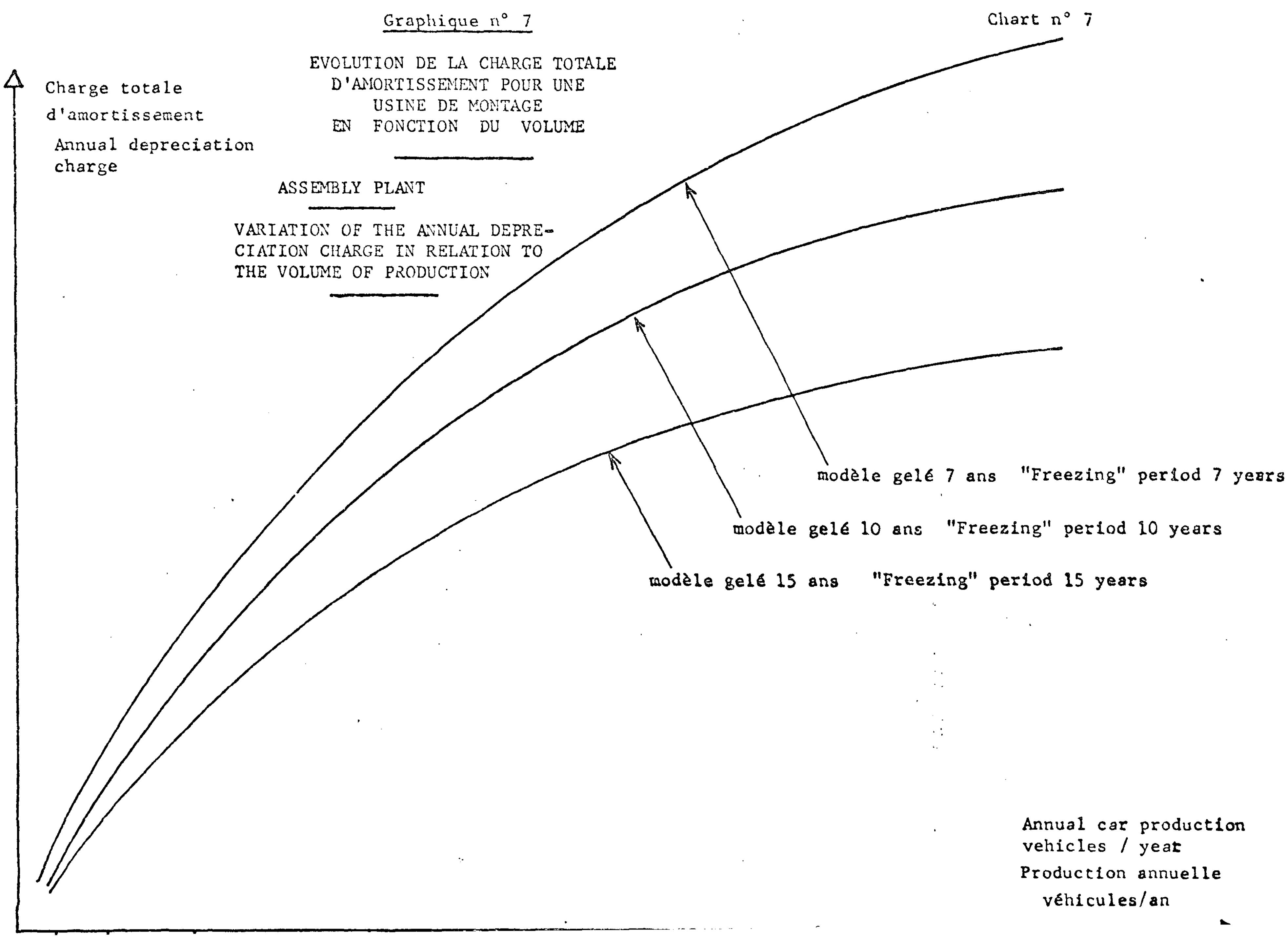
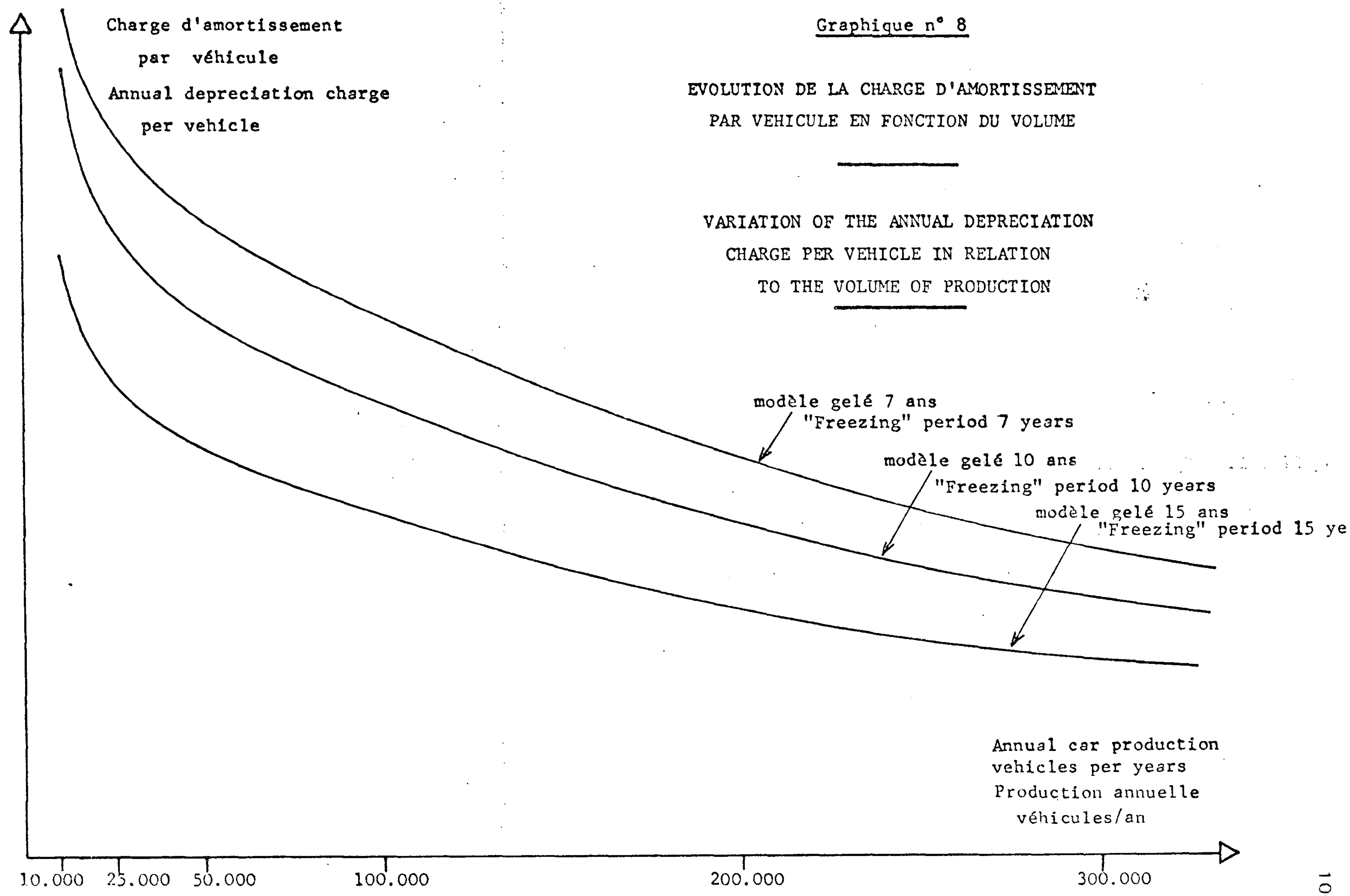

Graphique n° 7
Chart n° 7
EVOLUTION DE LA CHARGE TOTALE
D'AMORTISSEMENT POUR UNE
USINE DE MONTAGE
EN FONCTION DU VOLUME
ASSEMBLY PLANT
VARIATION OF THE ANNUAL DEPRE-
CIATION CHARGE IN RELATION TO
THE VOLUME OF PRODUCTION
Charge totale
d'amortissement
Annual depreciation
charge
modèle gelé 7 ans "Freezing" period 7 years
modèle gelé 10 ans "Freezing" period 10 years
modèle gelé 15 ans "Freezing" period 15 years
Annual car production
vehicles / year
Production annuelle
véhicules/an

Chart n° 8

Graphique n° 8

EVOLUTION DE LA CHARGE D'AMORTISSEMENT
PAR VEHICULE EN FONCTION DU VOLUME

VARIATION OF THE ANNUAL DEPRECIATION
CHARGE PER VEHICLE IN RELATION
TO THE VOLUME OF PRODUCTION



i - <u>Minimum period of accounting depreciation</u>

The laws of each country set a minimum period for depreciation for the different categories of investment.

In the automobile industry the depreciation periods adopted are generally:

. Buildings	20 to 25 years
. Equipment	
Spot-welding	7 years
Painting	10 to 15 years
Upholstery	7 years
Mechanical	7 years
Utilities - services	6 to 7 years
Maintenance	6 to 10 years
. Specific tools	3 years
. Non-specific tools	5 years

By specific tools is meant those tools that are used for only one model of vehicle; this is the case of the assembly jigs, the control body shell, the multiple-head welding machines etc.

Due to the very sharp competition among car manufacturers in the industrialized countries, the latter are obliged to introduce new models of vehicles more and more frequently (now every three years in many cases). As the output of these big manufacturers generally exceeds 150,000 vehicles a year for a widely diffused model, a three-year depreciation period is allowed for the special tools, since 450,000 units of the same vehicle are produced during this period at this level of production, depreciation charges per vehicle account for a small part of the assembly cost of a vehicle. As has been seen, depreciation ceases to diminish when output exceeds 150,000 vehicles a year, For a big manufacturer it is thus not worthwhile to depreciate specific tools over a longer period. On the contrary, rapid depreciation will protect him against the risk of failing to seell, in the event of poor economic conditions and in particular, the risk that his model will become obsolete if new competitive models appear on the market which are more attractive to the public.

ii - The value of "freezing" the models of vehicles

It should be stressed that the depreciation periods previously indicated are minimum accounting periods. As a matter of fact a model is manufactured during a much longer period, i.e, about 10 years though sales diminish towards the end of the model's life,

If it were possible to propose a guaranteed sales rate over a period of ten years, for example, to a car manufacturer without any risk of competition due to the appearance of new models, the decision could be taken from the very beginning to depreciate plant equipment and tooling throughout those ten years, so that reduced depreciation charges would be calculated for each vehicle starting from the initial sales of the model, thus making it cheaper to assemble the vehicle.

This would be possible if the authorities of the country decided to "freeze" the model which would obviously mean that they would prevent any competing model from appearing over those 10 years, Obviously, such a decision is never popular and this is why it must be taken by the highest authority in a country, as it constitutes a political and economic decision.

N.B. This possibility may be of interest to the developing countries. An attempt has been made to calculate the benefits that could be obtained in paragraph 2.4.2.

2.4 Overall examination of the cost of assembling a vehicle

2.4.1 Variation of assembly costs in relation to production

Paragraph 2,3.2 has shown the variation in each one of the factors that make up the assembly cost of a vehicle according to the rate of output.

These various remarks may now be summarized in order to show how the cost of assembling a vehicle may develop according to annual production. This variation is shown on Chart No. 9 where the ordinate shows the assembly overprice in relation to production volume.

For each level of production the overprice is estimated in relation to the assembly cost of the same model built in an industrialized country at a rate of 300,000 units per year. A popular medium-sized vehicle has been chosen in this case with a cylinder capacity of 1000 cm3. Overprice 0 thus corresponds to the production of 300,000 units a year,

This curve indicates that assembly overprice is very high for low rates of production and that it decreases rapidly as the output increases, From 90 to 140% for 10,000 vehicles a year, it drops to 70 to 100% for 25,000 vehicles a year and is

Chart n° 9

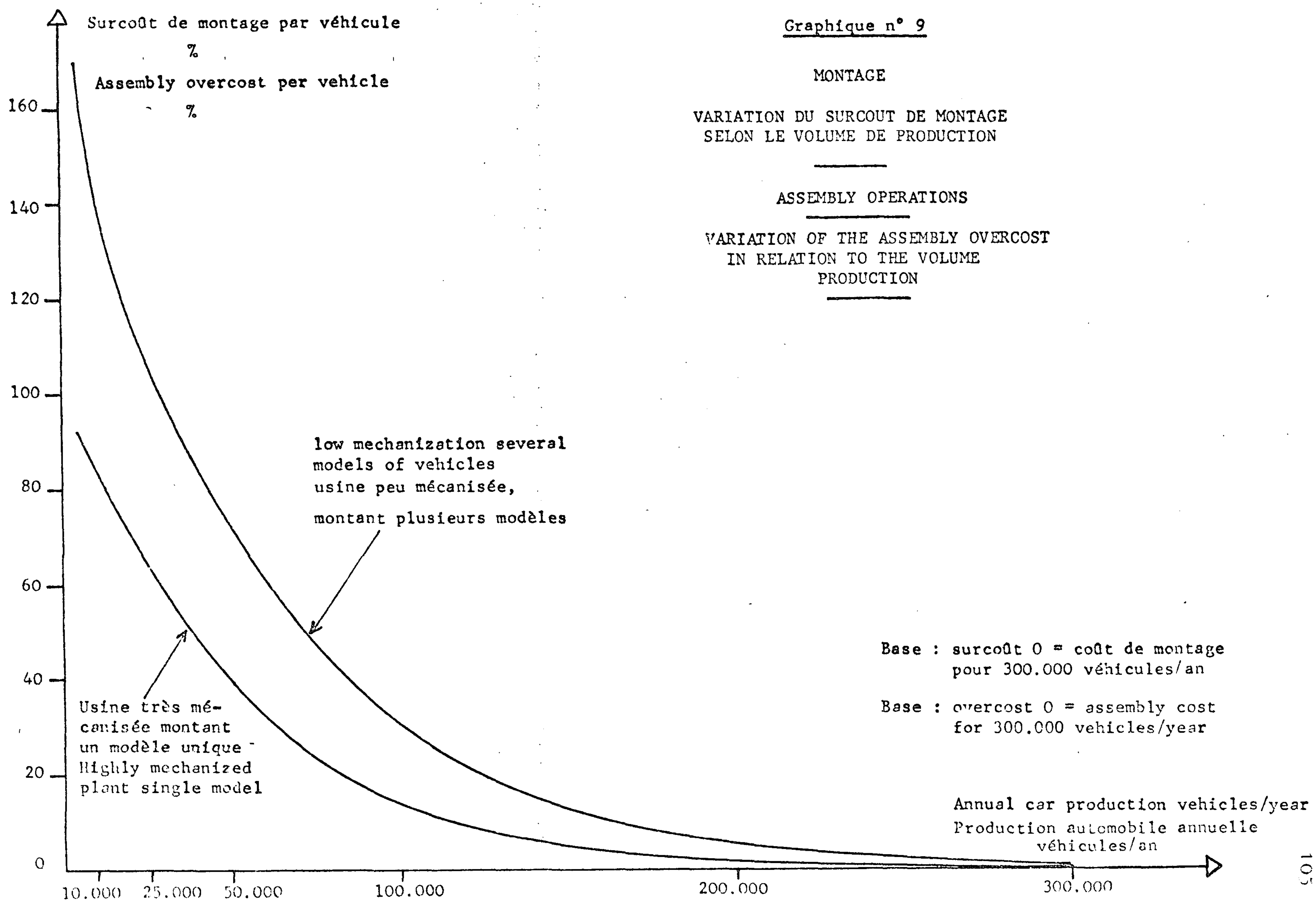
Graphique n° 9

MONTAGE

VARIATION DU SURCOUT DE MONTAGE
SELON LE VOLUME DE PRODUCTION

ASSEMBLY OPERATIONS

VARIATION OF THE ASSEMBLY OVERCOST
IN RELATION TO THE VOLUME
PRODUCTION



only 15% to 30% for a rate of 100,000 vehicles a year.

On this chart, the upper curve corresponds to a low mechanized plant, assembling only one vehicle. It may be specially noted that low mechanization of a plant plus a great number of models results, for a given capacity, in a high overprice. The lower annual output, the higher the overprice.

2.4.2 Study of a numerical example

In order to clarify the previous ehapters, the variations of assembly costs for a private vehicle have been computed.

A) Calculation hypotheses

The vehicle chosen is a popular medium-sized one, Assembly is done in a country which is already fairly industrialized with moderate climate. Furthermore, it is assumed that the plant is highly mechanized, even for low rates of output and that it only assembles one model of vehicle.

For an output of 10,000, 25,000, 100,000 and 300,000 vehicles a year. the assembly cost has been reconstructed on the basis of the four main factors previously indicated.

The labor hourly rate has been fixed at 12 FF.

Minimum depreciation periods have been calculated as follows:

Buildings	20 years
Equipment (except painting)	7 years
Painting equipment	10 years
General facilities and services	7 years

Tools, specific or not, are small if compared with total investment, and therefore have not been detailed separately in this example; they are included under "equipment" and are therefore depreciated over 7 years.

N.B.: Land is not depreciated.

For each level of production, total investment has been measured on Chart No. 1. The proportion of the different categories of investment in the total amount of investment has been chosen as follows:

Buildings	40%
Equipment (except painting, including tools)	25%
Painting equipment	15%
General facilities and services	15%
Land	5%
Total investment	100%

For each level of production, the assembly cost has been calculated for three different periods in the life of a model, corresponding to a decision to "freeze" the model of the vehicle for 7, 10 or 15 years.

B) <u>Breakdown of assembly costs per vehicle</u>

With a view to detailing the structure of assembly costs, Table No. 2 shows, for different levels of production, the breakdown of assembly costs according to its four components. This chart corresponds to a model "frozen" for 10 years. It was not considered necessary to indicate the percentage corresponding to a model "frozen" for 7 or 15 years since the figures would be practically the same.

It should be emphasized that this assembly cost structure refers to a country which is already industrialized and where labor is expensive. This is the reason why direct labor expenses already represent 30% of the assembly cost at a level of 10.000 vehicles a year and more than 50% in cases (theoretical cases) where output totals 300,000 vehicles a year,

Table No. 2

Breakdown of the unit's assembly cost in a country which is already industrialized

(value added)

	Production: vehicles/year			
	10,000	25,000	100,000	300 000
Percentage of unit assembly cost	%	%	%	%
. Direct labor costs	34	37	43	51
. Manufacturing costs	29	28	27	25
. General overheads	24	23	19	16
. Depreciation	13	12	11	8
UNIT ASSEMBLY COST	100%	100%	100%	100%

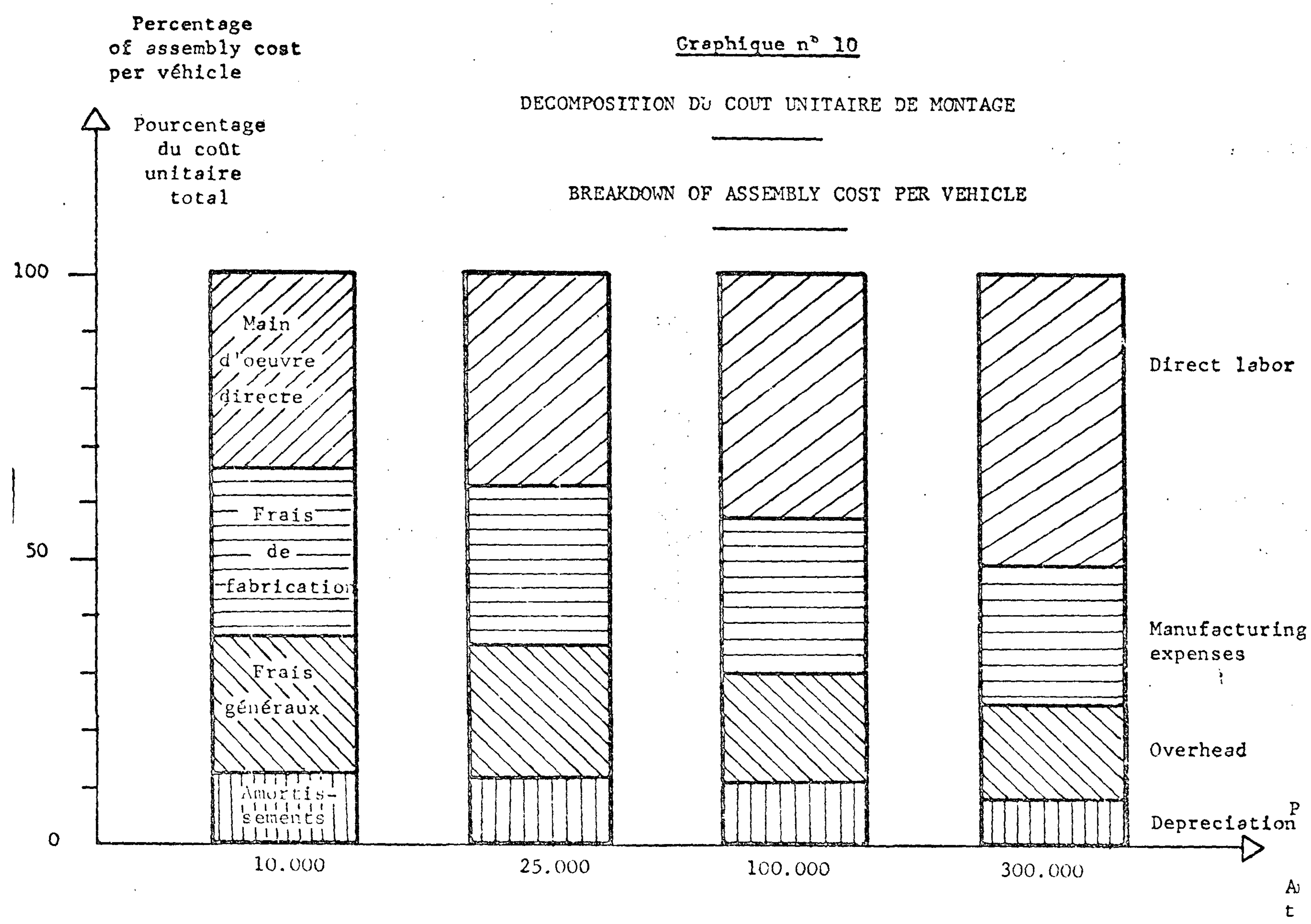
* This table is illustrated on Chart No. 10.

Chart n° 10

Graphique n° 10

DECOMPOSITION DU COUT UNITAIRE DE MONTAGE

BREAKDOWN OF ASSEMBLY COST PER VEHICLE



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C) Examination of results

Table No. 3 shows the assembly cost per vehicle for different levels of production and for different periods in the life of the model studied.

Figures are given as indices; base 100 represents the minimum assembly cost for a production level of 300,000 vehicles a year, the model being frozen for 15 years.

For a better illustration of the results, Chart No. 11 shows the assembly costs per vehicle, according to the production, On this chart, three similar curves may be seen, each corresponding to one of the three freezing periods of the model.

The "freezing" of the model will be seen to reduce assembly costs, particularly when the model is frozen for a longer period. On the other hand, this advantage is greater when output is low.

However, mention should be made of the fact that the freezing of a model only reduces slightly assembly costs because in the case

Chart n° 11

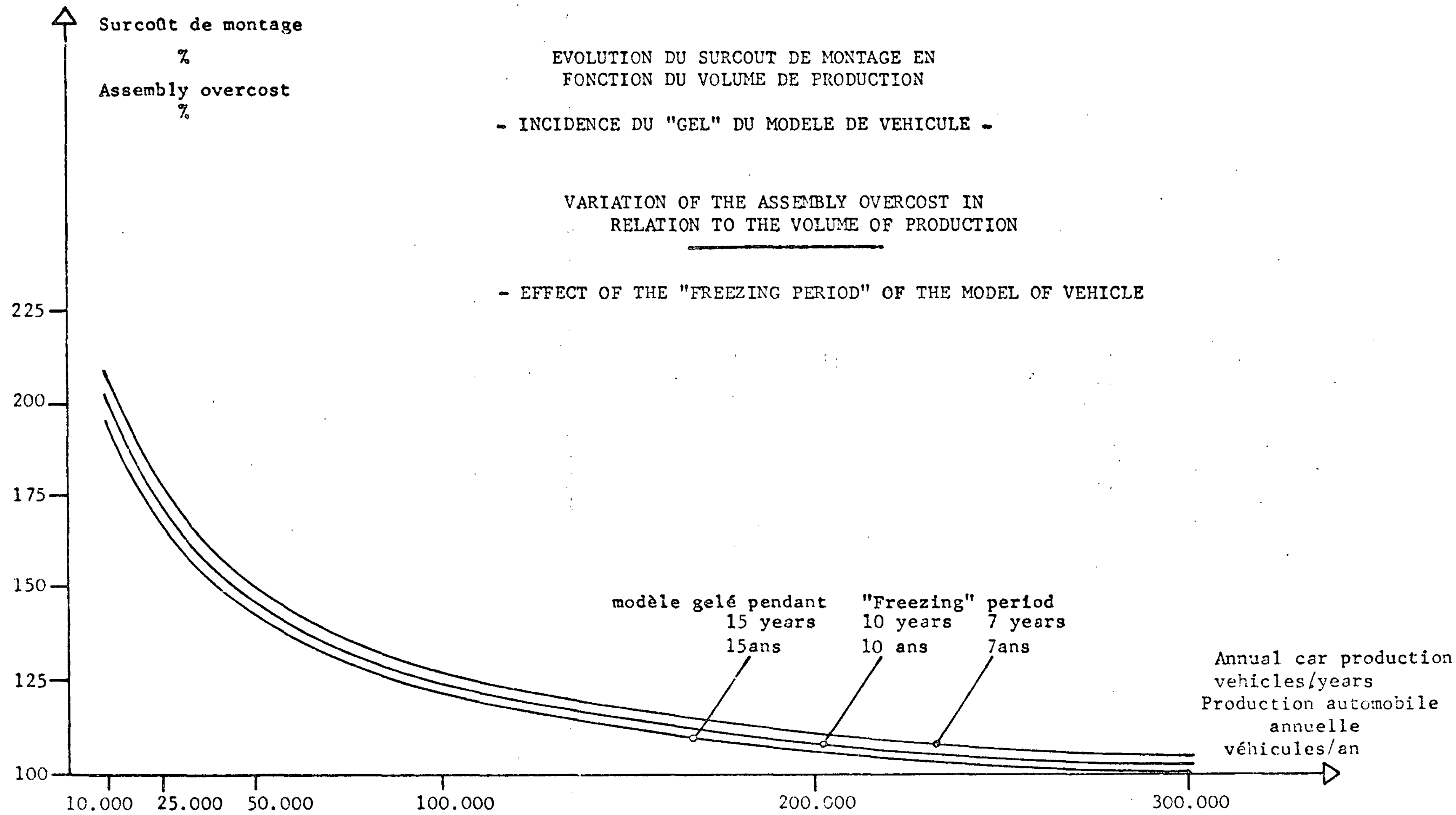
Graphique n ° 11

EVOLUTION DU SURCOUT DE MONTAGE EN FONCTION DU VOLUME DE PRODUCTION

- INCIDENCE DU "GEL" DU MODELE DE VEHICULE -

VARIATION OF THE ASSEMBLY OVERCOST IN RELATION TO THE VOLUME OF PRODUCTION

- EFFECT OF THE "FREEZING PERIOD" OF THE MODEL OF VEHICLE



of an assembly plant, investment in equipment is of little importance compared with a machining or pressing shop. Only investment in buildings is high, but as the law requires a minimum depreciation period of 20 years, this does not have much effect on assembly costs, as the life span of a model is always less than 20 years,

Table No. 3

Variations in Assembly Costs in Relation to Production

The case of an industrialized country (as an index)

Assembly cost per vehicle	Production: vehicles/year			
	10,000	25,000	100,000	300,000
model frozen for 7 years	203	176	128	105
model frozen for 10 years	201	172	124	103
model frozen for 15 years	197	168	121	100

The very rapid decrease that is observed on Chart No.11 as soon as production increases to 10,000 vehicles a year, is due to the fact that the hourly rates of direct labor used in the calculations are high. As soon as production goes up, and because the plant chosen for the example is highly mechanized, assembly time decreases apace and the effect on direct labor costs is all the more appreciable as labor rates are high.

For 100,000 vehicles a year, the assembly overprice is not more than 25% and it becomes negligeable for 200,000 vehicles a year.

D) Conclusion

This example confirms the remarks made in the preceding paragraph and gives a clearer insight into the value of "freezing" the model of a vehicle.

In general, it may be said that the cost-volume ratio is very obvious in the case of an assembly plant. Assembly overprices are very high for production levels of under 25,000 vehicles a year and becomes very low as soon as 100,000 vehicles a year are attained with with an insignifcant overprice only from

200,000 vehicles a year and over.

The mechanization of the assembly shop reduces the assembly overprice. On the other hand, multiple models increase assembly costs particularly when output is low.

However, because of the reasons that have been mentioned above the freezing of models has but little bearing on assembly costs (3% variation in assembly costs for an output of 10,000 vehicles a year, from a model "frozen" for 7 years to a model "frozen" for 15 years; because assembly costs represent about 10% of the cost price of a vehicle, the final effect on the ex-work price of a vehicle would be only 0.3%).

2.5 The Developing Countries

2.5.1 Effects of hourly labor rate and productivity

In the previous example, a high hourly rate for direct labor corresponding to an industrialized country was used.

This hourly rate may be much lower in other countries, especially in developing countries; direct labor costs and therefore, total assembly costs may be considerably reduced if the assembly plant is located in a less industrialized country.

However, the workers' productivity is frequently lower in the less industrialized countries, particularly in hot countries, This is a disadvantage which prevents countries from taking full advantage of a low labor rate,

A) Calculation hypotheses

In order to illustrate this, the previous example has been reintroduced using as hypothesis an hourly labor rate of 6 FF. and productivity equal to 2/3 that of an industrialized country.

The other assumptions used in the example of paragraph 2.4.1 will remain the same, For example, it was assumed that the plant was highly mechanized and assembled a single model. Total investment in a plant of a given capacity is therefore identical and depreciation is also the same. Moreover, overheads for the different rates of production have not been altered.

Under these conditions, the influence of the hourly labor rates on assembly costs may be clearly determined.

B) Result of calculations

The result of the calculations is shown on Table No. 4 The assembly costs appear as indices, the cost basis is identical to the one used in the previous example; base 100 corresponds, therefore, to the assembly costs of a leading European car assembler assembling 300,000 vehicles a year of a single model, with an hourly labor rate of 12 FF and productivity of 100, corresponding to productivity 66 in a less industrialized country.

Table No. 4

Variations of assembly costs in relation to production

The case of less industrialized country

Assembly costs per vehicle	Production: vehicles/year		
	10,000	25,000	100,000
Model frozen for 7 years	185	157	110
Model frozen for 10 years	182	154	108
Model frozen for 15 years	176	150	106

A study of the above table will reveal that assembly costs, at the same production level, are much lower than in an industrialized country (Table NO. 3). In particular, the assembly overprice becomes negligeable for levels of production of about 100,000 vehicles a year. Thus the favorable effect of low hourly labor rates on assembly costs becomes obvious even if the productivity of the workers is much lower than in an industrialized country.

C) Analysis of the results

One must realize, however, that the benefit on assembly costs may be considerably reduced, if a lower degree of mechanization is chosen, because in this case assembly overtime becomes much higher and may even cancel out the benefits in direct labor expenses.

On the other hand, it is interesting to note that the overheads used in our calculations, could be lower in a country that is not very industrialized; this would mean an appreciable reduction in assembly costs that might be evaluated at approximately 15%.

D) Breakdown of assembly costs in a country with a low level of industrialization

To make the preceding example clearer, Table No. 5 shows the breakdown of assembly costs for different production levels in countries with a low level of industrialization.

This table refers to a real cost structure.

The table shows that labor costs represent a small part of assembly costs because in the countries examined the labor rate is not very high.

On the other hand, attention should be drawn to the fact that the overheads are not as high as in the first example (see Table No. 2).

Finally, the very important share of manufacturing costs should receive special attention. This increase is due in particular to the cost of indirect labor; a plant located in a less industrialized country will frequently call in European supervisory personnel. Thus, travel and accommodation expenses and salaries will be high and this will expand the share of manufacturing costs in assembly costs, as compared with a plant located in an industrialized country.

Table No. 5

Breakdown of assembly costs in less industrialized countries

	Production: vehicles/year		
	3,500	4,500	12,000
Percentage of total cost	%	%	%
Direct labor costs	15	19	23
Manufacturing costs	52	48	45
Overheads	18	18.5	19
Depreciation	15	14.5	13
Assembly cost per vehicle	100	100	100

2.5.2 Effect of assembly costs on the sales price of a vehicle

It is important to estimate the effect of assembly costs on the market price of vehicles: first, on dealer prices, and second, on customer prices.

A) Dealers' prices

In the following example, it is assumed that there is no local incorporation in the country where assembly is done, in order to grasp more clearly assembly costs in the strictestsense. The following comparison may then be made with a built-up vehicle directly imported form the same foreign country: Table No. 6.

Tn this table, the CKD collection is assumed to have a value of 100. In this case:
- the corresponding built-up vehicle for an manufacturer is worth 110.
- the CKD, because of costs of collecting and packaging parts and the value of the packages, is sold at 112, that is, 2 points more than the built-up one. This result may seem, a priori, rather paradoxical, but in fact it reflects the true situation;

the reason is that collection and packing costs are relatively high, and that the boxes containing the CKD must be of very good quality to avoid deterioration of the parts (usually throw away packing is used).

Table No. 6

Breakdown of dealer's price in the distribution network

	Locally assembled vehicle			Imported built-up vehicle
	Assembly rates			
	10,000	25,000	100,000	
Total value of the CKD collection	100	100	100	
Built-up value				110
CKD conditioning	12	12	12	
Transport, insurance commissions, freighter, maritime transport	8	8	8	11
Customs duties	(to be considered accordingly)			
Local assembly cost	20	17	12	
Dealer's price in distribution network (cost price)	140	137	132	121
Overprice in relation to an imported built-up vehicle	15%	13%	9%	-

The advantages of the CKD are felt in the transportation expenses; of course, it is difficult to mention here any figures of absolutely general value, as it is well known that maritime transport varies greatly, not so much according to distance, but to the intensity of the traffic between the two countries under consideration. In the example, figures for transport between Europe and a main Latin American country (Mexico, for example) have been used. The transportation of CKD boxes is of course, less expensive than built-up transportation which is bulkier; the relative advantage, however, is not generally as important as may be imagined on the face of it, because as the example showed, the difference is only about 3 points with the result that the built-up and CKD will reach the port of destination at very similar prices. Furthermore, the vehicle delivered as CKD will be assembled locally at a price which as has been seen in this chapter will be as high as the output of the assembly plant is low.

The previous table studies the cases of assembly plants with the following levels of output:

- 10,000 vehicles a year
- 25,000 vehicles ayear
- 100,000 vehicles a year

and for those levels, it may be considered that assembly costs, compared with those of a leading international manufacturer are higher, i.e. about:

- ≠ 100%
- ≠ 70%
- ≠ 20%

respectively.

Thus the differences, compared with a built-up vehicle, are approximately as follows:

- 15% for 10,000 vehicles a year
- 13% for 20,000 vehicles a year
- 9% for 100,000 vehicles ayear

Obviously, these are average figures that may be modified in many cases for several reasons ranging from particularly advantageous sales conditions granted to a developing country (dumping by an international manufacturer) to advantages due to differences in tranportation costs between CKD's and built-ups that may be higher, than those used here. As a result, it appears that the assembly operations carried out in developing countries, and for small markets as it is often the case, the locally assembled vehicle will reach the dealers at prices that are 15 or 20% higher than imported vehicles. It should be noted that in relation to the price of the country of origin, the overprice is even greater because in the case of a plant assembling 10,000 vehicles a year the index 140 should be compared to the index 110, i.e. a difference of 27 or 28 %.

But the fact is that very often assembly operations are carried out, in developing countries at a rate which is much lower than 10,000 a year,

Chart No. 11 suggests that for the case of production levels below 10,000 a year, assembly costs tend to increase very rapidly; differences of about 80% may be easily attained compared with the prices obtained by very developed countries, in the case of assembly plants whose output is very low.

B) Customer prices

The dealer's distribution margin which varies in the different countries between 12 or 15% to 30%, slightly modifies the effect of assembly costs on customer prices.

Assuming that the distribution margin is 25% the figures would be as follows:

Table No. 7

Customer's Price Breakdown

	Locally assembled vehicle			Imported built -up
	Vehicles/year			
	10,000	25,000	100,000	
Dealer price	140	137	132	121
Distribution margin	46	45	43	40
Customer price	186	182	175	161
Overprice as compared with built-up	16%	13%	8%	-

2.6 Conclusions on the Cost-Volume Ratios for an Assembly Plant

From the remarks made in the previous chapters, it may be concluded that:

2.6.1 Necessary investment

- The amount of investment in an assembly plant increases with that of production. Investment increases rapidly for small output, (scale-up factor 0.70), but this increase slows down when high assembly rates of the order of 100,000 vehicles a year are reached (scale-up factor 0.4).

The amount of the investment will depend on the degree of mechanization chosen for the plant; this effect is only felt in the case of small volumes of production since higher production volumes require, necessarily, a highly mechanized plant.

On the other hand, the number of models assembled, causes an increase in investment that will be greater as the plant is more mechanized, because in this latter case specific costly equipment must be used for each model.

2.6.2 Cost of assembling a vehicle

As far as the assembly cost of a vehicle is concerned the situation may be summarized as follows:

- The unit assembly cost depends largely on the volume of production and decreases as the assembly rate increases (Table Nō. 8). This decrease is very rapid in the case of small rates of production up to 50,000 vehicles a year. For higher volumes of production, the benefit on the assembly cost is smaller and negligeable for an output of 200,000 vehicles a year, Assuming the rate of production is equal, in the case of small output, a greater amount of mechanization will considerably reduce assembly costs, The savings may be as much as 30% for 10,000 vehicles a year. Considering the fact that a plant producing more than 50,000 vehicles a year must necessarily be highly mechanized, at this level, the difference in assembly cost between a relatively less mechanized plant and a plant having attained maximum mechanization is insignificant.In these conditions the assembly overprice becomes negligeable as output totals 150,000 a year.

- The decision to assemble various models, output being equal, causes assembly costs to escalate, and the overprice resulting from a large number of models is particularly noticeable in the case of low or medium rates of production of about 25,000 to 50,000 vehicles a year.

As to the freezing of models which makes it possible to depreciate specific equipment over longer periods, this does not allow any appreciable cost reduction in assembly operations because of the proportion of the cost structure between direct labor and depreciation.

Table No. 8

Average Variation in Unit Assembly Overprice According to the Volume of Production

Base: Overprice 0 for 300,000 vehicles a year

Rate of production vehicles/year	3,500	5,000	10,000	25,000	50,000	100,000	200,000
Overprice in relation to the basis of 300,000 vehicles/year %	200 extrapolation	145 (115 to 175)	115 (90 to 140)	85 (70 to 105)	55 (40 to 70)	22 (15 to 30)	3

Finally, as far as the developing countries are concerned, where labor is normally less expensive than in the industrialized countries, the economy in labor costs makes it possible to reduce the assembly costs; it has been calculated that with an output of 10,000 vehicles a year, assembly costs would normally be twice what they are in a plant producing large series; in a developing country, even if labor productivity is very low as compared to the more developed countries, price distorsions may be brought down to 85% instead of 100%, the normal figure,

In one way or another, assembly costs amount to only 10 to 12% of the cost price of a vehicle and therefore the doubling of assembly costs would only cause a rise of about 10% in the selling price of the vehicles. However, the small difference in price between a CKD completely packed and a built-up vehicles is not such that one could reasonably expect, except in special cases where the savings obtained on CKD transportation costs would be very important, to limit the difference in price to less than 15% between a locally assembled vehicle in a developing country and the same vehicle imported as a built one.

However, from the point of view of a developing country this difference in price is generally justified:

- first, within the framework of the "social value" of such projects since these will result in a considerable value added in the countries;

- second, because of indirect effects; assembly is a necessary stage opening the way for industrialization in the future.

Chapter 3

The Machining and the Mechanical Parts Assembly Shops

Machining shops have a place of prime importance in a complete automobile manufacturing plant both because of the investment required and the quantity and quality of the labor needed. The contribution of the machining and mechanical assembly shops to the value added by the manufacturer is a high one. It represents more than a of the total value added, that is, about 12% of a vehicle's cost price.

Machining techniques, though conventional, require very costly equipment, especially when producing large series as most of the very numerous machining operations are entirely automatic. The manufacturing methods used are characteristic of mass production, and therefore cost prices greatly depend on the volume produced.

This chapter will in the first place briefly describe the machining and assembly of mechanical parts. Then it will consider the investment necessary for a complete machining shop, according to the amount of production expected.

Secondly, machining costs will be analyzed in detail and particular attention will be given to the cost price of certain parts in relation to the rate of production.

It should then be possible to determine critical masses of production for the main mechanical parts and establish a machining overprice curve in relation to the rate of production.

3.1 Machining and assembly of mechanical parts

3.1.1 Mechanical parts

Machining and assembly operations essentially involve the following mechanical units:

- engine
- gearbox
- front and rear axle
- steering
- transmission.

In the chapter on "General Data on Automobile Industry" it was stated that these mechanical units represent about 35% of the cost price of a vehicle; the machining operations described in this chapter represent, in themselves, about 12% of the cost price of the vehicle, that is, one third of the price of the mechanical parts.

3.1.2 Classification of operations

The operations done in the machining and mechanical assembly shops may be divided into three main categories:

- machining: machining in the strictest sense and gear cutting
- heat treatments
- assembly of mechanical parts (assembly, testing and painting of mechanical parts).

3.1.3 Machining

A) Definition: By machining is meant on the one hand, well known metal working operations by removal of particles that will be called machining in the strictest sense, and on the other hand, the cutting of gears, a less conventional operation to be done on special machines.

B) Machines used: The different machines used in the machining section may be classified in three main categories:

a) Conventional general-purpose machines: these belong to the following types:
- lathe
- turret lathe
- horizontal, vertical or universal milling machine
- sensitive drilling machine or radial drilling machine

These machines are also used by other industries than the automobile industry. They are not expensive and are part of the normal equipment of small mechanical or maintenance shops. There is always a second hand market for these machines even if they are 20 or 25 years old.

b) Standard machines

These are semi-automatic machines, for example, multiple spindle lathes and automatic lathes. These machines, though expensive, are well known in the engineering industry where they are used for mass production. They are not specific to the automobile industry and may be reused for other manufactures although not so easily as the general-purpose machines. This is the reason why their resale price after depreciation is appreciable, in particular if they have not become obsolete upon the appearance of new models.

c) Special or transfer machines

Machines specially designed for very specific operations on given parts fall into this category, for example, multiple head machines drilling and milling machines specially equipped with clamping and handling features. These machines cannot be adapted to the machining of other parts unless very importan modifications are made, involving a large of the value of the machine. These are very expensive machines and are used only for very large series.

From this brief description it is easy to see that for different production rates, tools and machines are designed quite differently depending on whether the series is small, large, or very large. Most of the machines first are of the conventional type but then, more and more of the machines are standard automatic machines, and finally a large number are transfer machines producing large series.

Considering the very high cost of high output machining equipment, it is obvious that investment in equipment (machines and tools) will increase heavily with the rate of production; this problem will be studied in more detail in chapter 3.2.

C) Description of the machining shop

The organization of a machining shop may be described as follows:

a) Warehouse

The parts coming from the forging and casting shops are stored in this section. The parts delivered to the machining department are, in principle, in good condition, however they undergo reception checks (quantity, aspect, labeling) and mechanical checks (hardness testing). These parts are grouped by type of vehicle.

b) <u>Productive sections</u>

This covers the different departments of the shop where the machining operations are done. They may be classified as follows:

i - machining of engine mechanical parts
- engine block
- cylinder lining
- cam shaft
- crankshaft
- pistons
- connecting rods
- clutch
- water pump
- oil pump
- rocker arm
- exhaust and intake manifolds

ii - Machining of the mechanical parts of the of the gearbox - differential
- gearbox
- differential
- transmission

This part includes both machining and gear cutting operations.

iii - Machining of strictly mechanical units
- steering
- front axle assembly
- rear axle assembly

c) Others

i - miscellaneous chemical products deposit and tool warehouse

ii - tool and maintenance shop
tool sharpening shop
gauging shop

d) Control section

This section is in charge of the quality control of machining, first during manufacture and second, on the final product. After control, the parts are classified as follows:

- good products
- reworks
- rejects
- recoverable products

3.1.4 Heat treatments

In a machining shop the purpose of the heat treatment is to modify the mechanical properties of the surface of the machined parts in order to increase the superficial hardness of the parts. Greater hardness will ensure greater resistance to wear and tear.

The part is first heated to its point of transformation, then it is cooled fairly rapidly in water, oil , or a bath of a special composition.

Hardness is a function of:
- heating temperature
- cooling speed
- cooling agent.

Furthermore, drop-forged parts coming from the forge must be submitted to a normalizing treatment and then will go to the shot blasting.

The parts that are to undergo heat treatment are arranged in trays according to the type of part. They include connecting rods, steering knuckles, wheelshafts, pinions, synchro-mesh body, sliding gears, and secondary shafts. The heat treatment will be, in this case, adapted to each type of part.

The other parts, will be arranged in bulk in boxes; these are various axles, fork shafts and forks.

The equipment used for heat treatment may be classified in two main categories:
- ordinary heat treatment equipment:
  - furnace
  - controlled atmosphere generator
  - revolving furnace
  - crucible furnace
  - annealing furnace
  - hardening press
- induction quenching material with high frequency heating.

3.1.5 Assembly of mechanical units

All the mechanical units out of the machining, and gear cutting shops after the appropriate heat treatment are stored in a special warehouse for manufactured products. There is also a reception shop for parts needed for the assembly of the mechanical units and coming from the outside.

The six main mechanical units may be divided into 3 groups:
- the engine
- the units: steering
  front axle mechanism
  rear axle mechanism
- the mechanisms: gearbox - differential
  transmission

For each one of these six units the following operations must be done in the assembly department:

A) Preparation

This involves checking, in order to allow for adjustment and subsidiary assemblies, and then, mounting of the sub-assemblies. All the sub-assemblies needed for the assembly are gathered together and taken to the assembly stations.

B) The Assembly Line

The assembly line involves a sequence of operations in which the main part receives as it moves along the line, the subsidiary assemblies and the secondary parts.

Different solutions may be adapted for the assembly line. The usual principle is to place the main part of the unit to be assembled on the line, at the top. The parts that have to be integrated are then placed all along the line in storage boxes, according to the sequence of the operations.

Less automatic lines may, however, be used; in general, the following lines are to be found (they will be chosen according to the rate of assembly, the amount of mechanization, or the type of unit to be assembled):

- individual station
- manual round conveyor
- mechanical round conveyor
- manual horizontal tray
- mechanical horizontal tray (tourniquet)
- manual ground conveyor
- mechanical ground conveyor
- overhead conveyor with carrier arms

In the line as well as in the preceding preparation stations, numerous non-specialized tools will be found such as:

- presses
- screw drivers
- compressed air cleaner
- special parts
- dynamometric wenches

as well as erection assemblies and control assemblies which are, in principle, specific to a type of unit and to a type of vehicle.

C) Testing

The purpose is to ensure the good working order of the units which have been assembled. Essentially this involves:

a) Engine tests

i - working tests - all motors undergo these tests which make adjustments possible. The engine is installed on a testing bench, the ignition mechanism is adjusted and the noise level of the cylinders is checked. Testing time is from 5 to 10 minutes.

ii - sample tests - a certain number of engines undergo more complete tests during which endurance and consumption are tested and motor power is measured.

b) Gearbox testing

All gearboxes go through the noise level test in a soundproof chamber. Testing is done at all speeds forward and backwards.

D) Touching-up

The units which are not up to the manufacturer's standards are sent to this section where the necessary corrections are made. The units are then sent back to the testing section for further checking.

E) Assembly - painting

The engines and gearboxes approved by the testers after the checks are coupled. The motor-gearbox unit which has thus been formed constitutes the power-train unit and is then placed in a special cabin to receive a coat of paint.

F) Control

All along the assembly line there are checking stations. To avoid any reworks it is necessary to assure:

i - the quality of the parts and sub-assemblies ii - the cleanliness of the parts (absence of dust); parts are washed or blown.

iii - the absence of damage generally caused by faulty packing or handling mistakes,

The main parts to be checked will be (for the engine):
- fitting of the connecting rod - axle and piston group
- dynamic balancing crankshaft/steering
- lateral clearance of crankshaft
- rocker arm adjustment
(for the gearbox):
- interlocking of gears
- conic distance
- ball-bearing final fitting
- working tolerances

3.2 Determination of investment in machining and mechanical assembly shops

In this chapter the total amount of investment necessary for a machining and mechanical assembly shop will be determined according to the different hypotheses of production rates.

Furthermore, the effects of the degree of mechanization and of the variety of models on investment will be examined.

3.2.1 Classification of investment

In general, investment may be divided into the following main groups:

- land including land grading
- buildings: industrial halls
  service buildings
- shop equipment: machines and installations
  manufacturing and control tools
- general services and utilities:
  electricity - compressed air - water - vapor

It may be estimated that in total investment the share of each of the following categories is roughly as follows:

- land grading (purchase price not included	1 to 3%
- buildings	8 to 13%
- equipment	75 to 85%
- utilities, general services	2 to 5%

N.B. This classification does not include the price of the land which will mainly depend on where the plant is located,

In order to give a more detailed picture of the share of a machining and mechanical assembly shop in a complete manufacturing plant, for example, investment in a machining and mechanical assembly shop in a complete manufacturing plant producing 100,000 vehicles a year, with an integration rate of 95%, could be said to represent about 35 to 40% of the total investment in the complete plant.

The previous table shows that investment in equipment accounts for nearly all the investment.

3.2.2 Investment and annual production ratio

The equipment used in machining, as has been stated, varies considerably according to the rate of production; in particular, faster and more specialized machines will be used as output goes up, which also means that investment in machinery will be increased as the production increases. It may therefore be concluded that the increase of production is tied to a higher degree of mechanization and automation.

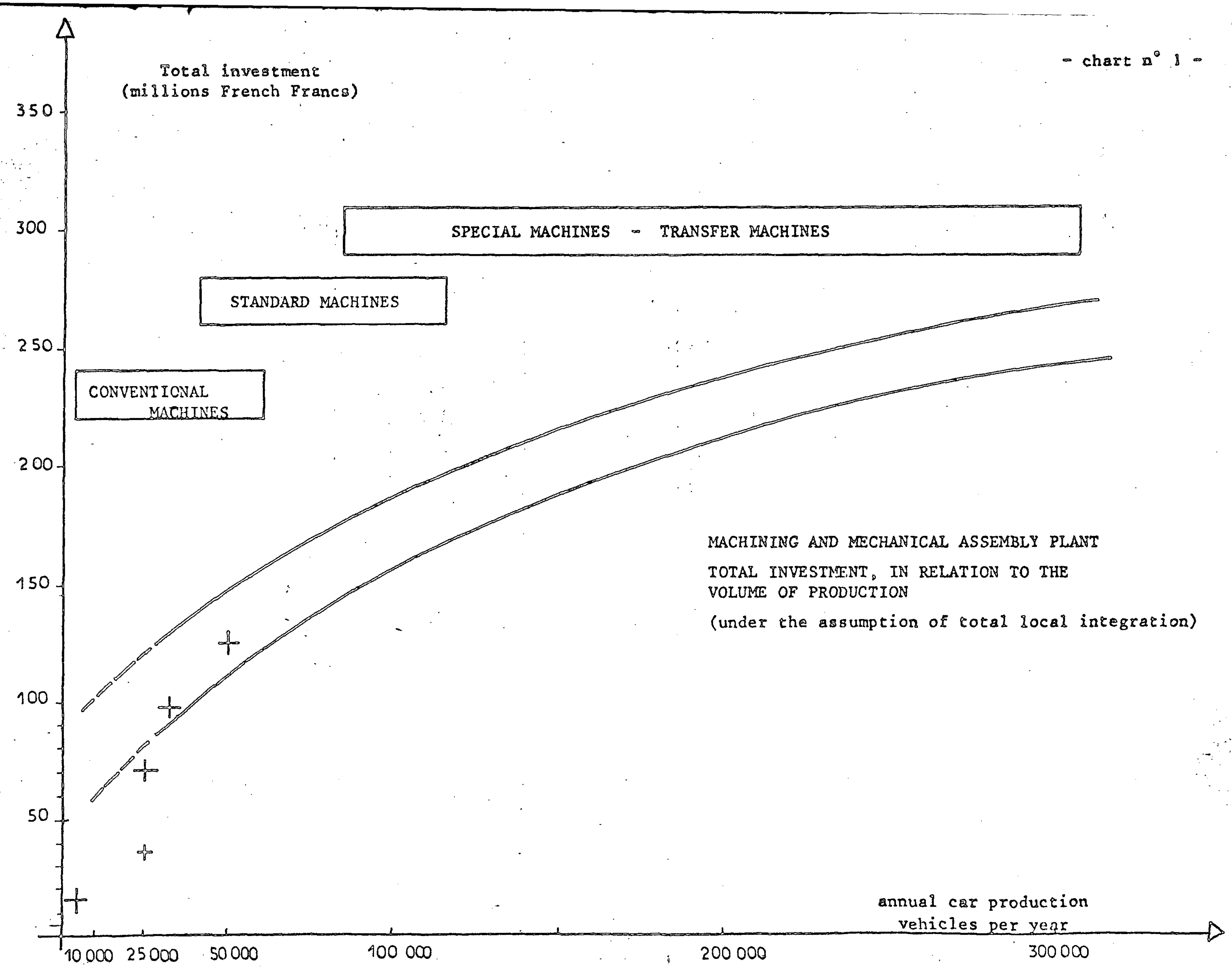
All of these observations have been plotted on Chart No. 1 where annual production is found in the abscissa and the total amount of necessary investment (land excluded) is shown on the ordinate.

A) The effects of economy of scale

a) Low and medium rates

If all the machining operations are to be integrated for productions of 25,000 vehicles

- chart n° 1 -


Total investment
(millions French Francs)
350
300
250
200
150
100
50
SPECIAL MACHINES - TRANSFER MACHINES
STANDARD MACHINES
CONVENTIONAL MACHINES
MACHINING AND MECHANICAL ASSEMBLY PLANT
TOTAL INVESTMENT, IN RELATION TO THE VOLUME OF PRODUCTION
(under the assumption of total local integration)
annual car production
vehicles per year
10 000
25 000
50 000
100 000
200 000
300 000

a year, it should be noted on Chart No. 1 that investment is high even for low rates of production. Between 25,000 and 100,000 vehicles a year, the scale-up factor is about 0.4. This means that when production is doubled, investment is multiplied by 1.32 to 1.35

b) High rates

When dealing with high production rates, the scale-up factor is about 0.37. If annual production is doubled, passing from 100,000 to 200,000 vehicles a year, investment in the machining shop would need to be multiplied by 1.28 to 1.30. This high investment corresponds to the purchase of an increasing number of special machines and transfer machines.

c) Progressive integration of machining operations

However, it should be noted that very frequently only part of the machining operations are done, when output is less than 100,000 vehicles a year. The purpose being to reduce investment which, as has been seen, is very high. Obviously, integration is progressive. At a rate of 25,000 vehicles a year, machining operations will be done for those parts in which a fairly competitive cost price can be obtained in comparison with the leading manufacturers. More so, only those parts that may be machined with low investment will be manufactured.

For about 80,000 to 100,000 vehicles a year, machining operations are usually fully integrated. In the paragraph on "Machining Costs" it will be seen that at this level, a cost price only slightly higher than that of a big car manufacturer is obtained, and thus total integration is preferred.

B) Effects of mechanization

Machine tools are divided into three categories according to their use: small series, big series, very big series. Each category is adapted to the corresponding rate of production, that is, the rate of production at which the minimum machining costs are obtained, as will be seen further on in this study.

It would not be economical therefore to use conventional general-purpose machines for very big series as the machining cost would be very high due to the number of machines and workers that would be proportionately necessary with the increase in production. It would also be necessary to enlarge the building surface. Thus, no profit would be obtained from the effects of economy of scale and the total investment curve on Chart No. 1 would be a straight, 60 degree line.

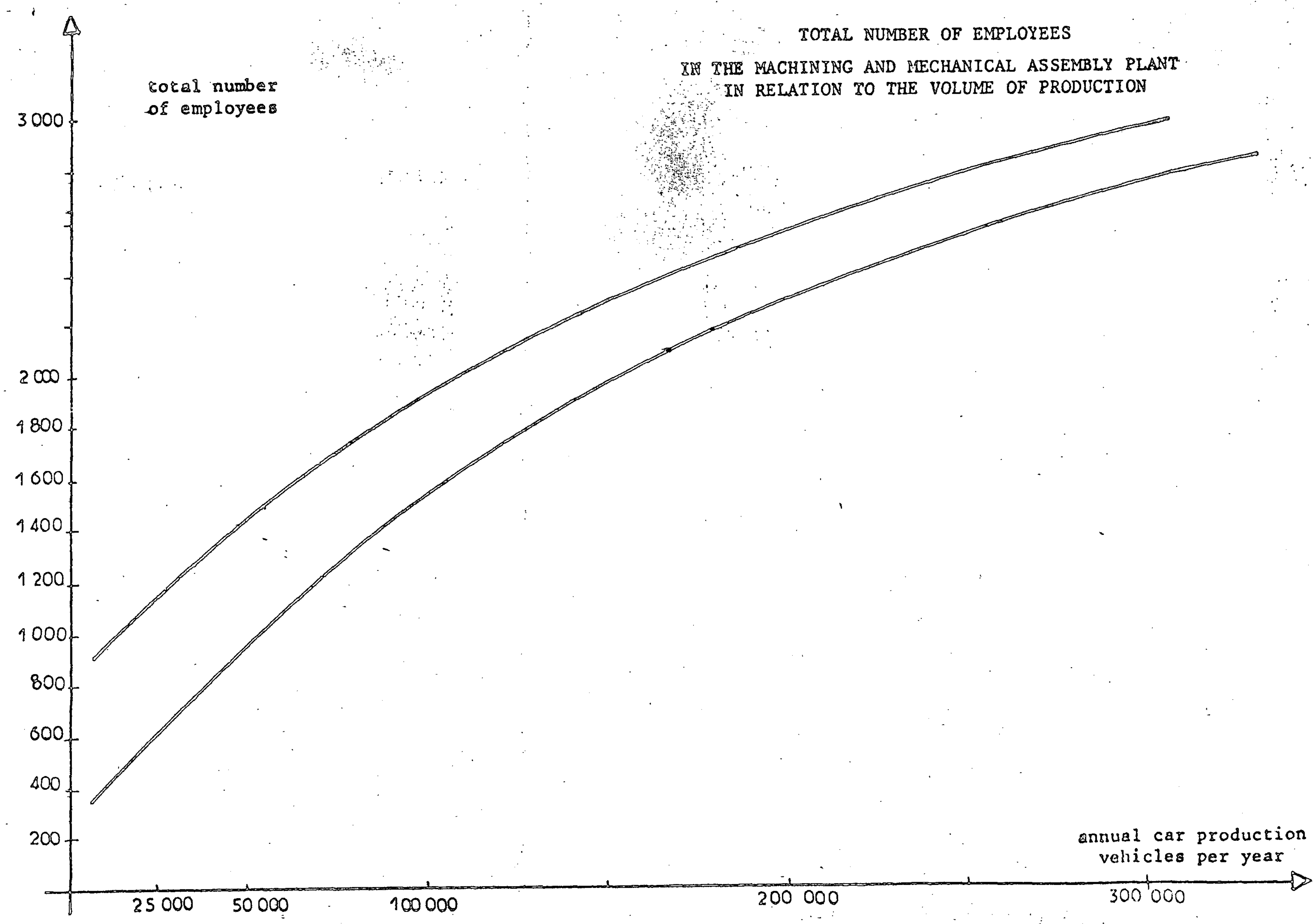
Conversely, special machines of the transfer machine type should not be used for a low output; these machines are very costly and must therefore be depreciated over a very great number of vehicles if reasonable machining costs are to be expected.

It is therefore important to realize that for each production rate there is a given type of machine and, consequently, a given investment level. This is shown on Chart No. 1 which shows the type of machinery to be used according to production rates.

However, a compromise may be reached between on the one hand, a high investment with specialized, costly machines and a smaller work force; and on the other hand, a smaller investment with a greater number of general-purpose machines which are less expensive, and a big work force. This is a matter that must

- chart n° 1a -

TOTAL NUMBER OF EMPLOYEES
IN THE MACHINING AND MECHANICAL ASSEMBLY PLANT
IN RELATION TO THE VOLUME OF PRODUCTION



be studied on a case-by-case basis and which depends on the cost of labor in the country under consideration.

If the mechanical unit assembly shop is studied, a particular amount of lmechanization may be eventually considered for the same given volume. If a less mechanized assembly shop is chosen, it is clear that the labor force will have to be enlarged, but investment will be relatively lower,

However, in a mechanical assembly shop, the plant, machinery, equipment and tools represent but a small part of the investment needed for a machining and gear cutting shop: about 4 to 7%. High mechanization in the mechanical assembly shop would mean a cost increase of about 50% out of a total of 4 to 7% of the total investment required, that is, that it would mean only a small increase in total investment for a complete machining - heat treatment and mechanical assembly shop, Even assuming that the machining shop is not very mechanized, i.e. with a low output and general-purpose machines, the part of the mechanical units assembly is always small; an increase of automation in this assembly equipment which is not justified in this low rate hypothesis, will have little effect on the total cost of a full shop.

C) Effect of a large variety of models on investment

As has been seen, the rate of production offers a certain choice in machining procedures.

As production increases, expensive high speed machinery specific to a particular model is more necessary. This is the case, in particular, of transfer machines that are very difficult to adapt to new models.

However, an automobile manufacturer will try, once he has decided to change a model, to keep as many of the main characteristics of the mechanical units as possible, to be able to reemploy certain very specialized machines.

This is only possible when the models are not very different as to power, cylinder capacity, and engine design. For very different models, it is not possible, in general, to reuse the special machines except when very important and expensive modifications are made.

Of course, as far as small outputs are concerned, because general-purpose non-specific machinery is used, a change in model does not imply large additional investment.

It may then be concluded from this rapid analysis that a large number of models will push up investment, and that this will be higher in the case of high rates of production and models with a great difference in mechanical design.

The problems arising from a variety of models will be dealt in the chapter on " Total Machining Costs" as it is from this angle that investment should be considered.

3.3 Study on machining and mechanical assembly costs

In the first place, the way in which these costs may be broken down will be studied, and the variation of the different parameters of machining and assembly costs will be analyzed in relation to annual production rates. At the same time, the effects of greater or lesser mechanization will be considered.

It will then be possible to examine the total variation of machining and assembly costs in relation to production.

In the course of this study, detailed examples will be given on the machining cost of certain mechanical parts. With this information, it will be possible to examine in detail, in chapter 3.4 the machining and assembly overprices at different rates of production.

3.3.1 Breakdown of machining and mechanical assembly costs

It is necessary to divide these into two parts: machining costs and assembly costs.

A) By machining cost is understood the total cost of obtaining machined parts from rough parts. Thus the cost price of the machined parts is the sum of two elements:
- the cost of rough parts
- machining costs (value added)

a) the cost of the raw parts is the direct cost price at shop level of the parts manufactured in the forging shop or foundry or from steel sheets.

b) machining costs are costs relating to three operations:
- machining
- heat treatment
- gear cutting

B) By assembly costs is meant all expenses necessary to obtain mechanical assemblies from machined parts. The cost price of assembled units is therefore the sum of two elements:
- the cost of machined parts
- the assembly cost.

3.3.2 Analysis of the cost price of an engine

The total cost price of an engine including accessories, may be broken down in such a way to show the value added by the manufacturer. The following example corresponds to a medium-cylinder capacity engine of about 1100 cm3.

	%
Raw material purchases (steel sheets, steel bars, iron, aluminum)	9 to 11
Purchase of manufactured products (carburator, dynamo, coil, starter)	35 to 40
Processing cost (value added)	50 to 55
Total Cost Price	100

The processing cost, that is, the value added, covers the various operations done in different shops (forge, foundry, machining, heat treatment).

The value added may be divided among the different shops as follows:

Breakdown of the value added in an engine	
	%
Iron foundry	25 to 30
Aluminum foundry (cylinder head)	3 to 5
Forge	3 to 5
Steel sheets	2 to 4
Machining, heat treatment, (screw cutting)	50 to 55
Assembly	9 to 11
Total Value Added	100

N.B. In this example, the share of the forge is rather small ; in this case a manufacturer sub-contracts a large number of the forging operations.

The very large share of machining operations in the manufacture of an engine should be noted (more than half the total value added by the constructor) while assembly is only 10% of the total value added.

The value added by the machining shops (machining, heat treatment, screw cutting) may be broken down into different factors:

	%
Direct labor	25 to 30
Manufacturing expenses	35 to 40
Overheads	12 to 16
Depreciation	18 to 22
Value added by machining shops	100

This subdivision shows the importance of depreciation in a machining shop, about 20% in this example.

3.3.3 Analysis of the cost price of a gearbox

For a medium cylinder capacity vehicle of about 1300 cm3, the cost price of the gearbox is established as follows:

	%
Raw material purchases	10 to 15
Purchase of manufactured products	30 to 35
Processing cost (value added)	45 to 50
Total cost	100

N.B. Purchases of manufactured products account for a high proportion in this example; they are mostly rough forged parts bought from a sub-contractor. This example is, however, meaningful as it reflects the general tendency of big car manufacturers to subcontract forging operations so as to devote themselves to the more difficult operations, in this case, the cutting of gears, also requiring a a higher investment.

The value added by the manufacturer in the different shops may be broken down as follows:

	%
Aluminum foundry	1 to 2
Forge	7 to 9
Machining, gear cutting	76 to 82
Assembly	9 to 10
Total Value Added	100

N.B. The example refers to a gearbox with aluminum housing. It should be mentioned, however, that many manufacturers continue to manufacture cast iron housings.

The share of the forge is obviously small as the manufacture of rough forge pinions is farmed out.

3.3.4 Analysis of unit machining costs

It has been observed that for different production rates, it is necessary to adopt different manufacturing techniques which are suited to those rates. Manufacturing techniques are characterized by the percentage of each one of the categories of machines used:

- general purpose machines
- standard machines
- special or transfer machines.

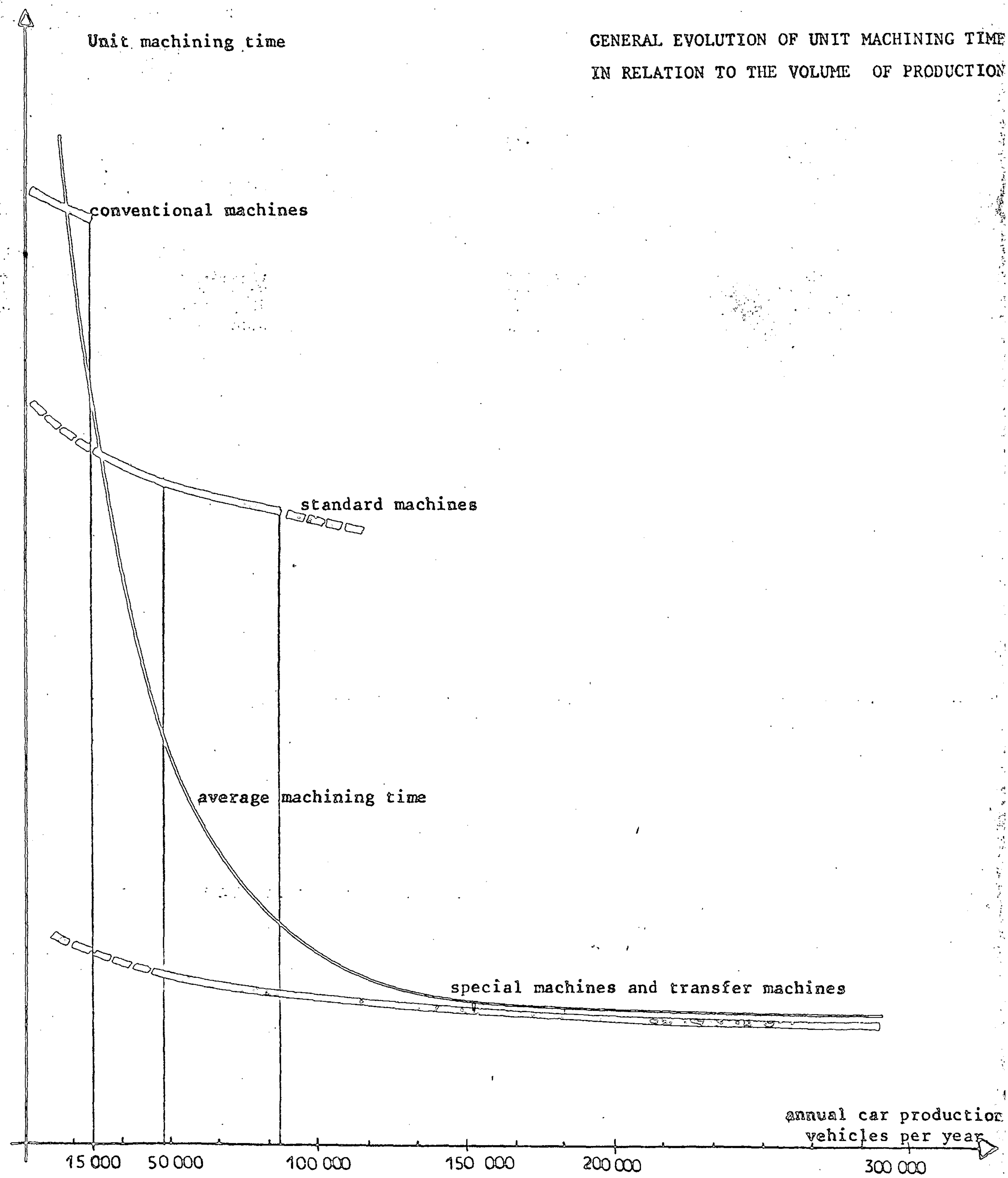
A) Machining times

As more and more standard machines and special machines are used, machining time decreases. this variation in machining time is shown in curve 2A which plots this general trend according to the technique used at different rates. Indeed, for each rate a different proportion of machines in each category will be used and the curve of average machining time will regularly fall, as shown in the chart.

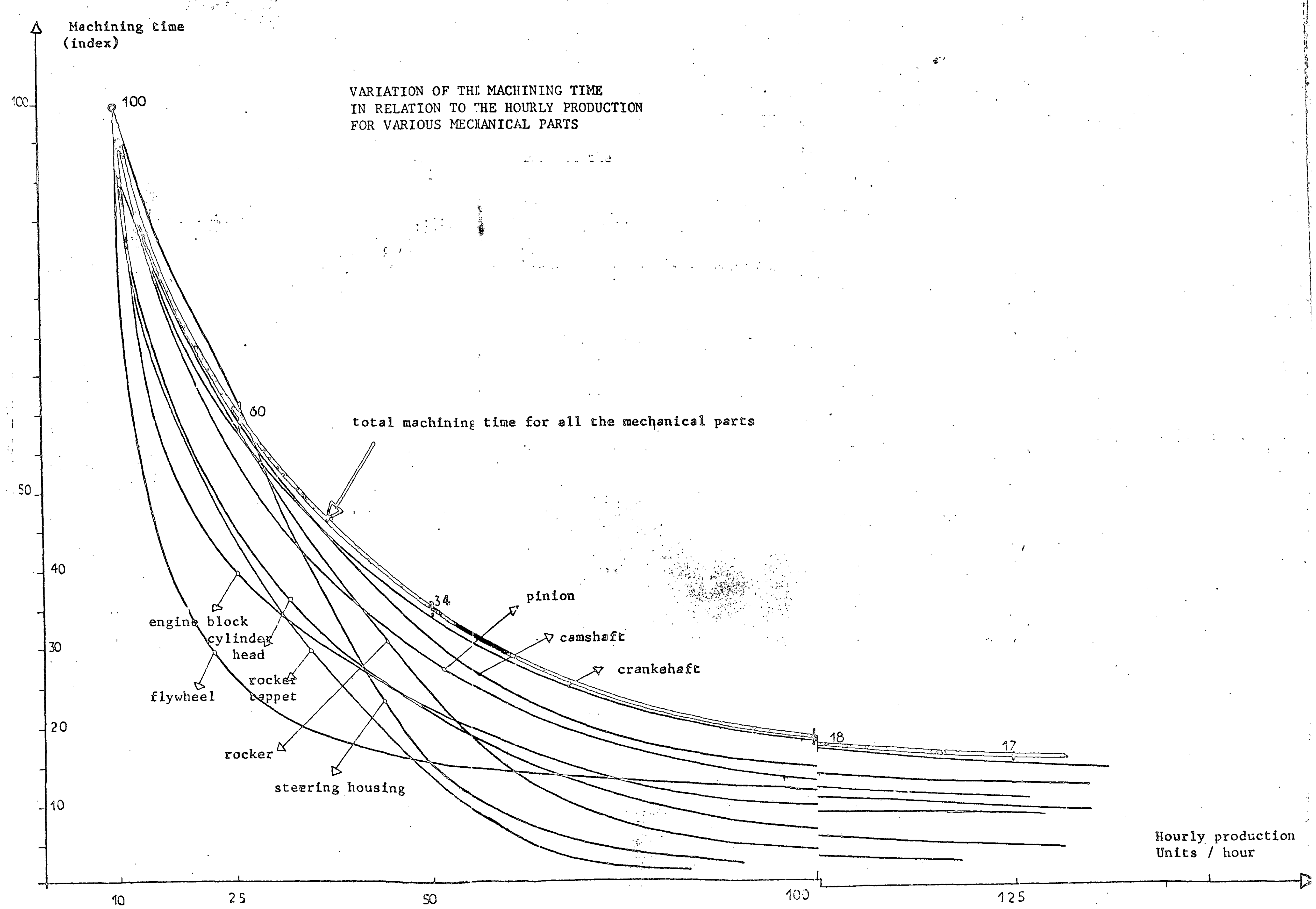
In order to show the savings in machining time, Chart 2B shows the variation of machining time in index number for different mechanical parts. Base 100 has been taken as being common to all parts and is equal to a machining time of 10 units an hour.

- chart n° 2a -

GENERAL EVOLUTION OF UNIT MACHINING TIME IN RELATION TO THE VOLUME OF PRODUCTION



- chart n° 2 b -


Machining time
(index)
VARIATION OF THE MACHINING TIME
IN RELATION TO THE HOURLY PRODUCTION
FOR VARIOUS MECHANICAL PARTS
100
60
34
18
17
total machining time for all the mechanical parts
pinion
camshaft
crankshaft
engine block
cylinder head
rocker tappet
flywheel
rocker
steering housing
100
50
40
30
20
10
10
25
50
100
125
Hourly production
Units / hour

If it is considered that parts such as the engine block and the crankshaft constitute the major part of the machining cost of the mechanical units, it is possible to roughly plot the variation curve of total machining time for mechanical units. This is shown by the thickly marked curve on Chart No. 2B. Machining time varies as follows:

Units/hour	10	25	50	100	125
Total machining time for mechanical units (INDEX)	100	60	34	18	17.5

B) Depreciation

The cost of machinery will be increasingly higher, as more special machines are used. Investment in machinery will, then, have to be depreciated over a vast number of parts.

In reference to depreciation periods, the following rates would be feasible:

General-purpose machine	10 years
Standard machine	7 years
Special machine	6 years

Depreciation charges for each machined part will be very high therefore for small volumes but will decrease rapidly as the rate increases; this is due to the fact that special and transfer machines which are the most expensive ones are also the most specific to a given mechanical part and, in general, to a specific model of vehicle. It is therefore necessary to depreciate over a fairly small period, i.e. the minimum expected market life of the model, that is, about 5 or 6 years. As these special machines are only used for a very big output, they are only likely to be depreciated over a rather small number of years.

C) Manufacturing costs

As far as manufacturing expenses are concerned three main groups may be distinguished:

- indirect labor
- consumable goods
- maintenance costs.

All of these items increase proportionately or less than proportionately to production: consumable goods increase proportionately with production. indirect labor costs increase less than proportionately with production, but they will be higher if increasingly specialized machines are used, in which case the organization of the shop will be more complex and more technical supervisory personnel will be needed. Planing will have to be done with great care, since a shop with special machines can be operated much less flexibly than a shop using general-purpose machines only.

Finally, maintenance costs are much higher in a very automated shop with transfer machines. Logically, due to the very high rates and the specialization of the machines, it is absolutely vital to avoid any trouble or unexpected breakdown.

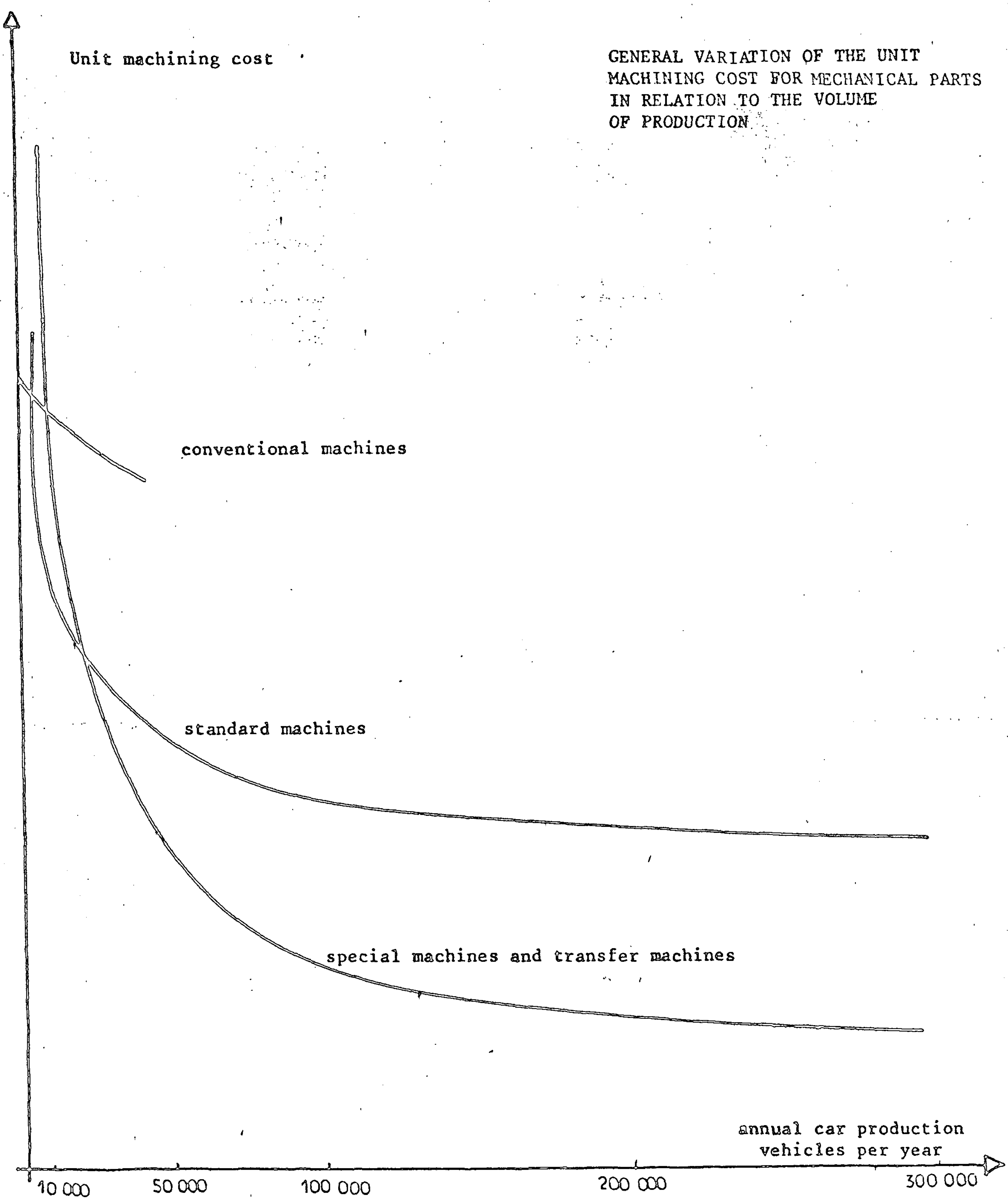
D) Variation of the machining unit costs in relation to production

The previous analysis, together with a more detailed study carried out at certain plants leads one to the conclusion that unit machining costs fall sharply when production increases.

The general shape of the curves is seen on Chart No. 3: the abscissa shows the annual production and the ordinate the unit machining cost for one mechanical part.

- chart n° 3 -

GENERAL VARIATION OF THE UNIT MACHINING COST FOR MECHANICAL PARTS IN RELATION TO THE VOLUME OF PRODUCTION



However, the break-even point for standard machines and for special machines will be different according to the parts under consideration. It will therefore be necessary to make a cost forecast for each part and for the output desired in order to be able to determine which is the best manufacturing technique.

Labor skills

It should also be mentioned that general-purpose machines demand a higher proportion of qualified workers; in spite of the use of machining assemblies to guide the worker, work on general-purpose machines demands a great deal of care and attention. This may be a disadvantage in a country where skilled labor is rare. In the case of special machines, the number of qualified workes needed is much smaller. But on the other hand, special and transfer machines require control, maintenance and check-up personnel which is relatively numerous. In the latter case, however, it is a matter of indirect labor which increases less than proportionately with the volume.

3.3.5 Analysis of the mechanical assembly cost

In the case of a mechanical assembly shop, the variation of the unit assembly cost will be very similar to the one just studied; the unit assembly cost of a mechanical unit decreases very rapidly as production increases but this decrease is no longer noticeable if annual production totals more than 100,000 vehicles a year. This decrease is due to a better organization of the assembly shop, partially because of a higher degree of mechanization in the assembly line.

However, an automobile manufacturer has a wider margin to choose from when deciding the degree of mechanization for the mechanical units assemly line. In the case of a mechanical assembly shop, a low degree of mechanization will mean assembly overtime, and thus, higher labor costs. This increase will not be completely offset by smaller investment. The unit assembly cost will thus be higher if there is little mechanization; this tendency will be more marked if the mechanical unit assembly rate is low. Indeed, it would not be economical to have an assembly shop with little mechanization for high output because it must be able to follow the manufacturing pace of the machining shop.

This is why on Chart No. 4 there are two curves that tend to join for high assembly rates. The upper curve shows assembly costs for a shop with reduced mechanization and the lower curve shows the same cost for a highly mechanized shop. This is a rather theoretical hypothesis and the chart only shows the general trend of the curves. In fact, it may be considered that as soon as a production of 50,000 vehicles of the same model is reached, the assembly shop is highly mechanized.

3.3.6 Detailed analysis of the machining cost of certain mechanical parts

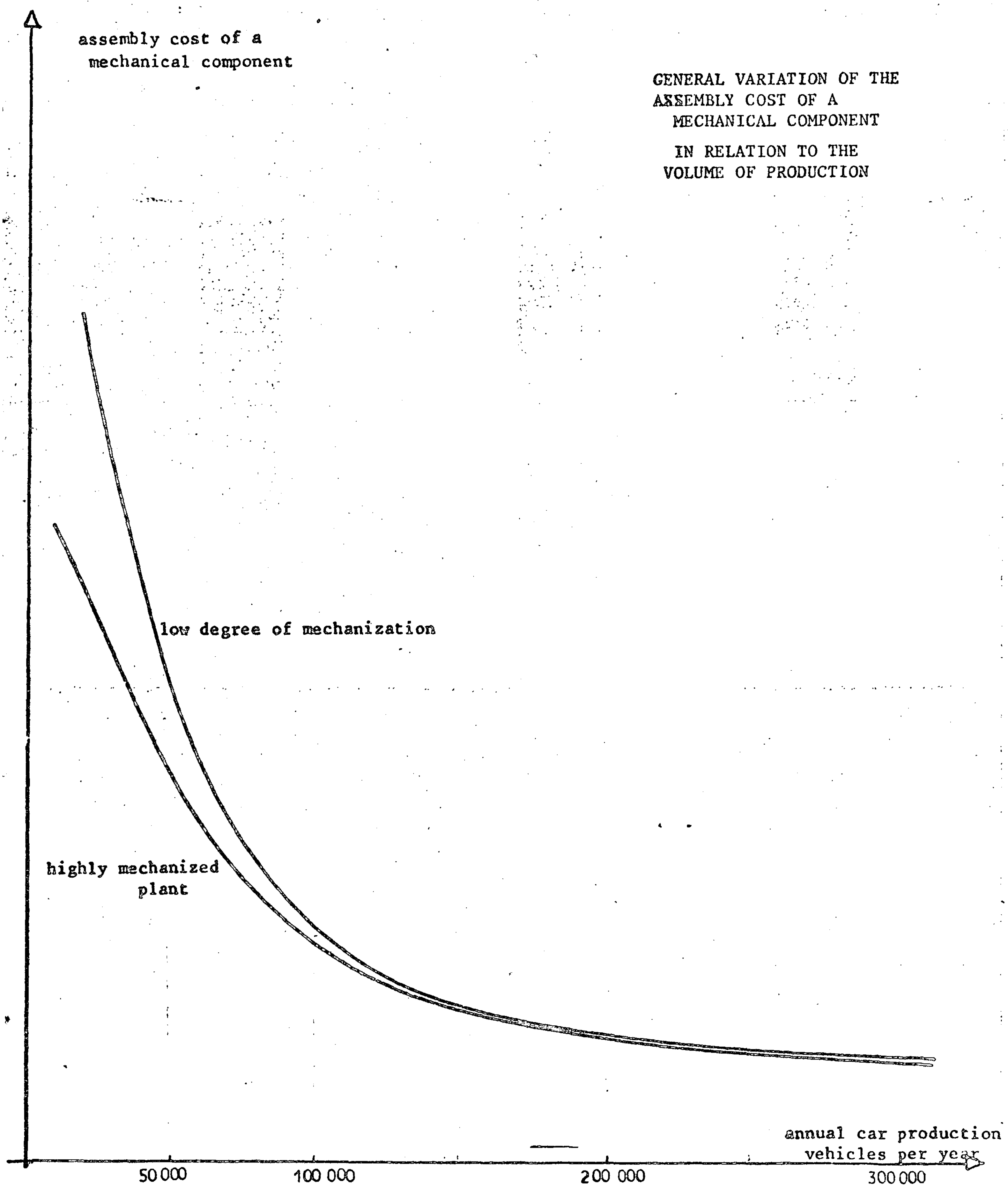
In order to give a more precise illustration and to confirm the preceding analysis, the following paragraphs explain in detail how the machining costs vary for certain characteristic mechanical parts.

A) Calculation bases

a) The mechanical parts that have been chosen represent about 25% of the cost price of a complete engine with all accessories. The machining of the following parts has been studied:
- engine block
- crankshaft

- chart n° 4 -

GENERAL VARIATION OF THE ASSEMBLY COST OF A MECHANICAL COMPONENT IN RELATION TO THE VOLUME OF PRODUCTION



- cam shaft
- connecting rod body
- valve rocker.

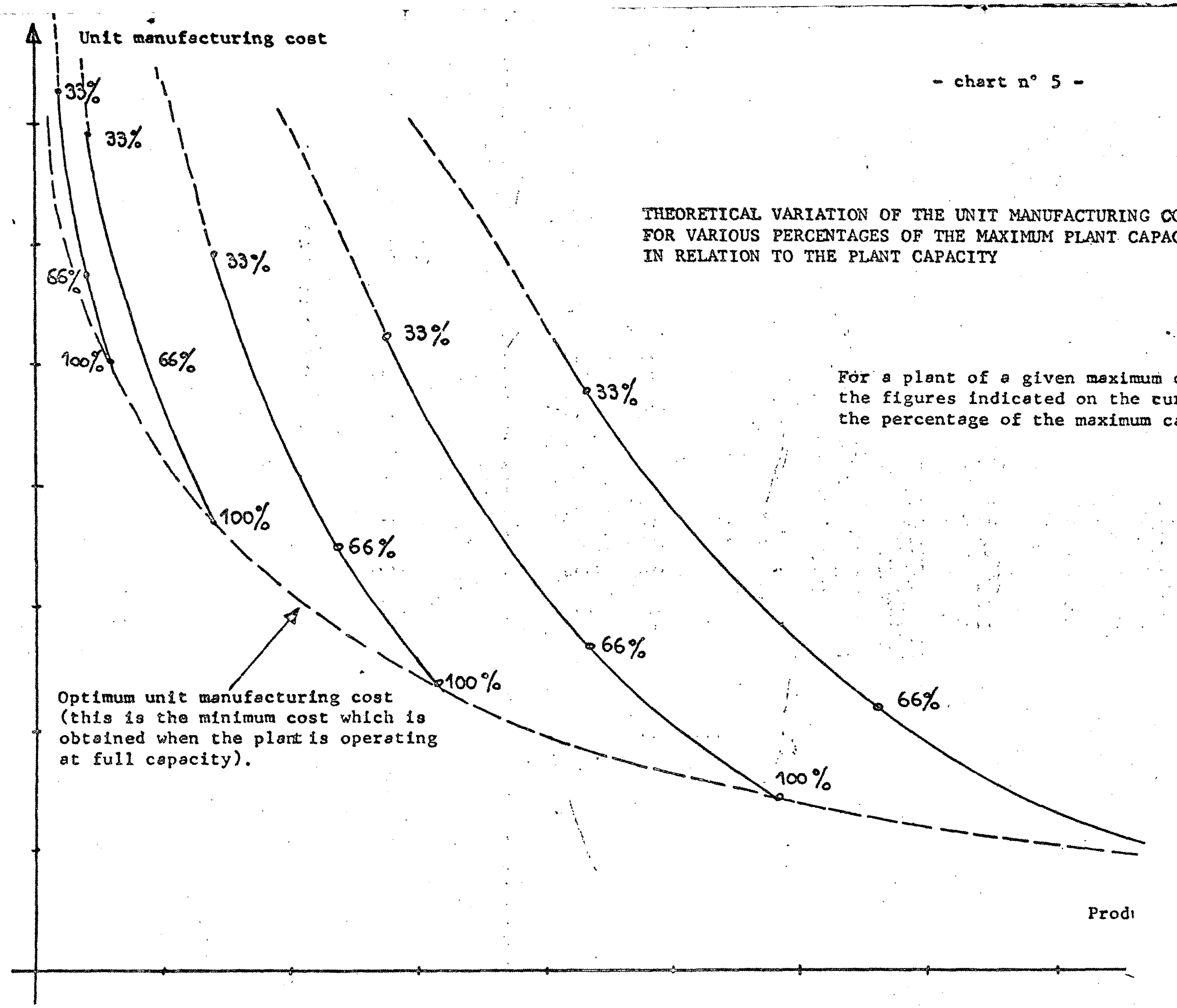
Machining time for these parts represents about 30% of the total machining time for the mechanical componenbs.

b) For each part a unit machining cost has been determined at different rates of production using the most suitable technology for each rate.

c) In the following calculations, it has been assumed that the plant is used at full capacity. In fact, if this were not the case, there would be a production overprice which would be as high as the rate at which the plant is used is low. Thus, a ratio between the overprice and the percentage of maximum capacity used will be obtained in the form of a regularly decreasing curve. For each plant of given capacity, the corresponding curve may be obtained. Thus, the machining cost curve, in relation to production, is a contour line that passes by the points expressing minimum cost price that have been obtained for each plant operating at full capacity. This is shown on Chart No. 5.

- chart n° 5 -

THEORETICAL VARIATION OF THE UNIT MANUFACTURING COST
FOR VARIOUS PERCENTAGES OF THE MAXIMUM PLANT CAPACITY
IN RELATION TO THE PLANT CAPACITY



d) By way of example, the following table gives a breakdown of the cost price of an engine, that is, the part of the engine that has been produced by a manufacturer. So the table refers to the engine alone, without accessories.

Mechanical parts	% of cost price
Crankshaft	24
Connecting-rods	6
Pistons	3.5
Cylinder head	19
Valve mechanism	2
Cam shaft	2.5
Engine block	35
Oil sump	8
	100%

The crankshaft, the engine block and the cylinder head will be seen to represent in themselves 78% of the manufacturing cost price of an engine for a car manufacturer. The machining cost of the parts studied in the following paragraphs represent about 71% of the cost price of the engine alone, without accessories.

e) The following estimations are only given as an indication. They are only rough estimates as it is obviously very difficult to determine accurately machining times, and depreciation charges for each case. Furthermore, the incidence of the overheads and manufacturing costs which are grouped under one heading is difficult to estimate with any exactitude.

These calculations are thus somewhat theoretical and serve only to give some idea of the general appearance of the cost curves according to changes in output.

This is why the different machining costs have been indicated in index numbers. The base 100 for cost estimation could not be chosen on an identical basis because of the lack of information. In general, costs have been estimated with reference to the machining cost for a production of at least 100,000 vehicles a year; that is, that of a leading European manufacturer.

B) Machining of the engine block

a) Calculation hypotheses

This study refers to an iron cast engine block. Three machining methods have been compared for three different daily rates :

- machining with high rate machines and transfer machines
- machining with standard machines producing in large series
- machining with conventional general-purpose machines.

Machine depreciation has been divided into three categories:

- 5 year depreciation for machines or parts of machines good for only one model of a part
- 8 year depreciation for special machines which may be adapted to any model
- 10 year depreciation for general-purpose machinery.

Buildings are depreciated over 20 years. The working day has 8 hours for one shift and there are 250 working days a year.

Depending on the daily rate, 1 or 2 shifts may be necessary. Whenever it was possible to choose between 1 or 2 shifts, with the same daily rate, 1 shift with a higher hourly production rate was preferred to minimize labor costs which are smaller if only one shift is used.

The result of the calculations is summarized in the following tables. Machining costs are indicated in index numbers. The base 100 corresponds to machining costs for 500 engine blocks a day using only transfer machines.

Engine blocks /day	500	250	150	100	50	25
Machining cost (index)	Transfer machines					
	100	122	208	430		
	Standard large series machines					
	125	140	170	225	360	
	General-purpose machines					
					430	450

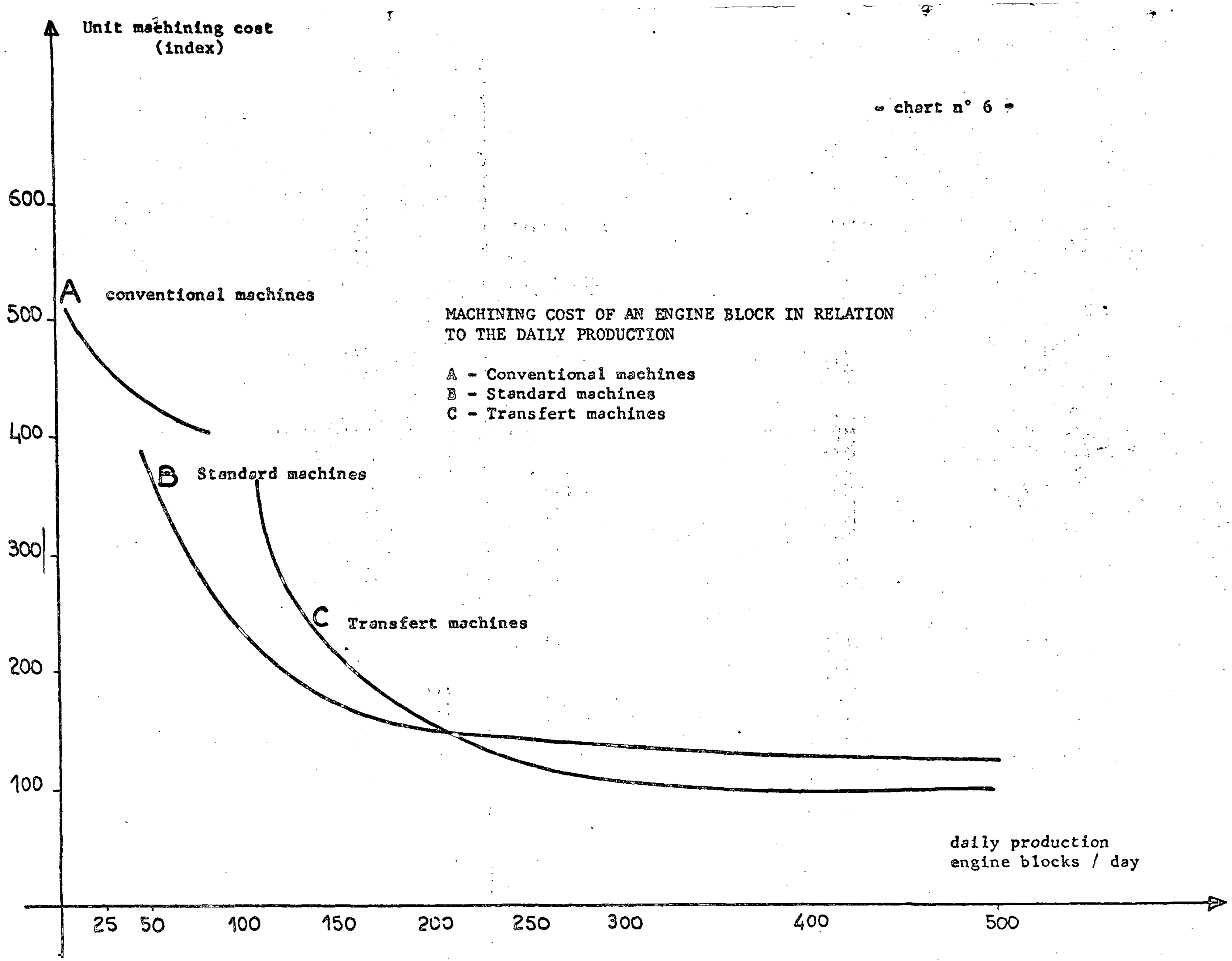
b) Examination of results

The results of these calculations are illustrated on Chart No. 6.

The results obtained show that the use of transfer machines may be economically interesting for a rate of more than 200 a day. For these rates the use of transfer machines or of machining procedures using standard machines producing in large series leads to an identical manufacturing overprice in relation to the basic cost 100 obtained for 500 engine blocks machined daily (that is 125,000 vehicles a year).

However, it is important to realize that this theoretical break-even point for transfer machines does not mean that it is advisable to set up this type of machine for rates of about 200 a day. As a matter of fact, a decline in production causing the output to fall to less than 200 a day would bring manufacturing costs to a definitely higher level than if less specialized machines were used such as standard machines producing large series. This is because of the high investment in transfer machines, involving considerable

- chart n° 6 -



Unit machining cost
(index)
600
500
400
300
200
100
A
conventional machines
B
Standard machines
C
Transfert machines
MACHINING COST OF AN ENGINE BLOCK IN RELATION
TO THE DAILY PRODUCTION
A - Conventional machines
B - Standard machines
C - Transfert machines
daily production
engine blocks / day
25
50
100
150
200
250
300
400
500

depreciation charges for each engine block manufactured, if machining output is too low.

C) <u>Machining of crankshafts</u>

The crankshaft is a part which has a high machining cost and which requires large-scale investment.

Machining costs have been calculated for production rates of 10, 25, and 50 crankshafts an hour. The cost of machining 125 crankshafts an hour was already known. For each rate, the most suitable machining technique was chosen by considering that a different percentage of general-purpose (C), standard (B), or special (A) machines was used according to the rate chosen. This choice is summarized in the following table:

	Hourly rate : crankshafts/hour									
	10			25			50			125
Type of machine	A	B	C	A	B	C	A	B	C	
% of machines of each type	2	62	36	38	32	30	60	26	14	
Total number of machines		53			35			50		
Machining time (index)		4.7			3.1			1.85		1
Depreciation (index)		4.8			3.5			2.3		1
Overheads and manufacturing expenses (index)		1.7			1.3			1.13		1

With the help of these data, variations in the cost of machining the crankshaft may be established in relation to production rates. All the results are shown on Chart No. 7.

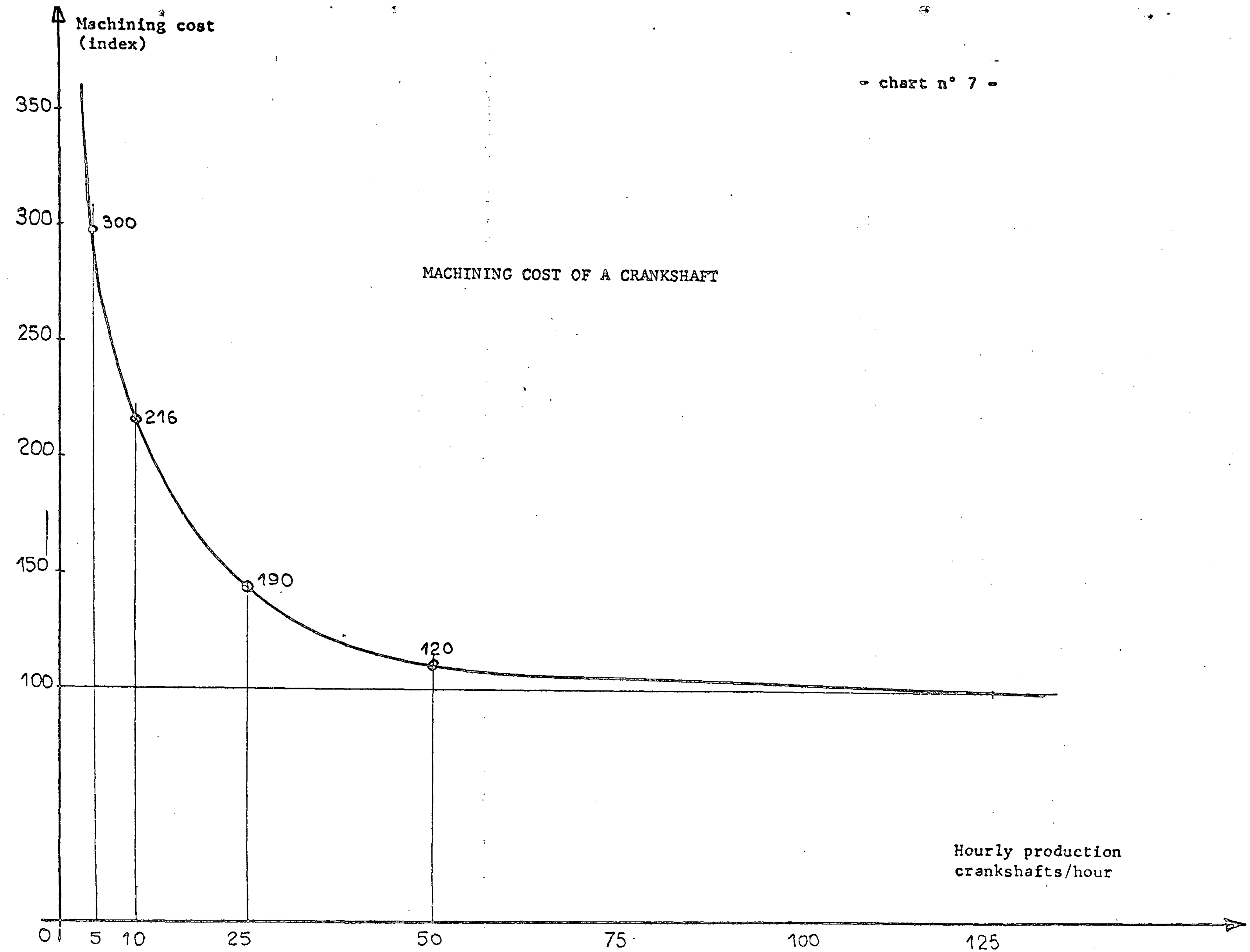
The ordinate shows the machining cost in index numbers and base 100 corresponds to the machining costs for 125 crankshafts an hour, that is, 250,000 crankshafts a year. This chart shows that machining overprice is negligeable for quntities exceeding 75 crankshafts an hour, i.e. an annual production of 150,00 vehicles.

D) Cam shaft machining

In order to study the variations in machining cost, the production rates of 125, 50, 25 and 10 cam shafts machined per hour have been chosen. For each rate the number of machines in each category has been determined, so that the manufacturing technique is the best suitable for each production rate.

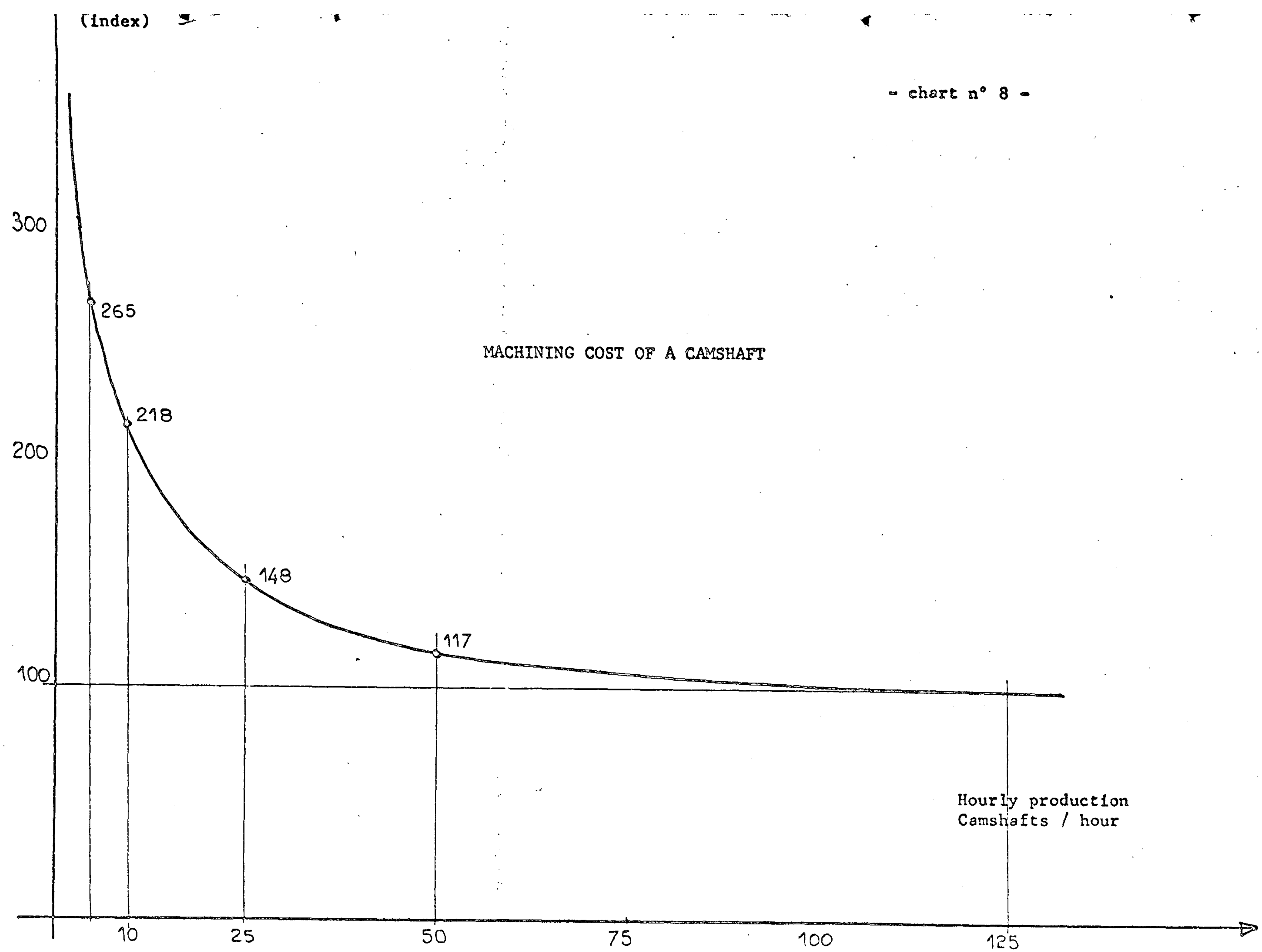
As in the case of the crankshaft, the relative variation in machining times, depreciation charges, manufacturing expenses and overheads has been studied. The hypotheses used as well as the results of the calculations are indicated in the following table:

- chart n° 7 -


Machining cost
(index)
350
300
250
200
150
100
MACHINING COST OF A CRANKSHAFT
300
216
190
120
Hourly production
crankshafts/hour
0
5
10
25
50
75
100
125

Camshafts/hour	10			25			50			125
Type of machines	A	B	C	A	B	C	A	B	C	
% of machines of each category	10	22	62	12	47	41	57	43		
Total number of machines	22			17			22			
Unit machining time (index)	5			3.8			2.2			1
Unit depreciation charge (index)	2.8			1.8			1.4			1
Unit manufacturing expenses and overheads (index)	1.7			1.3			1.13			1

These data have made it possible to plot the curve of the cam shaft machining cost in relation to production, This curve is shown on Chart No. 8, The manufacturing rate at which the machining overprice becomes negligeable is about 75 cam shafts an hour, i.e. an annual production of 150,ooo cam shafts or 75,000 vehicles a year.


- chart n° 8 -
MACHINING COST OF A CAMSHAFT
(index)
300
200
100
265
218
148
117
10
25
50
75
100
125
Hourly production
Camshafts / hour

E) Piston machining

Studies on machining costs were carried out according to two different technical hypotheses, one employing special machines for pistons, and the other, using standard automatic machines that could eventually be useful for other manufactures.

The daily production rates used as a basis for this study are: 9,000, 3,000, 1,200, 480 and 100 pistons a day.

The depreciation of the machine tools employed has been calculated as follows:

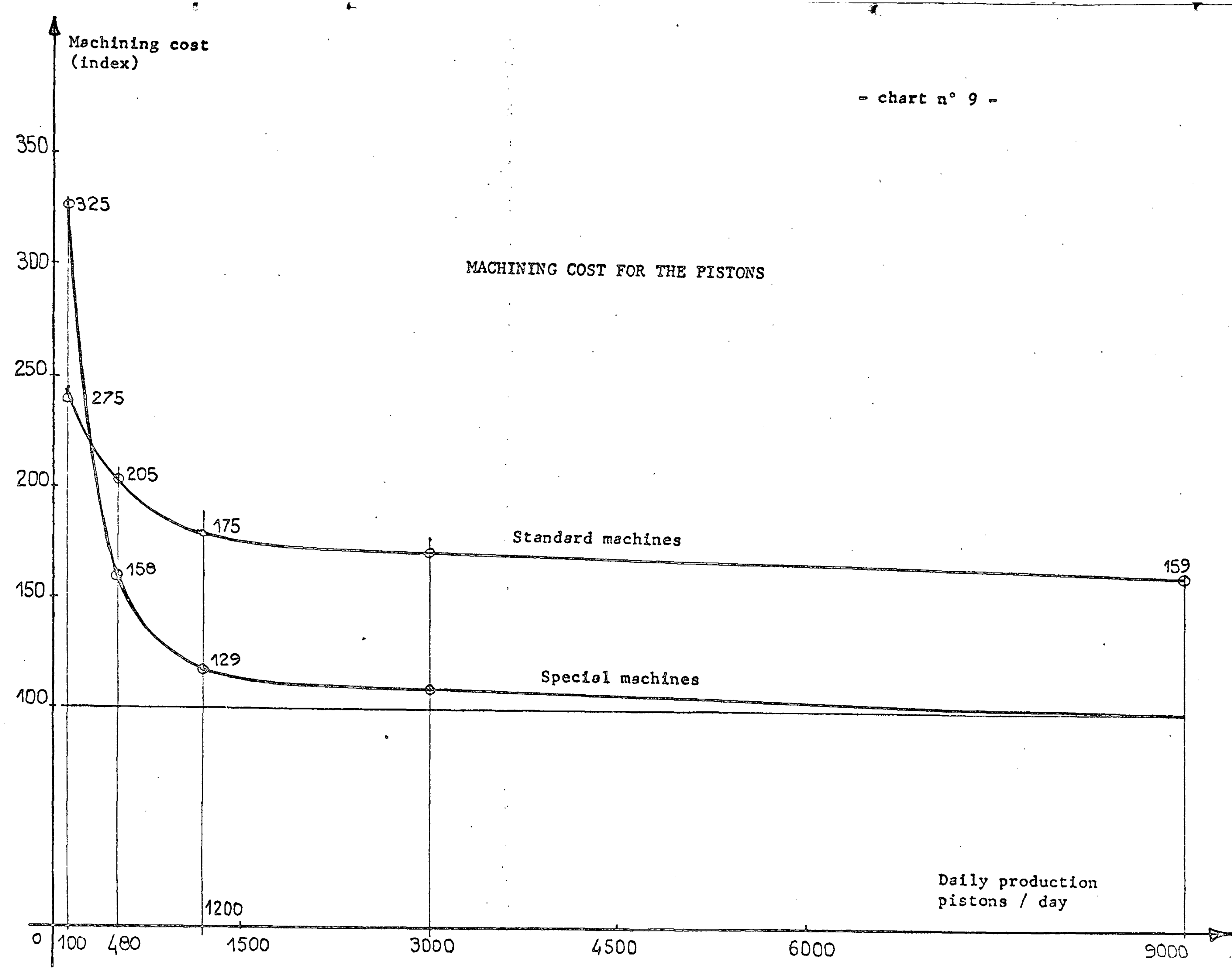
- 5 years for the special machines for pistons
- 8 years for standard automatic machines.

Unit machining time as well as depreciation charges per part are indicated in the following tabel for the different rates studied.

Pistons/day	100	480	1200	3000	9000
		Special machines			
Number of machines	9	10	13	22	63
Machining time (index)	3.5	2.5	1.38	1.03	1
Unit depreciation charge (index)	11.3	3.1	1.05	1.01	1
		Standard automatic machines			
Number of machines	13	18	38	80	240
Unit machining time (index)	1.40	1.25	1.18	1.02	1
Unit depreciation time (index)	4.75	1.37	1.9	1.1	1

Chart No. 9 shows the results of the calculations. The machining cost of a piston is shown in the ordinate for different daily rates; index 100 corresponds to the unit machining cost for a rate of 9,000 a day. It is preferable to use special machines for rates of more than 300 pistons a day as the machining cost for special machines is less for standard machines. However, the same applies here as the engine block : a decline in production to less than 900 pistons a day will push up costs if special machines are use. Thus a careful choice of the manufacturing technique is necessary if

- chart n° 9 -


Machining cost
(index)
350
300
250
200
150
100
325
275
205
158
175
129
159
MACHINING COST FOR THE PISTONS
Standard machines
Special machines
Daily production
pistons / day
0
100
480
1200
1500
3000
4500
6000
9000

output fluctuates around the break-even point for special machines.

Moreover, the chart shows that the piston machining overprice becomes negligeable for rates of 2,000 or more pistons a day passing through special machines. It may thus be concluded that the critical mass is to be found at a rate of about 50,000 vehicles a year.

F) Machining of the connecting-rod body

According to the information obtained, this study covers the manufacturing and machining of connecting -rod bodies including stamping operations, heat treatment, gauging, etc. Manufacturing operations, therefore include not only machining but also work done in the forge shop.

A cost study has been made for rates of 9,000, 3,000, 1,200, 480 and 100 parts a day. Both special machines and standard automatic machines have been considered for the machining of connecting-rod bodies.

The data used in the calculations are set out in the following table.

Neither overheads nor manufacturing costs have been shown but they have been taken into consideration in the calculation of the unit cost. The overheads and manufacturing costs represent the normal charges corresponding to a mechanical shop; the corresponding unit charge is higher for the lower rates and it decreases rapidly as the production rises.

Connecting-rod bodies /day	100	480	1200	3000	9000
Special machines					
Number of machines	14	16	21	46	129
Unit machining time (index)	1.60	1.35	1.20	1.07	1
Unit depreciation charge (index)	8.90	2.18	1.15	1.03	1
Standard automatic machines					
Number of machines	19	21	40	88	268
Unit machining time (index)	1.32	1.22	1.13	1	1
Unit depreciation charge (index)	4.6	1.37	1.13	1.03	1

The result of the calculations based on the information in the above table is shown on on Chart No. 10.

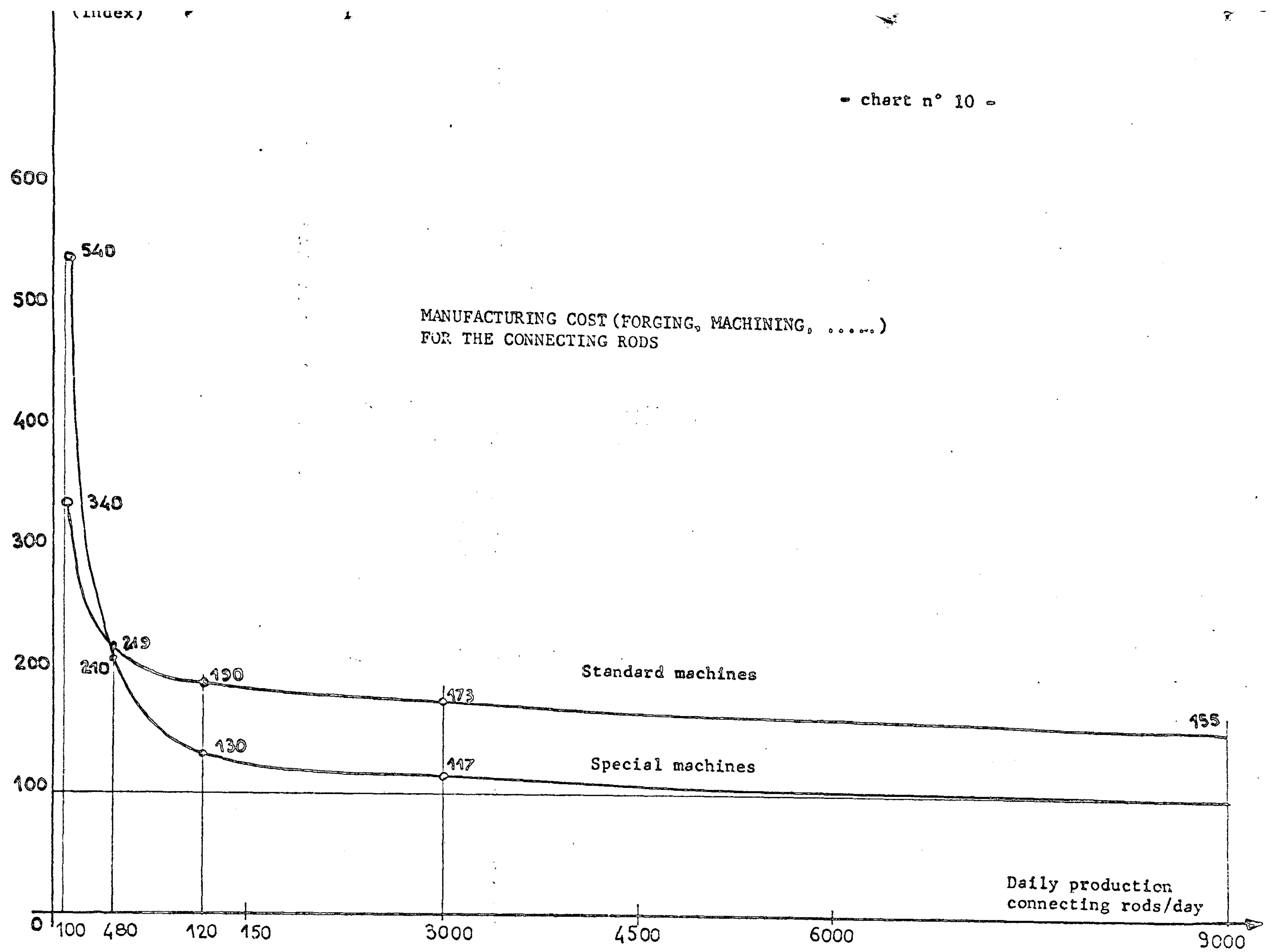
The ordinate shows the machining cost for a rod-body in index numbers for different daily rates of production. Index 100 corresponds to the unit machining cost for 9,000 connecting-rod bodies a day.

The break-even point for special machines is about 400 connecting-rod bodies a day, but here again the same reservations should be expressed as before, as regards the risk of overprice if output fluctuates around the break-even point.

It should be noted that the overprices are very high in the case of small rates of production, and that the overprice does not become negligeable until about 3,000 connecting-rod bodies are produced a day, that is, 750,000 a year or 180,000 vehicles a year. This is a very high rate of production attained only by the big car manufacturers.

G) Valve rocker machining

As before, a study has been made of the variations of the machining cost of a valve


(Index)
- chart n° 10 -
MANUFACTURING COST (FORGING, MACHINING, ...)
FOR THE CONNECTING RODS
600
500
400
300
200
100
0
540
340
219
210
190
173
155
130
117
Standard machines
Special machines
Daily production
connecting rods/day
100
480
120
150
3000
4500
6000
9000

rocker for hourly rates of 200, 50, 25, and 10. For each rate the most suitable technique was chosen using where necessary different percentages of special, standard and conventional machines.

The result of these calculations is shown, as an indication, on Chart No. 11. Base 100 represents an output of 400 valve rockers an hour, i.e., 100,000 vehicles a year. It may be noted that the machining overprice for the lower rates is very high, and becomes insignificant only for a rate of 300 valver rockers, i.e. 75,000 vehicles a year.

3.4 Analysis of the machining and mechanical assembly overprice

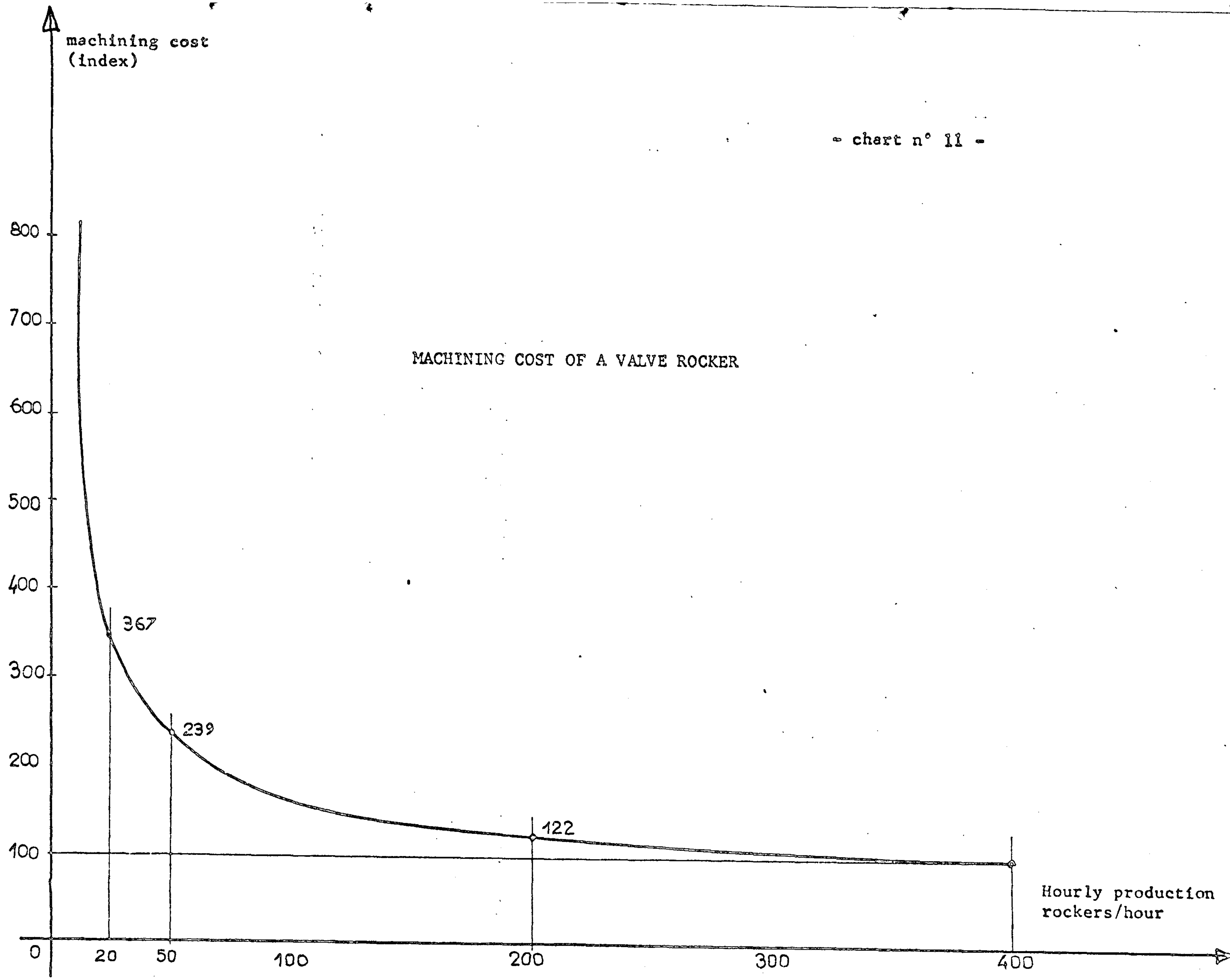
The calculations made set an order of magnitude for the cost of machining the mechanical units in accordance with the rate of production,

The general appearance of these curves is shown in Charts Nos. 3 and 4 in Chapter 3.3.

With the help of the preceding examples, the approximate overprice for different production rates may be worked out. These results are shown on Charts Nos. 12 and 13.

- chart n° 11 -

MACHINING COST OF A VALVE ROCKER



3.4.1 Machining overprice (Chart No. 12)

A) Variation of the machining overprice in relation t
production

The curve shows that machining overprice drops very rapidly when production increases from 10,000 to 100,000 vehicles a year, since the overprice passes from roughly 130% to 27%.

The decrease in the machining cost is due to a change in the production technique as shown on the chart.

For rates of production of more than 100,000 vehicles a year, there is only a slight decrease in the machining cost, because the same special machine technique is used.

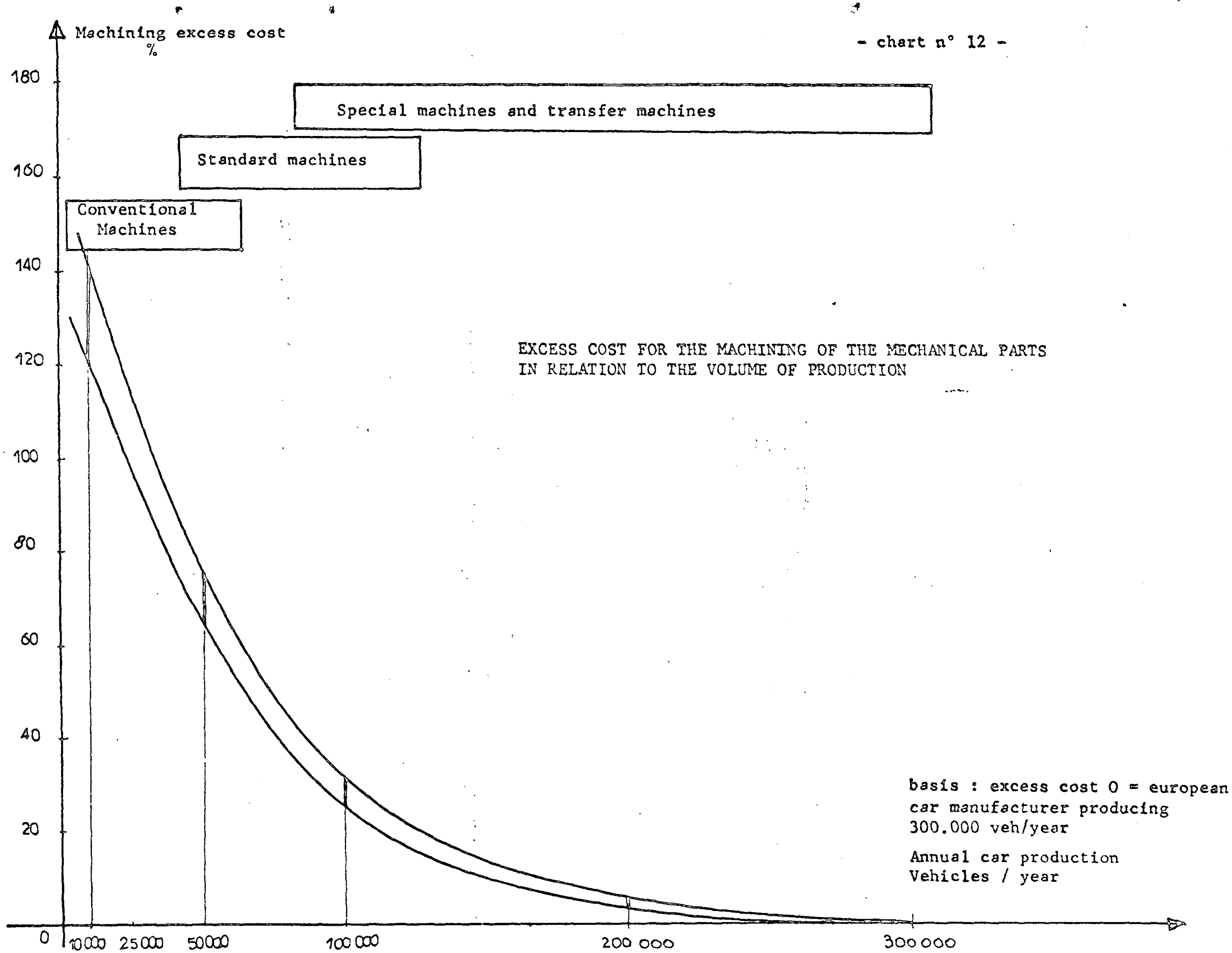
The critical mass of production for mechanical parts would theoretically be about 300,000 vehicles a year. However, for more than 200,000 vehicles a year, the overprice becomes very small, about 5% only.

B) Effect of a great number of models

This is a factor which may have unfavorable consequences if the models are very different.

- chart n° 12 -

EXCESS COST FOR THE MACHINING OF THE MECHANICAL PARTS
IN RELATION TO THE VOLUME OF PRODUCTION



In general, each mechanical unit is specific to a model, except when the vehicles are very much alike, especially if they belong to the production range of the same manufacturer.

If, however, output is small, general-purpose machines will be used, as was stated before. Consequntly, as these machines are not specific to any model, the variety of models will have little effect of machining costs. Indeed, the situation is very theoretical because the machining of mechanical units is very seldom done for small outputs as the machining overprice would be very high.

On the contrary, it should be emphasized that for higher rates, i.e. about 25,000 to 50,000 vehicles a year, a great number of models will mean a lower assembly rate for each type of vehicle and this in turn will mean that the large-scale economical manufacturing techniques will have to be abandoned. These techniques require high production rates. Smaller series of mechanical parts will have to be machined with standard or ordinary general-purpose machines and, thus, the machining cost will be higher as was seen in the study of specific examples.

C) The value of "freezing" the models of vehicles

As the investment in a machining shop is very high, it may be a good idea to "freeze" the model of vehicle over a long period of time so as to depreciate the equipment over a greater number of vehicles. Under these circumstances, it will be particularly interesting to contemplate using the very large-scale production techniques as these very expensive machines can then be depreciated over 10 years instead of 5 years, for example. Thus, depreciation charges per vehicle will remain at a reasonable level while benefiting from a considerable reduction in machining time and, therefore, in machining costs.

3.4.2 Assembly overprice of mechanical units

Chart No. 13 shows variations in the mechanical assembly overprice in relation to production.

As an indication, the assembly curve for a slightly mechanized shop has been plotted.

The effects of slight mechanization are only felt in the case of small volumes and this may lead to an increase of about 20% in the assembly cost as compared to a highly mechanized shop.

C) <u>The value of "freezing" the models of vehicles</u>

As the investment in a machining shop is very high, it may be a good idea to "freeze" the model of vehicle over a long period of time so as to depreciate the equipment over a greater number of vehicles. Under these circumstances, it will be particularly interesting to contemplate using the very large-scale production techniques as these very expensive machines can then be depreciated over 10 years instead of 5 years, for example. Thus, depreciation charges per vehicle will remain at a reasonable level while benefiting from a considerable reduction in machining time and, therefore, in machining costs.

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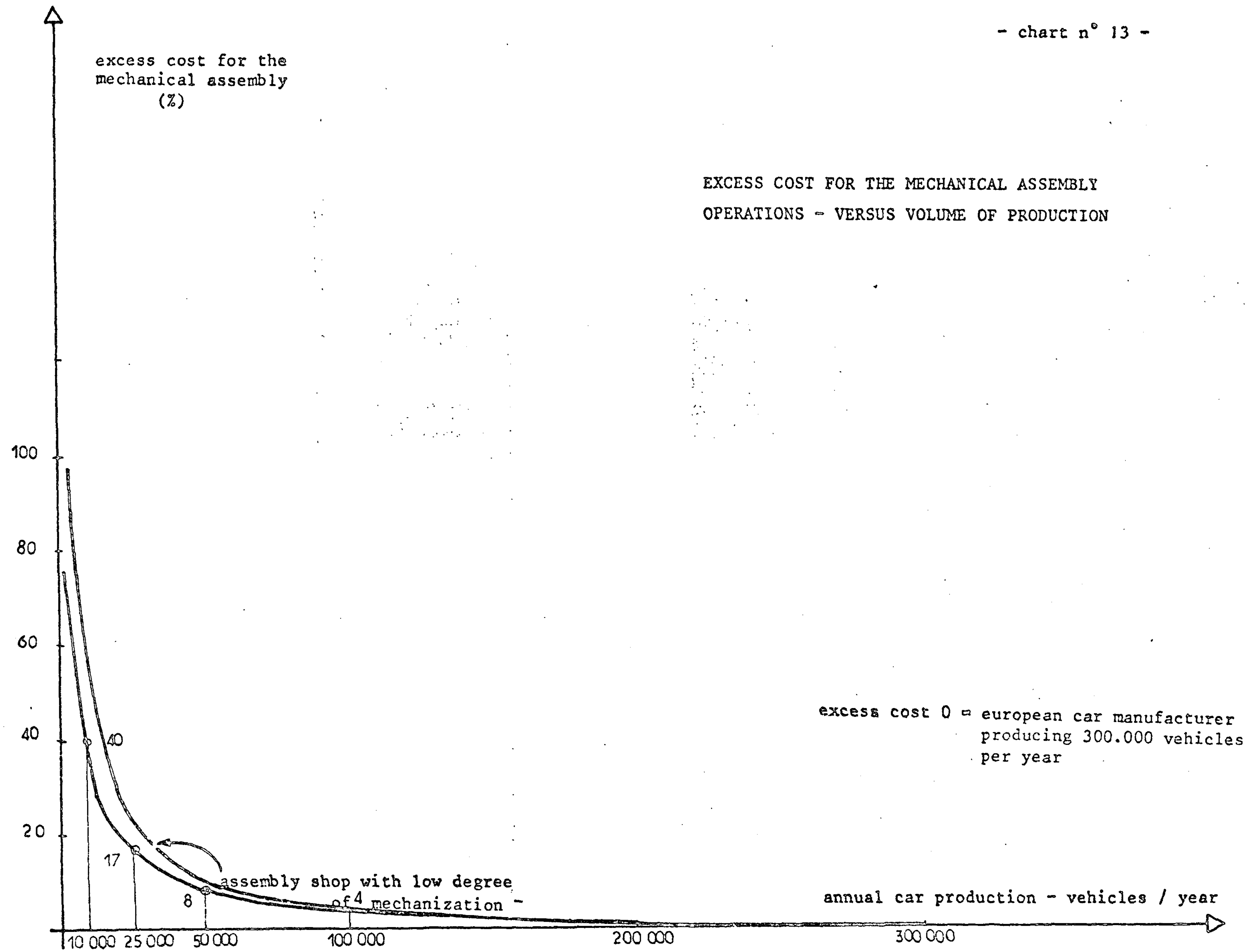
- chart n° 13 -

EXCESS COST FOR THE MECHANICAL ASSEMBLY OPERATIONS - VERSUS VOLUME OF PRODUCTION



In the case of high outputs, the assembly shop is necessarily very mechanized.

Assembly overprice falls rapidly for small rates, from 70% for 10,000 vehicles a year to 8% for 50,000 vehicles a year.

The assembly overprice is almost negligeable for production rates of 50,000 vehicles a year. As far as a wide variety of models is concerned, it has already been stated that this has little effect on the assembly cost, even less so when the assembly line is more mechanized.

3.5 Conclusions on the machining and assembly of mechanical units

Machining shops demand very high investment, in particular for large-scale production. In fact, the cost is about 30 to 35% that of the total cost of a complete plant; however, the machining and mechanical unit assembly shops more than a third of the total value added by an automobile manufacturer.

This is why machining techniques are of interest to industrializing countries, which try to extend the percentage of local integration in the most satisfactory economic conditions. As final assembly is the first step in the development of a national automobile industry, the integration of machining techniques for mechanical units represents a second and very important step.

3.5.1 Investment

This chapter has emphasized the very close connection between first, the amount of mechanization, and second, the level of investment and production costs.

Moreover, for each rate of production, there is an optimum manufacturing technique which will produce at the lowest cost for that rate. This technique is the result of a careful combination of different manufacturing procedures and accordingto each case, either conventional small-scale equipment, or large-scale equipment (standard machines which are more expensive), or, finally, fully automated machines (very expensive transfer machines) will be chosen.

An increase in output is thus accompanied by far-reaching modifications in the organization of the machining shop, because a greater number of large-scale machines will be used or, in the case of very high output of more than 100,000 vehicles a year, a majority of transfer machines will be used. Under these conditions, investment in machinery and plant rises considerably with the rate of production; thus, total investment is practically doubled when output passes from a relatively low rate of 50,000 vehicles a year to a large-scale production of about 300,000 vehicles a year.

3.5.2 Machining overprice and value of gradual integration

A) Parallel to this increase in automation, there is a sharp decline in the machining overprice when the output rises from 50,00 to 200,000 vehicles a year.

In fact, the overprice is very high for low outputs (about 100 to 150%) and it is preferable, in this case, to integrate only part of the machining operations. In this case, a relatively large proportion of the machined parts will be imported by the manufacturer as CKD parts; the mechanical units may be assembled locally in relatively economical conditions as the assembly overprice is not very high even for low rates.

B) The break-even point for total integration of machining operations alone seems to be found at a rate of roughly 100,000 vehicles a year, though the machining overprice is still about 30%. The cost of raw materials, and the cost of producing forged parts and castings must be taken into consideration; it would then appear that the overprice of mechanical parts is well above 30%.

C) It must, then, be considered that the integration of machining operations on the part of a manufacturer in a developing country must be studied against the background of the general development of the engineering industry in that country. Two important factors must be taken into account: one, capability to supply forged parts and castings; and two, the skill level of the work force. The latter factor is of extreme importance as the mechanical engineering industry requires higher labor skills as the level of automation is lower. And this is the case of low rates of production.

3.5.3 The value of specialization for the less industrialized countries

Thus, the effects of an economy of scale are particularly marked in the case of machining operations. This is why the critical masses of production are generally very high; this is a serious disadvantage for the developing countries who nevertheless find it worthwhile to promote local integration of machining operations because the production techniques should make it possible in time, to form silled workers with a sense of responsibility and efficiency which is a decisive factor in the industrialization of a country and to develop a basic mechanical engineering industry.

A) A solution to this problem of critical mass would be for countries in the same geographical zone to specialize. Each country could specialize, and this is already happening in South America, for example, in the production of a mechanical unit. Thus, one country would manufacture engines; another, gearboxes; and another would be specialized in the cutting of gears. In these conditions, a higher volume of production would be secured, and thus would bring down the manufacturing costs to a really economical level. At the same time, this solution would limit the investment, which could be channelled into the purchase of high productivity machines only for those parts manufactured in that country.

B) In the long term, such a decision to specialize might result in cost prices and quality such that the countries concerned would become competitive in the face of the big car manufacturers because labor hourly rates are, in general, much lower than in the highly industrialized countries.

In these conditions, these countries could eventually supply not only their neighboring countries but also distant markets. In particular these countries would be in a good position to manufacture spare parts for big international manufacturers. For example, these countries could produce spare parts for models which are to be shortly discontinued.

The specialization of the less industrialized countries would thus promote the trade of manufactured products and would allow them to enter world markets in competitive conditions.

Chapter 4

Units pressing and assembly shops

Both the pressing and the units assembly shops are of great importance in an automobile manufacturing plant due to the very large amounts of money which have to be invested in them, particularly in the tooling.

In order to give some idea of the importance of the pressing shop and its annex, the units assembly shop, it is useful to indicate that they represent one-third of the total investment required for a complete plant manufacturing 100,000 vehicles a year, with a 95% integration.

The pressing operations for a medium-sized vehicle take about 4 hours, and those required for the assembly and welding of the units take about 7 to 8 hours; however, the value added by these two shops is about 9 to 11% of the cost price of a vehicle, that is, about one-fourth of the total value added.

The tooling used in a pressing shop is very expensive and it is specific for a given vehicle model. As a direct result of this, the cost-volume ratio is particularly important for this type of operation and, as may be expected, a large variety of models will have particularly unfavorable consequences on the cost of the pressing operations.

Under these conditions, the rate of depreciation of the toolings is of special importance and it will be analyzed in detail in the chapter concerning the cost of the pressing operations.

Beforehand, consideration will be given to the investment required for different rates of annual production.

The aim of the chapter as a whole will be to establish the overprices of the pressing operations at different levels of production.

The section will begin with a summary of the different pressing techniques and will include a brief description of the pressing and units assembly shop in order to point out the characteristics of the equipments required.

4.1 General considerations on the pressing techniques

4.1.1 The different pressing procedures

A) The conventional pressing techniques

Pressing is a technique used to obtain non-developable shapes by deformation of the sheet thus reproducing the different solid or hollow parts of a tool on which the iron sheet has been placed.

This is usually a complex operation which cannot be carried out without large-scale equipment.

Three main elements must be taken into consideration: the press, the tooling and the pressed part (pressing):

a) the press is a multi-purpose machine which is used for many different pressing operations irrespective of the shape required.

b) the tooling is specific for each model of vehicle and is mainly made up of:
   i - a female die;
   ii- a male die reproducing with a certain tolerance (i.e. thickness of the sheet) the inner part of the female die;
   iii-blank holders, if necessary, for deep or intricate pressings.

c) the pressing : the part produced by the pressing operation is called the "pressing" and is generally made up of three parts:

   i - the part itself;
   ii- the inner fitting around the female die which is not a part of the finished part, in the majority of cases, but is necessary for a good pressing.

iii-the outer flap around the female die.
Both fittings are waste material.

d) Choice of techniques according to the rate of manufacture

According to the manufacturing rate, two techniques may be considered:

i - Average rates
For 50,000 to 200,000 parts a year, the pressing operations are associated with other operations, thanks to the use of combined tooling.

ii- High rates
For more than 200,000 parts a year, body parts are entirely manufactured by series of presses with automatic handling of the parts from one machine to another.

e) Choice of press

As far as the machine is concerned mechanical presses are generally preferred as they allow a high level of production.

When, exceptionally, deep pressings for the car body have to be manufactured in a single blow, hydraulic presses have to be used. These machines operate slowly and can therefore be used only for low production rates, so that, generally speaking, they do not hold much interest for body parts.

B) Other manufacturing techniques

For the reader's information it is worth mentioning that there are other techniques which are less sophisticated than the conventional pressing technique.

a) Exclusively manual manufacture with pattern

Body parts are produced by cold hammering with a mallet or hammer with checks against the pattern during the process. This method requires highly qualified labor and is extremely time-consuming. This is mentioned solely for the purpose of information because it could only be used to make a few dozen parts.

b) Purely manual methods using shapes

This is another manual method for manufacturing body parts by cold hammering, but in this case, it is done on appropriate shapes. With this technique it is possible to slightly reduce the manufacturing time, and furthermore a less skilled labor is required. Eventually, this technique could be used for the manufacture of about a hundred parts.

c) Semi-manual techniques

In this case, presses will be used only for the pressing operation, and all other operations will be done by hand, i.e.:
- cutting with shears or a knurl;
- hammering the edges up or down with a mallet over the shapes.

Three types of tooling each corresponding to a volume of output may be employed in this case:

i - For body parts, the following tools are used:
  - pressing tools made of plastics for for all the parts for a production of 100 to 3,000 parts.
  - zamak pressing parts for productions of 500 to 10,000 parts.

ii- For small stampings and pressings, pressing tools made of steel will be used to produce about 3,000 to 40,000 parts.

4.1.2 Choice of the material used for the car body

In the present state of the art, that is the automobile manufacturing techniques, one of the following materials could be chosen for the pressing operations:

- steel sheets
- plastics (see chapter on "Plastics").

A) Steel sheets

Since the creation of self supporting bodies, the thin steel sheet is what is traditionally used for the making of automobile bodies. A full technology has progressively developed, starting with the manufacture of the steel sheets themselves and ending with their forming and their finishing to produce a finished body.

This technology has now been fully tested and accepted and there is some reluctance to introduce any sweeping changes.

The steel sheets used for body parts have the following characteristics: mild cold-rolled steel sheets for deep pressing. Two different qualities of steel are used for the inner and outer parts, as for the latter a satisfactory appearance is mandatory.

The thickness of the sheet varies according to the part, or model of vehicle, i.e. between 0.6 and 2 mm. The most common thickness used is 0.8 mm.

B) Plastics

This point will be dealt with in detail in the chapter on "Plastics".

For the last ten years certain manufacturers have been investigating the possibility of using plastics for making car bodies. However, for the time being, only one or two body parts are made with plastics, for certain large-scale series (roof panel of Citroen ID20 and DS21, roof panel for the Renault delivery van, etc.)

This is only a first step. At present only special types of automobiles are made entirely out of plastic (for example, in France, the Matra 530, the Renault Alpine). However, the Citroen Mehari is now being produced at a rate of 15,000 a year and is therefore attracting a great deal of attention.

At present, plastics is still an expensive raw material. Furthermore, the manufacturers have invested heavily in conventional equipment and tooling, and therefore the introduction of this manufacturing technique is not thought to be immediately applicable for large series in the near future.

4.1.3 Pressing tools

Three categories may be distinguished:
- plastic pressing tools
- zamak pressing tools
- steel pressing tools

Steel tools are mainly used for mass manufacturing because they are more expensive. The following comparison could be made between the three types of tools:

Table No. 1

Comparison of the different types of pressing tools

Type of pressing tools	Price (index)	Tool life
Steel tools	100	1 to 2 million parts
Zamak tools	30	3,000 to 15,000 parts
Plastic tools	25	3,000 to 15,000 parts

This table shows that the life span of each type of tool is very different.

A) Large series

Pressing tools are very expensive and specific to a given model. The depreciation period of the tools is therefore especially important and must be taken into account together with the life of the model of vehicle.

For large series, depreciation charges for the tooling are spread over 1 or 2 million vehicles. In this case, steel tooling only is used.

In the United States, where each manufacturer can produce one million vehicles of the same model a year, it is possible to change the models practically every year.

In Europe, each manufacturer requires an average of 4 to 5 years to produce one million vehicles of the same model, and consequently, the life span of each model will be determined by the depreciation of the tooling.

Steel tooling, permits the use of combined tooling, so that the manufacturing range is larger. Several operations can be performed in one drop on each press, thus reducing labor to a minimum, at the cost of considerable investment.

B) Small series

For low production rates, i.e. about 3,000 to 10,000 vehicles a year, the life of the model being about 5 years, either zamak or plastic tooling may be chosen as they can be depreciated over a smaller number of vehicles.

The manufacturing technique in this case will be different from the conventional pressing technique: the semi-manual procedure described in paragraph 3.1.1 B) and C) will be used.

In order to reduce cost prices, the tooling will be chosen according to the size and shape of the parts and to the annual quantity to be produced (steel, zamak or plastic).

As a general rule, the pressing tools for the roof panel, the outer door panel and certain big parts of a straightforward shape will be plastic.

The pressing tools of all other outer parts of the body are made out of zamak.

Only the pressing tools with intricate shapes or small parts, such as certain reinforcing parts will be made out of steel.

It is a matter, therefore, of making a sensible choice between manual and mechanical operations

For small series the solution described above has the advantage of reducing tooling costs, buton the other hand, it means that many more workers are required in the pressing shop.

4.2 Brief description of the pressing and units assembly shops

4.2.1 The pressing shop

The shop as a whole is made up of four sections:

A) Steel sheet stockyard

This is a roofed surface where the steel sheets are stored according to their different ticknesses. The steel sheets are received by this section and are classified and delivered to the sheet cutting shop according to requirements.

The cutting of the blank parts is done by presses when a high production is needed. For lower rates, this will be done manually for the standard size sheets with small tools,or mechanically on knurling machines for the big blank parts.

The deformation of the steel sheets by folding bending, and light pressing is done mechanically in the case of high production rates, or by cold or hot hammering on simple assemblies suited to the shapes desired, in the case of low output.

The finishing of the parts which are ready to be assembled, after pressing, is done manually. These may be lengthy and intricate operations for which highly skilled workers are required; especially, since certain parts that are to form the outer body of the car must have a perfect finish as far as appearance and dimensions are concerned.

C) The pressing shop

This shop does the pressing in the strictest sense. According to the type of the part and size, the following distinction is made:
- body parts;
- small pressings;
- large pressings;
- light hammering.

In the large manufacturing plants, "pressing lines" made up of several presses standing in a line are to be found. Each press does one stage of the pressing operation for the very big body parts; the part is not finished until it leaves the last press. The presses range from capacities of 200 to 1000 tons and may weigh as much as 200 tons; the total weight of the tooling may be 35 tons.

In which case the pressing operations are automated.

There is one worker for each press in charge of controlling and supervising it. Each press is automatically fed by a "blank feeder". Each pressing is taken away by an "extractor". Conveyors carry the part form one press to the other; the evacuation of iron scraps is also done automatically through spouts to the crushers.

According to requirements, the following presses will be found:
- double acting press
- single acting press
- open front press
- anvils

D) <u>Storage of parts before assembly</u>

Once the parts have left the pressing or cutting shops, and have been accepted by the assembly-welding controller they are oiled, handled with care, and stored to await assembly.

4.2.2 Units welding and assembly shop

The welding shop assembles the body from the rough parts manufactured by the pressing shop. The body is built from the side panels, the floor panels, the upright supports, and the roof panel; separate sub-assemblies like fenders, hoods, doors, are assembled in a nearby section: these sub-assemblies are called "separate parts".

A) Body

The points to which mechanical parts and separate parts have to be hooked must be carefully positioned and considerable care has to be taken in placing the different parts in their respective positions, in order to avoid any mistakes in the assembly and ensure that the separate parts are interchangeable.

B) Separate parts

Unlike the car body which requires great accuracy for its assembling but only a rough finishing (except for the visible parts), the separate parts demand a great deal of experience in the making of hollow bodies out of thin iron sheets. An outer door panel assembled on an inner panel will wave at the edges and will blister in the center if the rough parts have not been accepted as being up to standard. In this case, the assembly of the inner and outer panels is such that any touching up is impossible or virtually so; it would, in any case, be extremely difficult to do so owing to the thinness of the sheets and the perfect finishing required for these appearance parts.

The different parts are assembled by crimping or welding, ;and, in very exceptional cases by gluing.

In the large-scale manufacturing plants, crimping is done on special machines according to each shape.

C) Assembly by welding

Spot welding is usually done in the big plants with very costly and complex multi-spot machines and with a large number of single spot welding machines; this procedure requires the use of assemblies specially designed to receive the rough parts which are superposed and automatically positioned and then clamped with auxiliary jaws. The welding tongs have two copper electrodes closed by hydraulic control. The welding points in the visible areas will be touched up with a file or with a portable machine fitted with abrasive disks. The finishing is done with an emery cloth.

Careful checks of each unit will be made either by simple visual inspection or by suface lighting.

D) The units warehouse

The units are the body parts which are assembled in the welding shop: the roof, floor and side panels. They are stored after they have been covered with an anti-rust product.

Similarly, the separate parts will be carefully stored in special containers.

4.2.3 The tooling, steel work and maintenance shop

A) Maintenance

The tooling and maintenance shop is in charge of the following operations:

- Manufacture, maintenance and repair of tools and machine parts.
- Machining of the electrodes of the welding

tongs

- Preventive maintenance and repairs of mechanical, electric, hydraulic and pneumatic units of the machinery of the pressing department.

B) Storage

Furthermore, the pressing tools are stored in a section belonging to this shop.

Pressing tools have to be very different in size and weight according to the parts for which they have been designed; there are 4 dm3 assemblies which weigh about twenty kilos and big roofing tools which may measure as much as 3m x 1.50 m x 1m and weigh more than 12 tons. It will therefore be necessary to have a very wide range of maintenance equipment: tool carriages, monorails, fork lifters and travelling cranes.

4.3 Determination of investment in the shops where the units are pressed and assembled

This chapter will show the investment necessary for a pressing and assembly shop according to different output assumptions; the effect of the amount of mechanization and the number of models on investment will also be studied.

4.3.1 Classification of investment

In order to show clearly the magnitude of tooling costs the following classification has been chosen:

- land grading - roads
- buildings: industrial buildings
  service buildings
- shop equipment: machinery, equipment
- tooling: pressing tools
  assembly jigs
- utilities

The share of these differenttypes of investment in total investment may be considered to be roughly the following:

	%
land grading and roads	1 to 3
buildings	12 to 18
shop equipment, without tooling	30 to 35
tooling	50 to 38
utilities	7 to 10
TOTAL INVESTMENT	100%

N.B. This classification does not include the price of the land which generally depends on where the plant is sited.

It should be noted that the pressing shop accounts for the largest share of total investment.

pressing shop	89%
units assembly shop	11%
TOTAL INVESTMENT	100%

Furthermore, investment in buildings for the pressing shop is much higher than for a building in which the units are to be assembled; for the pressing a strong building is necessary with a metal framework that can support a large capacity travelling crane; moreover, presses are very heavy machines requiring deep foundations.

In order to make these concepts a little clearer the following average values will give some idea of the price per square meter of roofed surface for the different buildings:

Heavy-type building for a pressing shop	about 1000 FF/m2
One-story conventional building for a units assembly shop in a country with temperate climate	450 a 600 FF/m2

4.3.2 Ratio between investment and annual output

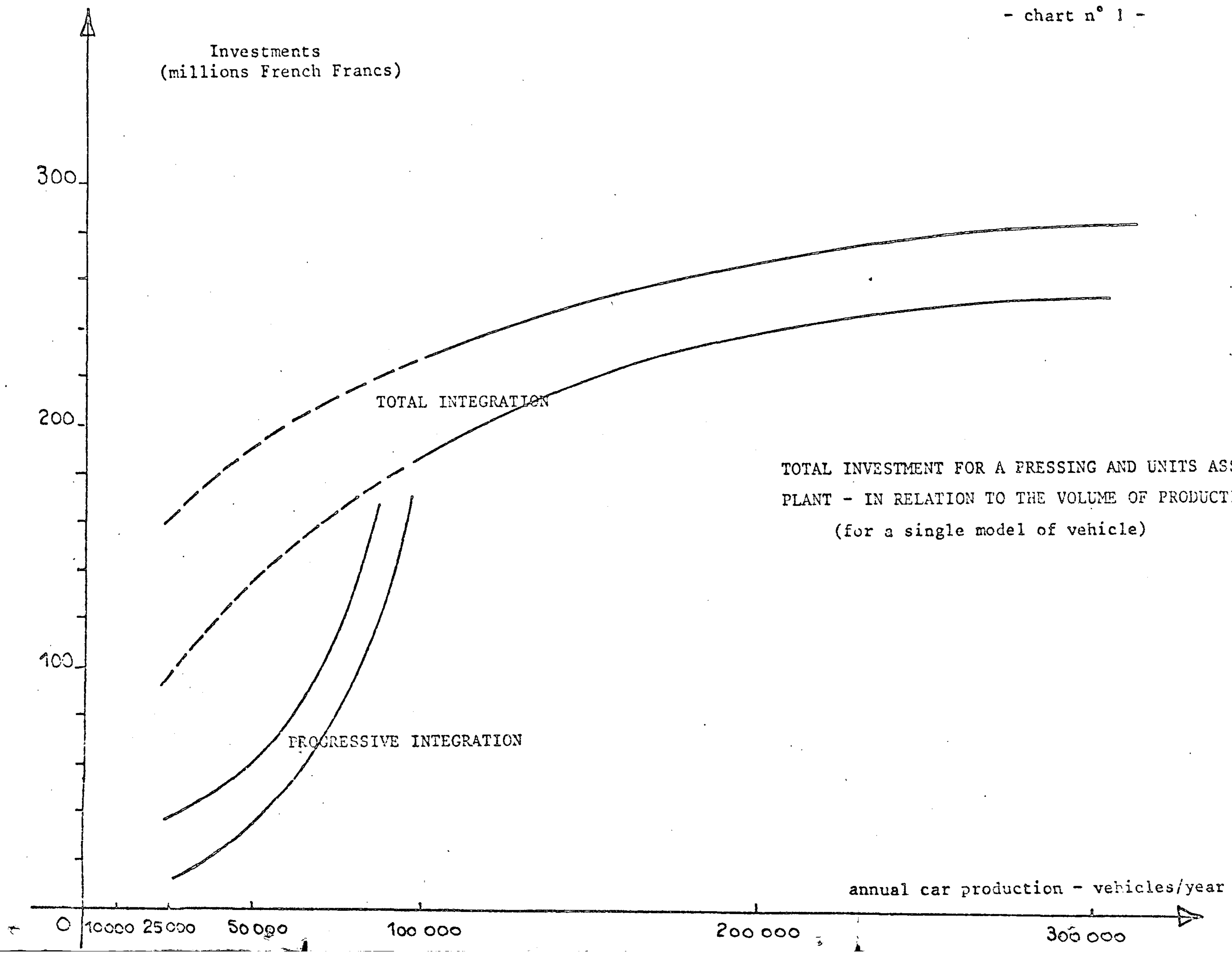
The total investment required for a pressing and assembly plant has been calculated according to different production volumes. The result of these calculations is found in Chart No. 1, which expresses in the abscissa the volume of annual production and in the ordinate, the amount of total investment excluding land.

As pressing tools are so expensive and, in principle, specific to a particular vehicle model, no plants do the pressing operations for every part of the vehicle body if the output is less than 50,000 vehicles a year: for smaller volumes, costs would be very high in the case of conventional steel pressing tools: the tools would be depreciated over a very small number of vehicles and therefore depreciation charges per vehicle would be prohibitive

A) Value of gradual integration of assembly operations

On the other hand, where output is low the various pressing operations can be gradually integrated. Under these circumstances it is possible to manufacture small, simple parts which do not require expensive tooling; these would be inner parts which do not require much

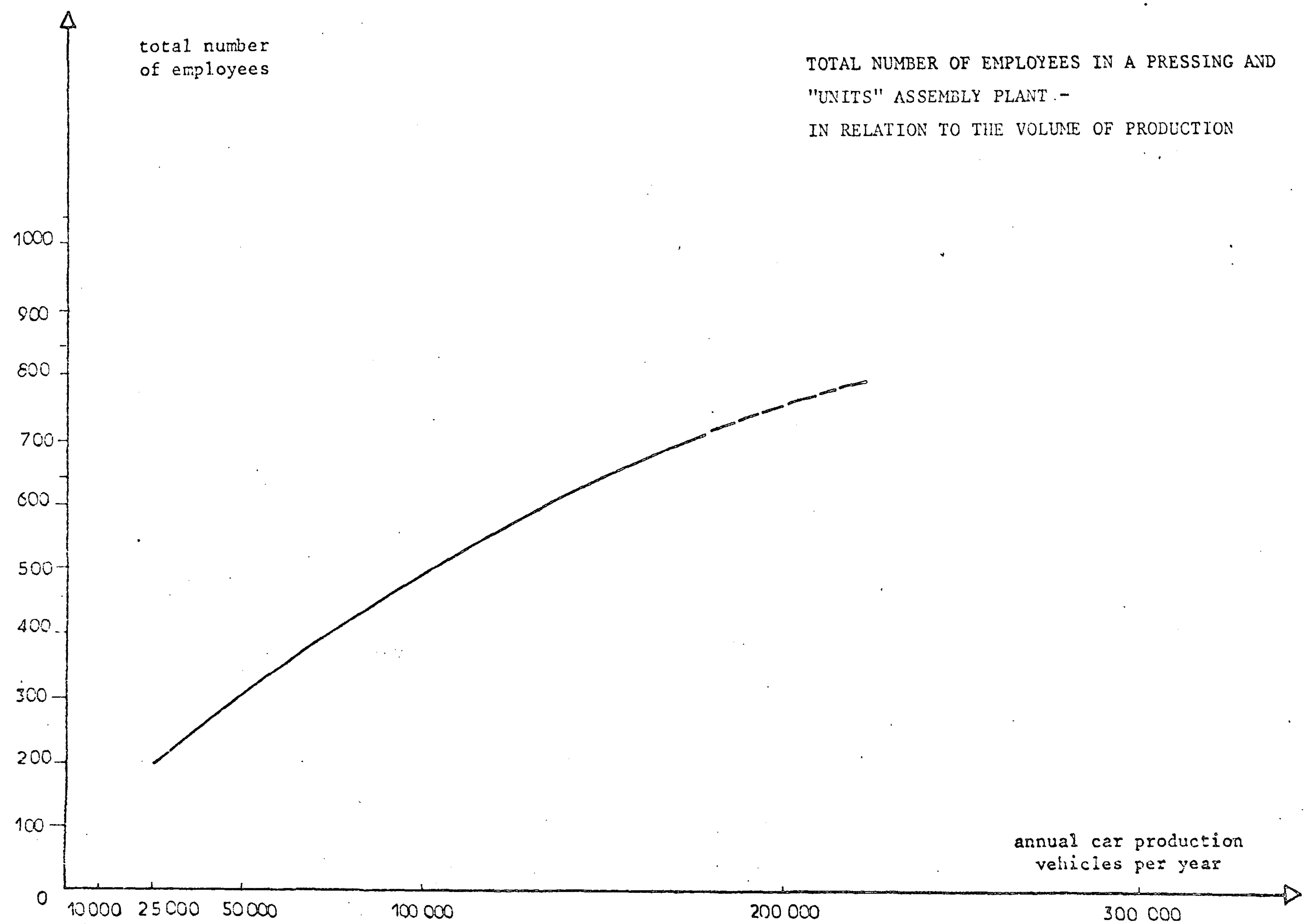
- chart n° 1 -



TOTAL INVESTMENT FOR A PRESSING AND UNITS ASSEMBLY PLANT - IN RELATION TO THE VOLUME OF PRODUCTION
(for a single model of vehicle)

- chart n° 1 bis -

TOTAL NUMBER OF EMPLOYEES IN A PRESSING AND "UNITS" ASSEMBLY PLANT.-
IN RELATION TO THE VOLUME OF PRODUCTION



accuracy in pressing or any particular quality of surface.

Thus Chart No. 1 shows the investment curve for different production rates under the assumption of gradual integration. Integration can begin as soon as output totals 25,000 vehicles a year, and full integration can be conceived for an annual production of 100,000 vehicles.

B) Examination of Chart No. 1

Chart No. 1 indicates that investment is very high even for low rates, in the case of full integration of the pressing operations and assembly.

a) Low and medium rates

In view of the fact that a very expensive press and pressing tools have to be installed when complete manufacture is considered even for low rates, investment rises rather slowly. Thus, if output is to be doubled, i.e. from 25,000 vehicles to 50,000 vehicles a year, investment must be multiplied by approximately 1.27, i.e. a scale-up factor of 0.34.

b) High rates

For more than 100,000 vehicles a year, the rise of investment is quite small. In order to double the output, i.e. from 100,000 to 200,000 vehicles a year, investment is multiplied only by about 1.23, a scale-up factor of 0.27 in this case.

C) Effect of the amount of mechanization

Paragraph 3.1.1 showed that, according to the volume of production, a highly mechanized or a less mechanized manufacturing technique could be chosen.

From a practical point of view, entirely manual techniques should be rejected because the resulting manufacturing costs would be extremely high.

The choice of the manufacturing procedure may, then involve:

i - semi-manual methods (paragraph 4.1.1 B)

ii- fully mechanized methods with combined tools (see paragraph 411 A d i)

iii-fully mechanized and automated methods (paragraph 4.1.1 A d ii).

The latter technique is reserved for plants producing very large series (about 200,000 vehicles a year). For less than 50,000 vehicles a year, either solution i or ii may be chosen, bearing in mind that though the semi-manual method requires much lower investment, it nevertheless involves a substantial increase in labor and consequently causes a sharp increase in the manufacturing overprice.

Thus it may be concluded that there can no longer be any freedom of choice in the extent to which the pressing shop will be mechanized; each rate of production determines an optimum manufacturing procedure, which is the one resulting in the lowest production overprice for a given rate. Any other solution would result in a very high manufacturing cost, because it would mean using either costly equipment which could only be depreciated over a small number of vehicles or very simple equipment involving high labor costs

Thus choice ranges between total or partial integration. And the answer to this question depends to a large extent on the country being considered.

D) Effect of a large number of models

This is a vital problem in the case of the pressing or the units assembly shop.

If total integration is chosen for the manufacture of a car body, very costly pressing tools and assembly equipment (assembly jigs, multispot welding machines) specific to a certain model will have to be used.

For example, for a popular vehicle of medium size, the pressing tools used by a manufacturer to produce the 600 or 700 different parts of the complete body would cost about 50 million francs. The cost might be as much as 100 million francs for vehicles of a higher cylinder capacity. In this case the tools would be steel, and designed for the manufacture of 1 or 2 million parts

a) Completely different models

If it were decided to manufacture two completely different models, a further 50 million francs would be necessary. For a level of 50,000 vehicles a year, this would mean that total investment in the pressing plant would have to be multiplied by 1.5, which is a very high figure.

For these production levels, it would seem preferable to have a partial integration, thus limiting the investment.

b) Value of derived models

A large number of models is thus a particularly unfavorable factor, especially in the case of complete integration with low or even medium rates.

However, it should be remembered that the above analysis refers to entirely different models.

In practice, a manufacturer frequently decides to have a wider range of vehicles while at the same time keeping a large number of body parts unchanged. This is the case of a manufacturer who produces a sedan, then decides to market a coupe, then a station wagon and finally a light pick up van, keeping the front part of the car body, exactly the same (for example, the 403, 404, and the 204 Peugeot, or the Opel models).. This will make it possible to reduce investment in specific tools, and will have the advantage of offering the consumer a wider range of products.

E) Value of car bodies made of plastics

It is now possible to manufacture plastic bodies industrially at very competitive cost prices.

This type of manufacturing is especially interesting for low rates of production, say 15,000 vehicles a year.

These new manufacturing techniques offer very attractive possibilities to developing countries where output is generally low and heavy pressing equipment involving conventional manufacturing procedures has not been installed. This point is mentioned here briefly but it will be studied in detail in the chapter on "Plastics".

4.4 Study of the pressing and units assembly costs

This chapter analyzes pressing and units assembly costs in order to ascertain the manufacturing overprices which are the result of a particular output.

Such a study is fairly difficult due to the virtual absence of proper figures on manufacturing costs for low rates of production. As a matter of fact, because of the very high investment needed for a pressing plant, it is extremely difficult to find a completely integrated body manufacturing shop for rates of less than 100,000 vehicles a year.

When the output is less than 100,000 vehicles a year, only the more straightforward operations tend to be done in order to limit the manufacturing overprice; usually a manufacturer will only produce the hidden parts which are easier to make and will import the more complex body parts, that is, the skin parts which involve the highest costs.

4.4.1 Breakdown of the cost price for an automobile body

The making of the body accounts for a very large part of the cost price of a vehicle, i.e. about 20%.

For a popular medium-sized vehicle, the manufacturing time will be about 11 to 12 hours in the case of large-scale production, that is, about 20% of the total manufacturing time for this type of vehicle (60 hours).

The cost price of the unpainted body, including the floor panel which is ready to be assembled, may be broken down as follows:

Table No. 1

Breakdown of the cost price of a body

Raw materials	32 to 35%	purchases 35 to 40%
Purchases of manufactured products	3 to 5%	
Pressing costs	20 to 25%	value added 60 to 65%
Units assembly cost (1)	15 to 18%	
Assembly cost of the units among them	10 to 12%	
Depreciation of non-specific equipment and tooling, and buildings	4 to 7%	
Depreciation of specific equipment and tooling	6 to 9%	
Cost price of the body ready for assembly	100%	100%

(1) The cost price given includes the cost of assembling the various units. This study has considered that this operation was done in the final assembly shop before assembly on the line; therefore, it will not be taken into consideration in the rest of the chapter.

(2) It should be noted that specific equipment and tooling are depreciated over the total number of manufactured vehicles; therefore, the depreciation is not necessarily based on the life span of the equipment and the specific tools. In the above example, the manufacturer has decided to depreciate the specific equipment over 2'000,000 vehicles for an annual output of 200,000 vehicles.

Notice should be taken of the large share of the depreciation charges in the cost price (10 to 16%), even if the total production has been calculated at 2'000,000 vehicles. This is one of the typical characteristics of production costs in a pressing and units assembly shop.

4.4.2 Study of the value added in a pressing and units assembly shop

The value added by the pressing and units assembly shop may be broken down as follows:

Processing cost -pressing shop 35 to 40% -units assembly shop 30 to 40%	65 to 80%
Depreciation of non-specific equipment	8 to 13%
Depreciation of specific equipment	12 to 18%
Value Added	100%

The share of the labor costs in the value added is approximately indicated in the following breakdown (all figures have been rounded):

Direct labor costs	25 to 35%
Manufacturing costs	30 to 35%
Overheads	8 to 11%
Depreciation -buildings and non-specific investment, 8 to 13% -specific investment, 12 to 18%	20 to 31%
Value Added	100%

In order to show the share of the different body parts in the value added, this may be broken down according to the main body elements, as indicated on Table No. 2; this breakdown refers to a modern vehicle whose back fenders have been incorporated to the side panels. For other types of bodies this breakdown will be slightly different. In general, it may be seen that the roof panel and the floor panel account for a high percentage of the value added.

Table No. 2

Breakdown of the value added in a pressing and units assembly shop according to the main units that form a body

Front fenders	3.92%
Front hood	4.14%
Trunk lid	2.40%
Front doors	7.63%
Rear doors	7.34%
Radiator grille	2.18%
Front wheel housing panel	4.70%
Dash panels	5.60%
Side panels	22.96%
Rear panel	1.62%
Roof panel	13.11%
Floor panel	24.40%
Value Added	100%

N.B. This refers to the value added, so that the price of the raw materials and purchase of manufactured products are not included.

A) Study of direct labor costs

It has been stated that pressing procedures will vary according to output and that much more time is required for pressing in the case of small outputs as compared with mass production.

Three pressing techniques have been considered according to the production expected:

a) Small series

For rates of about 40,000 vehicles a year, preference will be given to a semi-manual method, for which less presses will be necessary; these will only be used for the pressing operations in the strictest sense. Under these conditions, a great deal of time is required for the pressing.

It should be emphasized that very frequently, for this level of production, the most complicated body parts are preferably imported and that complete integration in the pressing shop is very rare.

b) Large series

For an output of 40,000 to 200,000 vehicles a year, all pressing operations and cutting of steel sheets is done by press.

The pressing shop will have more and more presses each of which will be increasingly specialized for the pressing of a particular part.

However, for relatively low volumes of production, the same press may be used for different operations by changing the pressing tools, but this is a lengthy operation which takes about 8 hours. This makes it possible to reduce the number of presses, at the cost of high increases in pressing time.

c) Very large series

In the case of very large series, i.e. more than 200,000 vehicles a year, all operations are done by press, each being highly specialized. As we have seen, in such conditions, the work is carried out on pressing lines, and the handling of the parts between the different presses is entirely automated.

This manufacturing technique allows pressing time to be reduced to a minimum.

d) Evaluation of manufacturing time

Because of the cost of the tools, machine time, and necessarily labor time, are not meaningful unless the manufacturing technique is known. As stated previously, the technique is chosen according to the particular output, that is, first the annual production rate, and second the total number of vehicles that are to be produced during the total life of the model.

Machine time differs considerably according to the amount of automation, that is, according to output.

For a popular, small-sized vehicle, the following machine time has been observed:

Machine time (min.)	Output (vehicles per year)		
Operations:	20,000	100,000	300,000
Cutting	21	8	6.5
Small presses	74	31	21
Medium presses	27	23	8
Large presses	34	36	30
Total time	156 min.	98 min.	65.5 min.
Index	238	150	100

These figures refer only to machine time. The labor time may be deducted by multiplying the figures given by about 1.6 or 1.8.

Moreover, the manufacturing time differs considerably for small and big vehicles.

As an example, the following times which have been observed for an output of 20,000 vehicles a year, are shown:

Operation:	Machine time in minutes		
	small vehicle	medium sized vehicle	higher category vehicle
Cutting	21	25	30
Small press	74	80	85
Medium press	27	30	35
Large press	34	40	45
Total	156	175	195
Index	100	112	125
Weight of the pressing	340 kg.	400 kg.	480 kg.

It thus emerges that, in general, pressing overtimes are very high for small rates; they fall very rapidly when manual operations can be eliminated. However, the minimum pressing time cannot be achieved unless the handling of the parts between presses is automated.

e) Labor skills

It should be noted that the workers must be more skilled in a plant with a low output because in this case a semi-manual manufacturing technique would be needed. The hourly rates for the direct labor would therefore be higher than in a plant producing large series. Consequently, it may be concluded from the above analysis that direct labor costs per vehicle will be higher for low production rates. These direct labor costs decline very rapidly and can be reduced to a minimum only if output amounts to 200,000 vehicles a year.

f) Advantages of working in 2 shifts

In view of the investment required, a double shift system is often decided upon for the pressing and the units assembly shops; this has the advantage of reducing considerably the costs of investment. However, due attention should be given to the fact that costs are not, as a result, divided by two as the increase in assembly capacity is due not only to an increase in the number of machines but also to a change in the production technique.

Furthermore, labor costs are always proportionately higher when the work is done in 2 shifts.

B) Study of the depreciation charges

Depreciation charges should be divided into two categories:
-depreciation of buildings, machines and non-specific equipment;
-depreciation of equipment specific to a given model of vehicle.

a) Non-specific depreciation charges

This includes buildings, utilities, machinery (presses and welding machines), and non-specific equipment.

Depreciation charges are based on the expected life of the corresponding investments. This life period is limited by either wear or obsolescence. The followin depreciation periods are typical of the automobile industry:

	Years
Buildings (including internal distribution networks for energy and fluids)	20 to 25
Non-specific presses and welding machines	10 to 15
Travelling cranes, conveyors	15
Equipment for the production and distribution of fluids	15
Various sheet metal working machines	10
Handling equipment	10
Fork lifters	4 to 5

b) Specific depreciation charges

This includes pressing tools, specific assembly jigs for the units and welding machines which are specific to a particular model of vehicle.

Depreciation in this case can no longer be estimated according to the expected life , but must be calculated in relation to the total number of vehicles that will be manufactured from that model. It is the life of the model, therefore, which has to be taken into consideration. Depreciation is expressed as the number of vehicles or parts expected.

In paragraph 3.1.3, the following rates are given:

Steel tools:	1 to 2 million parts
Zamak or plastic tools:	3,000 to 15,000 parts

C) <u>Effect of the total number of vehicles manufactured</u>

Specific depreciation represents from 6 to 9% of the cost price of the body ready to be assembled, and from 12 to 18% of the value added.

The considerable influence of the total number of vehicles made from the same model will be shown by a quick theoretical calculation of pressing and assembly costs in relation to the total production.

a) <u>Calculation hypotheses</u>

For the purpose of this calculation, it is supposed that the cost of the specific pressing steel tools is 60'000,000 FF. and that the cost of the specific material for the assembly of the units is 40'000,000 FF.

Total specific investment thus amounts to 100,000,000 FF. A calculation of the depreciation charges per vehicle for a declining number of vehicles manufactured will give the following results:

Total number of vehicles of the same model	2'000,000	1'000,000	500,000	250,000	125,000
Specific depreciation charges per vehicle (FF.)	50	100	200	400	800

It is known that this depreciation charge amounts to 12 to 18% of the value added, that is, an average of 15% for a total volume of 2'000,000 vehicles.

Therefore, the value added may be calculated in index numbers for different volumes of vehicles produced as a whole; the results of these calculations are shown on Table No. 3.

In order to show the result of these calculations more clearly, Table No. 3 indicates the number of years the model must last in order to attain the total number of vehicles produced under various assumptions of yearly production rates.

Table No. 3

Total number of vehicles of the same model	2'000,000	1'000,000	500,000	250,000	125,000
Value added (pressing and units assembly cost) indes	100	112	136	184	280
Minimum life required of a model to attain a given total in relation to annual production vehicles/year:					
200,000	10 years	5 years	2½ years		
100,000	20 years	10 years	5 years	2½ yrs.	
50,000	40 years	20 years	10 years	5 yrs.	2½ yrs.
25,000	80 years	40 years	20 years	10 yrs.	5yrs.

b) Calculation results and critical study

Though extremely theoretical, this calculation shows that for less than 100,000 vehicles a year, the pressing and unit assembly cost calculated as an index is very high, i.e. about 136 to 280 depending on whether the model is manufactured over a period of 5 or lo years. Of course, a plant producing 25,000 vehicles a year will not use the same technique as a plant producing 200,000 vehicles a year and in these conditions investment in specific material will be considerably lower. On the contrary, when low rates are concerned there will be a manufacturing overtime which will in fact push up the pressing and assembly costs.

i - Large series

For an output of about 100,000 vehicles a year, the real cost will be a little higher than the overprice that has just been calculated. In fact, at this level, it is necessary to use all the specific tooling required.

The only saving in investment (compared with the very large series of 200,000 vehicles a year) will be due to the fact that the handling of the parts between presses is not automatic. However, this causes an overtime in the pressing operations which is not offset by the lower depreciation charges.

ii- Small series

For the lower rates of about 25,000 vehicles a year, the real cost will be higher than the estimated cost, if the conventional manufacturing techniques are used, even if less mechanized than for large series. If it is decided to do certain operations manually and keep the presses for pressing operations the resulting overtime for the pressing and assembly operations will be very high. This cost will not be offset by the lower depreciation charge per vehicle, even though both specific and non-specific investment is much lower than in the case of high rates.

However, it seems possible to limit the costs if less conventional manufacturing techniques are used. A decision could be taken for example to make bodies out of reinforced plastic instead of steel sheets. It is very difficult to give an order of magnitude in this case as there are very few examples of plants manufacturing plastic bodies and it was not possible to obtain precise data from these plants.

4.4.3 Pressing and units assembly overprice according to output

The above analysis gives the data needed to plot the overprice curve for pressing and units assembly operations according to output.

This curve is shown on Chart No. 2.

A rate of 300,000 vehicles a year has been used as a basis for the overprice and it is assumed that the same model is manufactured over 10 years; in such conditions, a total of 3'000,000 automobiles would be made from the same model. This is a very high figure which is rarely attained in Europe, e.g. the Volkswagen beetle and probably the Renault R4 may be mentioned.

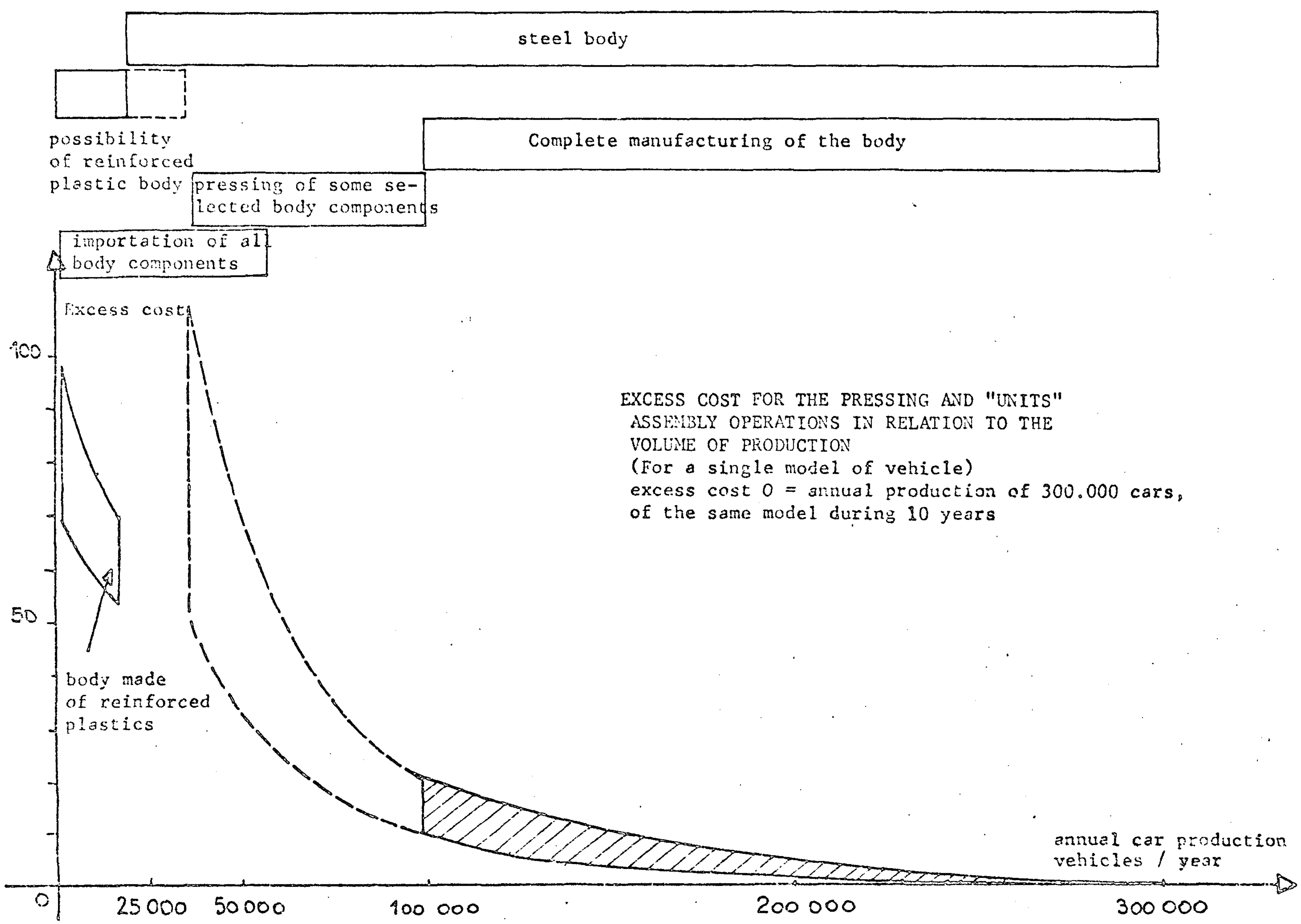
In view of the preceding considerations, it is not surprising to find that the curve in Chart No. 2 is not very clear for the low output zone. In fact, at this level it is possible to choose from several manufacturing procedures corresponding to very different overprices and in most cases the plant does only a small part of the pressing operations since most of the body parts are imported.

Furthermore, precise information is lacking as there are not many examples of plants which do the pressing operations for very small rates of production.

A) Critical mass

The curve indicates that the minimum cost for the manufacturing and assembly of body parts would be more or less achieved for about 200,000

- chart n° 2 -


steel body
possibility
of reinforced
plastic body
Complete manufacturing of the body
pressing of some se-
lected body components
importation of all
body components
Excess cost
100
50
0
body made
of reinforced
plastics
EXCESS COST FOR THE PRESSING AND "UNITS"
ASSEMBLY OPERATIONS IN RELATION TO THE
VOLUME OF PRODUCTION
(For a single model of vehicle)
excess cost 0 = annual production of 300.000 cars,
of the same model during 10 years
annual car production
vehicles / year
25 000
50 000
100 000
200 000
300 000

vehicles a year from the same model assuming the model to be used for 10 years. Therefore, the critical mass for the pressing operations is very high as it is necessary to manufacture a total of 2'000,000 vehicles of the same model to be able to depreciate the specific tools and at the same time benefit from the time saved by the use of automatic handling devices between presses.

B) Minimum production volume for complete integration

It should however be noted that a plant producing 100,000 vehicles a year over 10 years, will only have an overprice of about 10 to 20% which is still reasonable. This is a minimum figure that would be needed to consider complete integration of the pressing operations, assuming that all the vehicles manufactured have the same model of body.

C) Medium rates of production

For less than 100,000 vehicles a year, it seems preferable to do locally only a limited part of the pressing operations. In these circumstances, there will be an overprice of about 35 to 70% for 50,000 vehicles a year from the same model.

For productions of 30,000 to 40,000 vehicles a year and in the case of partial integration of the pressing operations, the overprice may vary from 50 to 120%; again, these are only rough values which are probably lower than the real ones. It seems, then, that this rate is a minimum for partial integration of the pressing operations and that at this level, it is obviously preferable to import all body parts.

D) Low rates

For low rates of about 25,000 vehicles a year or less, complete integration of pressing operations is not justified, unless extremely high overprices are accepted. Moreover, this overprice cannot be estimated as there are no examples of plants which do the pressing operations in such uneconomical conditions.

Accordingly, at this level of production, all body parts must be imported; however, a more favorable solution for the developing countries would seem to be the use of reinforced or heat formed plastics for the car bodies.

4.4.4 The problem of the "freezing" of the models

A) Large series

It has been shown that even if the model of the vehicle remained unchanged for 10 years, the critical mass was still to be found at 200,000 vehicles a year. Therefore, in those conditions, the total number of vehicles of the same model manufactured would total 2'000,000. Obviously, an output of this magnitude requires both a big domestic market and considerable export sales.

This is not of course the case of the developing countries.

In Europe for a given model of vehicle, the number of vehicles seldom amounts to more than a million, and about 5 years would be needed for this total if 200,000 vehicles are produced each year. In this respect, a European manufacturer has a considerable advantage over a developing country, as he is able to change his model, if he wishes, every five years, with only a slight overprice. During the same period of time, another country producing the same model at a rate of 50,000 a year will have only manufactured 250,000 vehicles in all, and the corresponding minimum overprice would be equal to 84% if there is complete integration.

B) Small series

Unfortunately, no developing country produces at present 50,000 vehicles of the same model a year. Production, in these countries, totals 25,000 vehicles a year in the best of cases. Thus, 10 years would be required to reduce the theoretical overprice to 84%; even assuming the model is identical for 15 years, the minimum theoretical overprice would still be 50%. Furthermore, it seems impossible to present the same model to the public for as long as 15 years.

All these considerations are more clearly shown on Chart No. 3. This is a theoretical and simplified chart that should be of value to assess the critical effect of "freezing" a model on the pressing and assembly costs.

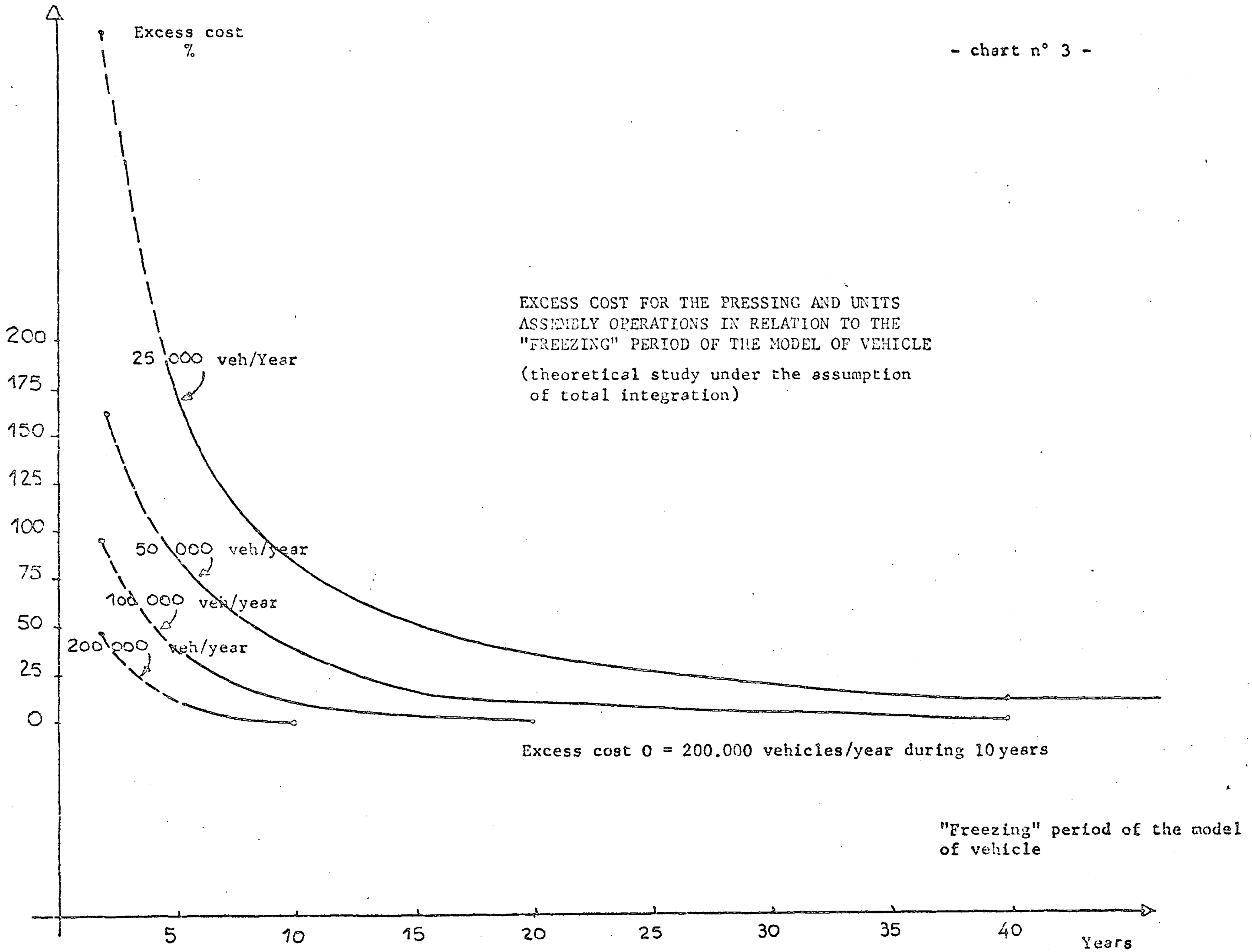
4.5 Conclusions on the pressing and units assembly operations

4.5.1 Main factors affecting the cost of producing a car body

A) Investment

The investment necessary for a pressing and assembly shop is very high, even for low

- chart n° 3 -


Excess cost
%
200
175
150
125
100
75
50
25
0
25 000 veh/Year
50 000 veh/year
100 000 veh/year
200 000 veh/year
EXCESS COST FOR THE PRESSING AND UNITS ASSEMBLY OPERATIONS IN RELATION TO THE "FREEZING" PERIOD OF THE MODEL OF VEHICLE
(theoretical study under the assumption of total integration)
Excess cost 0 = 200.000 vehicles/year during 10 years
"Freezing" period of the model of vehicle
5
10
15
20
25
30
35
40
Years

volumes; for 25,000 vehicles a year it would theoretically be necessary to invest about 100 million francs, if complete integration is desired. However, this is an unrealistic assumption because it would not be economical to invest in a pressing plant for that level of production because of the resulting overprices: about 200% in a completely integrated plant.

As was previously mentioned, almost one third of this amount is spent on pressing tools and assembly and welding equipment which are specific to a model. Thus, only for the large series can a reasonable depreciation of the investment be achieved, thanks to the number of vehicles produced during several years.

B) Minimum output for complete integration

In view of the manufacturing techniques used at present, it is preferable to import the majority of the body parts for production volumes of less than 40,000 to 50,000 vehicles a year. For higher volumes, gradual integration of the operations for the manufacturing of body parts may begin. This process will obviously begin with the manufacture of the simpler parts (hidden parts). Full integration is feasible only for an output of about 100,000 vehicles a year. In that case large-scale manufacturing procedures including the use of presses and steel pressing tools may be employed. As a consequence, investment is necessarily high, i.e. about 150 million francs, but on the other hand, the cost of the pressing operations is not very different from the minimum cost (about 10 to 20% higher).

C) Minimum manufacturing cost

The minimum manufacturing cost of body parts is only reached for production volumes of 200,000 vehicles a year. At this high level of production, mechanization is fully used and the handling of the parts between presses is automated.

D) Depreciation of specific equipment

The depreciation of pressing tools and units assembly equipment specific to a certain model is of great importance. Because of the extremely high cost of these materials (60 to 70 million francs for all pressing tools for a body) 1 or 2 million vehicles in all have to be produced in order to reduce depreciation charges per unit. Furthermore, even for these very large series, depreciation of specific materials represents as much as 6 to 9% of the cost price of a car body.

E) The life span of a model

Indeed, the most important thing in estimating costs for a pressing shop is the life span of the model. Even when very large series are involved -200,000 vehicles a year, for example- 5 years are needed for a total of 1 million vehicles, i.e. the volume necessary to depreciate specific equipment. This being so, 10 or even 20 years may be necessary to attain this same total.

Consequently, those countries which have a very small output are heavily penalized by the depreciation charges of specific tools and are thus forced to give up manufacturing the vehicle body unless they decide to freeze the model for 15 years or more, though this is not likely.

For the lower rates, i.e. about 25,000 to 40,000 vehicles a year, it is obviously preferable to import most of the body parts, and manufacture locally only a small number of simple parts requiring little investment.

Moreover, in certain cases of low output, it is possible to reduce investment by adopting semi-manual manufacturing procedures and using the less expensive zamak or plastic pressing tools, although in the latter case more skilled labor will be needed.

F) Plastic bodies

For 3,000 to 20,000 vehicles a year it would seem possible to manufacture the car bodies out of reinforced plastic. This manufacturing procedure is now being developed and it allows the manufacture of a car body without involving very high costs as is the case for conventional steel body pressing techniques. More specially, this technique will make it possible to reduce the manufacturing overprice, compared with the very large series, to a reasonable level, i.e. about 30 to 40%.

This solution should be of interest to the developing countries which cannot normally expect to manufacture car bodies locally with conventional techniques, because of their low output. In the chapter on "Plastics" the introduction of heat formed plastic bodies to the market will be detailed. This technique is expected to reduce considerably the manufacturing overprice for low volumes of production.

4.5.2 Factors to be considered for the installation of a pressing plant

It should however be noted that the setting up of a pressing plant in a less industrialized country may be facilitated if it is decided to insert this unit of production in a sufficiently wide industrial development program.

Under such conditions, the effect of the following factors should be studied in detail:

- exchanges between countries;
- diversification of the pressing shop;
- widening of the range of models offered, through the production of derived models.

A) Exchanges between neighboring countries

The purpose of these exchanges would be for a given country to specialize within the framework of a free trade area, in the manufacture of automobile bodies for private cars, trucks, agricultural machinery, etc. in such a way that body parts could be traded for mechanical parts, or foundry or forged parts.

As a result of this specialization, the volume of production would automatically increase and would warrant the investment in expensive equipment such as presses.

However, this type of exchanges cannot be easily established if due consideration is given to the economic differences existing between the countries (labor costs, stability of currency) and the very wide range of vehicles found in those countries.

B) Diversification of the pressing shop

It has been seen that investment in costly equipment such as presses and specific tools is not profitable for less than 50,000 vehicles a year.

However, such an investment may be justified if the presses are used for several types of industry and not the automobile industry alone, thus enabling higher profitability.

The presses could be used, for example, to manufacture several parts for the domestic appliance industry and for office furniture made of metal.

Thus the manufacturing would have to be done in regular series, according to the requirements of the various industries.

C) Models of vehicles derived from the sedan car

We have seen that in most cases the government of a less industrialized country will not usually want to present the same model to the public for 10 years or more.

This being so, output is too low to warrant the installation of a pressing plant.

However, starting from a given model -generally, the sedan- several other models may be derived from it: station wagon, coupe, light pick-up truck, and possibly the convertible. The cost of making the aforementioned models would be considerably less than if completely different models were manufactured due to the fact that the greater part of the body would be common to the derived models.

If this commercial policy were associated with a decision to exchange parts with neighboring countries, a larger range of models could be offered to the public while keeping the manufacturing overprice down to a reasonable level. Thus, investment in presses and specific tools could be made possible and at the same time the setting up of a pressing plant would be facilitated.

Chapter 5

The Foundry Shop

The foundry shop is often considered to be just an additional unit of the automobile manufacturing plant because of the relatively small investment it requires if compared with a machining or pressing shop. However, the foundry is a basic industry in an industrialized country and supplies the machining shop with the rough mechanical parts made of cast iron or aluminum alloy it has to machine.

The parts made by the cast iron foundry or the non-ferrous foundry represent about 5% of the cost price of a vehicle and in the total value added by a manufacturer, these operations constitute approximately 8%, i.e. 5 % of the total manufacturing time of a vehicle. (Foundry operations require about 3 hours)

This chapter will study the investment necessary for a foundry shop and will analyze the cost price of foundry operations, in order to calculate the manufacturing overprice for different volumes of production. It will then be possible to determine the critical mass of production required for a foundry shop as well as the threshold for complete integration of foundry operations.

In the first place, a brief summary of the foundry techniques will be presented, together with a brief description of a foundry shop.

5.1 General data on foundry techniques

5.1.1 Manufacturing procedures

Most of the different foundry techniques known today are used in the manufacture of automobile parts, in particular:

- sand-moulding
- shell-moulding
- gravity die-casting
- pressure die-casting

The choice of the manufacturing technique depends on:

- the possibility of conversion or adaptation to other industries
- the number of units in each series
- the mechanical or metallurgical properties desired
- the technical possibilities and local material available.

The chapter entitled "General Considerations on the Automobile Industry" has referred to two main alloys used in the manufacture of a vehicle: ferrous alloys: cast iron and steel; and non-ferrous alloys: aluminum and zinc alloys.

The following techniques are generally used:

- sand-moulding for ferrous alloys;
- gravity die-casting } for non-ferrous alloys.
- pressure die-casting }

The logical sequence of the operations is always the same:
moulding --- coring --- casting --- deburring --- heat treatment.

5.1.2 Materials used

A) Cast iron

The different types of cast iron used by the foundry shop are as follows:

- gray pig iron (engine block, fly wheel, exhaust manifold)
- ductile iron
- centrifugal iron (cylinder liner)
- malleable iron (brake drums)
- semi-steel (crankshaft, camshaft)

A further breakdown of each quality of cast iron would be needed to specify the small differences according to the part desired.

The different types of cast iron are obtained from the following components which are given as examples:.

%	Cast iron for engine block	Cast iron for cylinder liner	Malleable iron
Hematite	20	20	25
Scrap-iron	20	–	25
Phosphorous iron	–	30	–
Returns,gates	35	40	50
Cast-scrap	25	10	–
	100%	100%	100%

Moreover, in order to complete the input supply, it is necessary to add ferrous-alloys containing, in addition to iron, the following metals: manganese, silicon and chrome.

B) Non-ferrous alloys

According to the type of part desired, different qualities of alloys are chosen. By way of example, the following may be mentioned:

- AS - 5U3 for the parts obtained from sand-moulding (French standards);
- AS - 12 - UN for pistons (French standards);
- aluminum-magnesium alloy for the engine block when it is made of non-ferrous alloy;
- aluminum and zinc alloy (zamak) for parts cast by pressure die-casting and not subject to stresses (carburator, gasoline pump).

In the same way, moulding procedures will be different according to the type of part:

- gravity die-casting: cylinder head
  piston
  intake manifold
- pressure die casting: clutch housing
  gearbox housing
  steering housing
  water-pump body
  oil-pump body
  carburator
  gasoline pump

In order to give some idea of the amount of pig iron and non-ferrous alloys needed for the manufacture of an automobile it may be said that 111 kg. of parts are cast in a medium-sized automobile. The consumption of parts per vehicle may be subdivided, for example, in the following manner for a current model:

Type of alloy	Weight liquid state	Weight of rough parts ready for machining
Gray pig iron	87.9	56.7
Ductile iron	21.0	12.6
Centrifugal iron	11.4	10.0
Malleable iron	11.3	10.7
Cast steel	0.5	0.4
Aluminum alloys	20.7	20.7
Zinc alloys (zamak)	0.4	0.4
		111.5 kg

The engine block in this vehicle is made out of cast iron, though many modern vehicles have engine blocks made out of aluminum alloys. Therefore, the breakdown according to the type of ferrous or non-ferrous alloy may vary considerably according to the technical solution adopted.

For annual productions of 100,000 vehicles of the type mentioned above, annual requirements of cast iron would therefore be equal to 10,000 tons, plus 2,000 tons of non-ferrous alloy.

5.2. Brief description of a foundry shop

5.2.1 Stockyard

The foundry shop has a stockyard which is run differently according to delivery methods and types of material.

A) Deliveries

According to local conditions, they will be done:

- by wagon and unloaded by a travelling crane
- by trucks with tipping buckets
- by a combined method: a private railway junction and trucks. This is frequently the most economical solution.

B) Materials

There are several materials to be stored in a foundry shop:

a) in sheds: sand, coke, limestone flux, wood, carbon dioxide, liquid oxygen;
b) in warehouses: colloidal clay, blacking, core binder, ferrous alloys.
c) in open stockyards: pig iron, cast scrap, scrap iron.

C) Handling

There exist several mechanization possibilities:

a) Mechanized handling:

i - advantages: reduced labor force
fast work
smaller surface needed

ii- disadvantages: large investment

b) Manual handling

i - advantages: small investment
low operating costs
use of unskilled workers who can thus be recruited easily

ii- disadvantages: strenuous work
time-consuming handling operations
large surface needed

5.2.2 Pattern-making section

This section is responsible for making the patterns of the parts which have to be manufactured, and which will be used to make an impressi on the mould. All these are very intricate operations. For the manufacture of large series metal patterns are used. In the case of a foundry shop producing small series, it is usually more economical to purchase the metal pattern from an automobile manufacturer to avoid the adjustment difficulties in the case of local manufacture.

The pattern-making shop must:
- check the patterns and the core-boxes before and after use
- maintain, repair and possibly modify the patterns
- manufacture new tooling.

Tooling may consist of the following basic material:

a) wood: which may or may not be mounted on match plates;

b) metal: which may or may not be mounted on match plates;
die for gravity die-casting;
die for pressure die-casting;

c) plastics: which may or may not be mounted on match-plates.

5.2.3 The casting shop

A) Sand-moulding

To make the mould, sands and earth are used. They are prepared in the sand preparation plant. Usually a synthetic type of sand is employed for ferrous and non-ferrous alloys, to avoid the variations in quality which occur with natural sands from local quarries; this reduces ramming defects and a tighter check is kept on moisture content.

The caster makes the mould by ramming the sand around the pattern. The pattern, as explained above, is a hollowed imprint of the part to be manufactured. The whole operation is done mechanically and either a sandslinger or a conventional moulding machine may be used.

a) Sandslinger

The sandslinger system has the advantage of limiting investment and of introducing a certain amount of flexibility in the work of the work stations. On the other hand, it requires much skill in its handling and needs frequent adjustments.

b) Moulding machine - pressure - direct strippin

These machines allow more regular ramming and need less silled labor, because the quality of the ramming is not directly dependent on the desterity of the operator.

On the other hand, investment in these machines is high as a large number of machine are required; furthermore, a larger labor force is needed .

c) Coring

These operations consist in making the variou cores which will be subsequently placed in the moulds to stand in the place of the hollow space. Special sands are used, in particular, agglomerated sand and silicate sand. The cores are made in production lines with core bolowing machines. The agglomerated sand is baked before casting, so that it may desintegrate easily after the moulding and be eliminated. Certain procedures can avoid this baking as in the case of the CO 2 core strengthening process.

d) At present, the technique known as "Exporit" is used in sand moulding for the manufacture of rough parts of press toolings or frames for machine tools.

The pattern is made of polystyrene foam and then placed on the sand in the same way as a wood pattern. The liquid metal is directly cast on the pattern which vaporizes and leaves a hollow shape for the liquid metal. The advantage of this technique is the ease with which the pattern can be made, by cutting and gluing together polystyrene foam; however, one pattern is necessary for each casting since it is destroyed after use.

B) Gravity die-casting

The casting of parts in a metal mould that may be reused allows a better texture of the alloy, thus resulting in improved mechanical characteristics.

The metal dies must be cleaned every day with a vapor bolowing machine. Then, the dies must be heated in a muffle furnace at a temperature of about 180 to 200 degrees before the first casting.

In addition, a furnace heated with fuel is used for casting. The furnace is fed with hot metal through a suspended ladle. It is necessary to remove the gas from the metal before casting and to take a test piece.

C) Pressure die-casting

This consists in injecting mechanically the liquid or semi-liquid alloy into a re-usable metal mould at a very high pressure. This method allows high production rates.

The production cycle is as follows: closing of the mould, injection, cooling, opening of the mould, stripping of the casting.

a) Zinc alloys

For zinc alloys a machine with a hot chamber with its own furnace (temperature 100 degrees C) and where pressure and injection are hydraulically or pneumatically obtained (pressure of about 200 kg/cm2) is used. Metal is used in liquid form.

b) Aluminum and copper alloys

A cold chamber machine is used. The smelting furnace is a separate unit in this case and therefore the molten metal must be driven from the furnace to the hydraulic or oleo-pneumatic injection cylinder (pressure 500 to 1500 kg/cm 2).

c) Remarks on this procedure

i - advantages:

- thinner and more accurate parts can be cast with this method than with gravity die-casting;
- the quality of the surface (the"skin") is excellent;
- the cost of the following machining operations is reduced;
- the cost price of the rough casting is low;
- very little or no scrap (the material is recovered and remelted).

ii- disadvantages:

- it is essential to clean the mould very carefully;
- the moulds are expensive.

d) Tooling

The tooling will last for about 150,000 to 200,000 parts for aluminum alloys and a life span of 500,000 parts may be expected for zinc alloys (easier maintenance of the moulds). The cost of this tooling is three or four times more than for die-casting.

D) The mechanization of the casting shop

The mechanization of the casting shop will depend on the volume of production.

a) Large series

The casting shop is highly mechanized. Secondary operations and handling are done mechanically.

Because of this, the labor force is smaller and can be less skilled.

However, this technique lacks flexibility and it cannot be used for small series. Furthermore, a mechanized casting shop requires heavy investment.

b) Medium-sized series

In this case, the casting shop will be semi-mechanized: some operations will be done manually, others automatically; handling will be done by gravity.

The shop is run according to special methods, allowing it to operate flexibly. Medium-sized series may be produced at a satisfactory cost price, and the investment is not as high as for large series. A bigger and more skilled labor force will be necessary in this case.

5.2.4 The smelting shop

The smelting of the alloys is done in cupolas for gray pig iron, in electric induction furnaces for the cast iron used for cylinder liners, and in fuel-oil furnaces for non-ferrous alloys.

The smelting section has a stockyard where supplies are kept, distributed, and weighed to furnish the necessary components for each type of alloy.

These components (pig iron, scraps, hematites, shots) are then put into the cupola; this apparatus produces liquid cast iron at the lowest cost with good metallurgical qualities. According to the heating power of the coke used, a hot-blast or a cold-blast cupola will be chosen. A hot-blast cupola will be chosen if the coke is of an inferior quality; however, this hot-blast cupola is more expensive.

The electric furnace is used to melt non-ferrous alloys and is fed with ingots.

The distribution of liquid metal to the different casting shops may be done with:

- a travelling crane;
- an automotive lorry;
- a suspended ladle, the casting being done by only one man.

5.2.5 Shake- out, shot blasting, deburring

The cast parts made in the different shops are transported with their gates, adherent sand and cores to the place where they are to be shaken out.

A) Shake-out

In the course of this operation the rough part is extracted from the mould; this may be done either manually or mechanically.

a) Mechanical shake-out

The parts vibrate on a shake-out grid, the burnt sand is evacuated on a conveyor belt and discharged into an elevator which feeds a truck hopper.

b) Manual shake out

This operation is done with a miner's bar, a hammer, etc., on a fixed grid.

B) Shot blasting

This operation is necessary before deburring, its purpose being to:

- clean the parts;
- eliminate fins;
- detect important failures in order to eliminate the bad parts.

A shot blasting machine with a swivelling table may be used, for example.

For non-ferrous alloys, a shot of a lower degree of hardness must be used and the rotation speed of the shot blast turbine has to be modified.

C) Deburring

Before deburring, the gates and nobs must be separated. The gates are classified according to their metallurgical qualities so that they can be reused.

In the case of ferrous alloys, gates and nobs are knocked out, but for non-ferrous alloys they must be cut off with a band-saw or an abrasive disk.

The deburring itself is really a grinding operation which prepares the castings for machining.

Either a moving or a fixed grinding wheel will be used according to the size of the part. If a moving grinding wheel is used, the part will remain fixed; and if a fixed wheel is used the part will move.

Thus, grinding will be done with the help of a suspended grinder for cylinder blocks and cylinder heads, but fixed electro-grinders will be used for other grinding operations.

5.2.6 Heat treatment

Usually, the alloys will undergo heat treatment in order to give them particular mechanical properties.

Malleable cast iron parts will be obtained from parts cast in white iron and after an annealing operation in a nitrogen atmosphere with controlled temperature and pressure. This operation is done in a continuous tray furnace.

Furthermore, certain non-ferrous alloys will undergo stabilization treatment, particularly as regards the pistons. This is done in an electric furnace.

5.2.7 Other operations

This mainly involves checks and laboratory control.

A) Checking

Checks are necessary before and after heat treatment. All parts must be checked before heat treatment whether they are to be heat treated or not. Checks are made on:

i : appearance

ii : hardness (done either systematically or by sampling)

iii: size; for each part produced in the foundry shop a set of jigs must be availabl in order to make a quick check of dimensio In addition, the size is also checke by tracing the final dimensions on some castings.

iv : watertightness under pressure; this control is most necessary for engine blocks without liner, because leaks can thus be detected. Repairs may then be done in certain cases. The method generally used is to fill the part with water after closing all the openings and then submittir the part to pressures of 7 to 8 kg/cm 2.

This test may also be carried out with compressed air, the part will then be submerged in water.

B) Laboratory

Generally, a chemical and metallurgical analysis laboratory is necessary. The laboratory has to make a chemical analysis of the raw materials and must control the quality of the alloys while they are manufactured.

The following tests will be carried out:
- measuring of the carbon contents;
- measuring of the sulphur contents;
- measuring of other elements.

The laboratories will prepare test bars and check and measure their mechanical properties with conventional testing machines.

It should be noted that very frequently this physics and chemistry laboratory also serves the forge shop.

5.3 Ratio between investment and production in a foundry shop

5.3.1 Classification of investment

A simplified classification is used for the different categories of investment. An approximate percentage for each of these categories is given in the following table:

Buildings, land grading, utilities and general facilities	20 to 25%
Equipment, machinery, materials	50 to 60%
Tooling	20 to 25%
Total investment	100%

The requisite surface is relatively small: about half of that needed for an assembly shop; that is, about 12,000 to 15,000 m2 for a foundry producing all cast parts for a total of 100,000 vehicles a year.

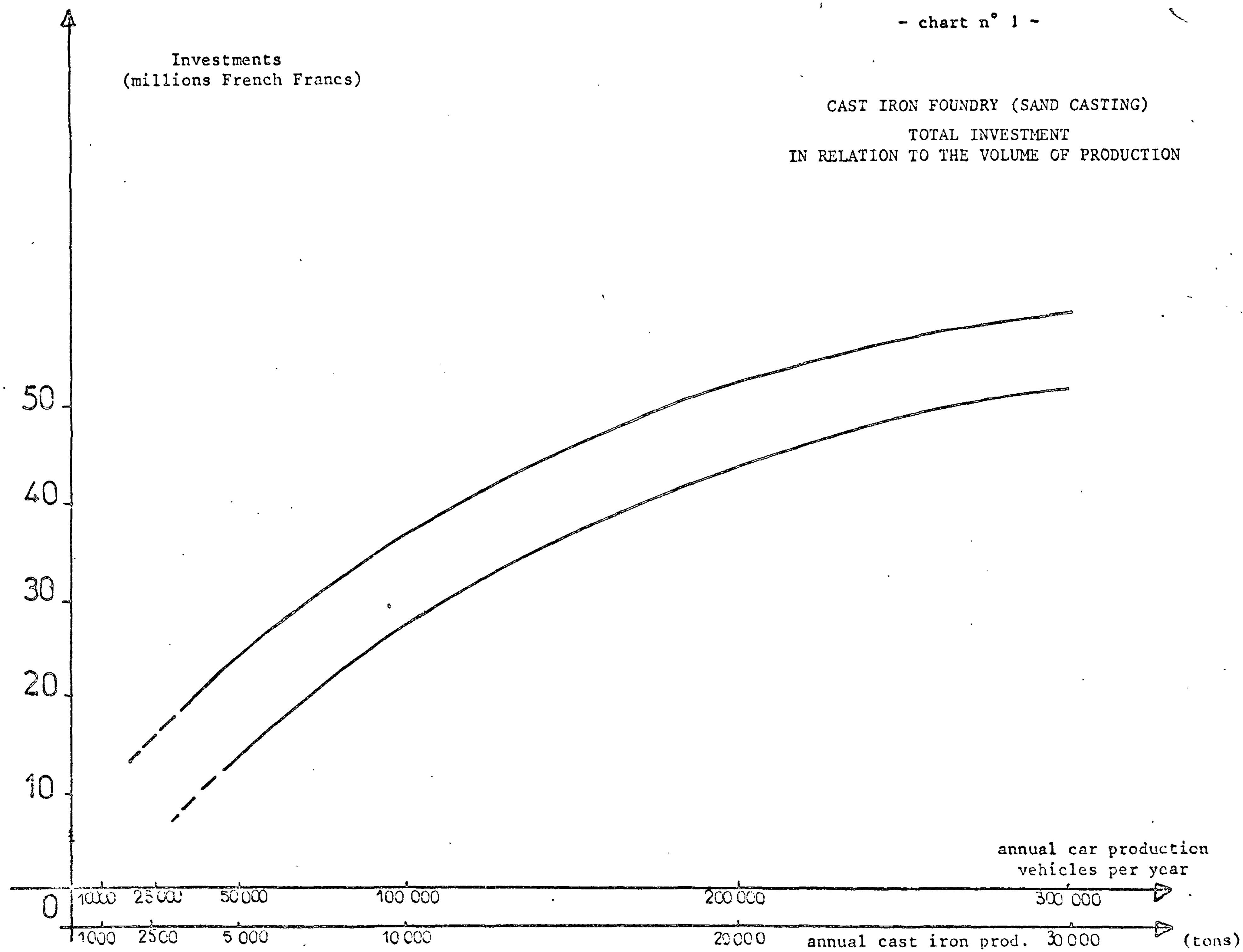
Foundry equipment and tooling account for a small part of the total equipment necessary for a full manufacturing automobile plant: about 6 to 8% of total investment in equipment and tooling.

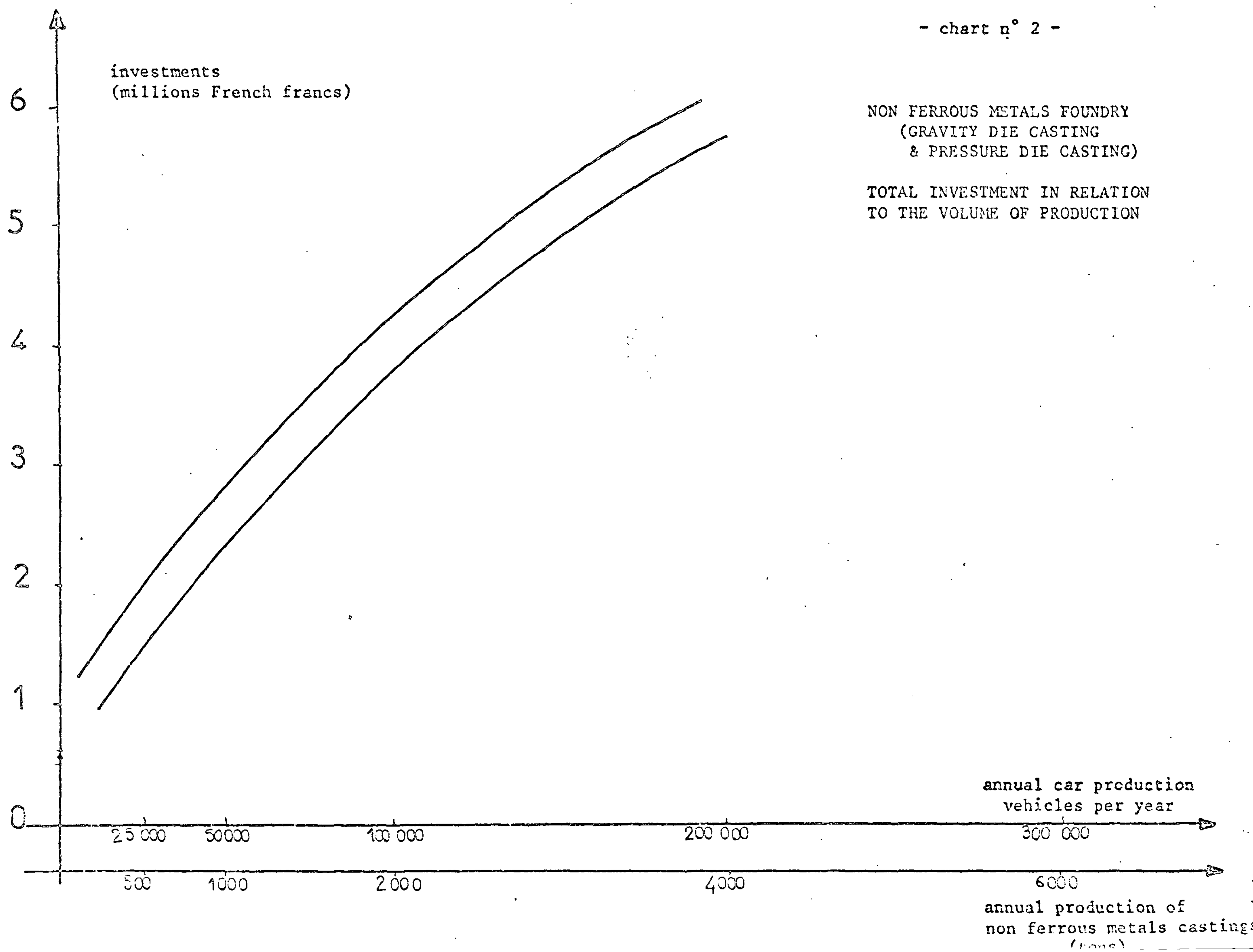
With these data, total investment in a foundry shop can be calculated according to the rate of production. The results of these calculations are given on Charts No 1 and No. 2. According to the information available, two different curves must be presented: Chart No. 1 corresponds to a cast iron foundry and Chart No. 2 corresponds to a non-ferrous alloy foundry. In the case of high rates of production, these two shops will be merged and integrated to the manufacturing plant.

- chart n° 1 -

CAST IRON FOUNDRY (SAND CASTING)

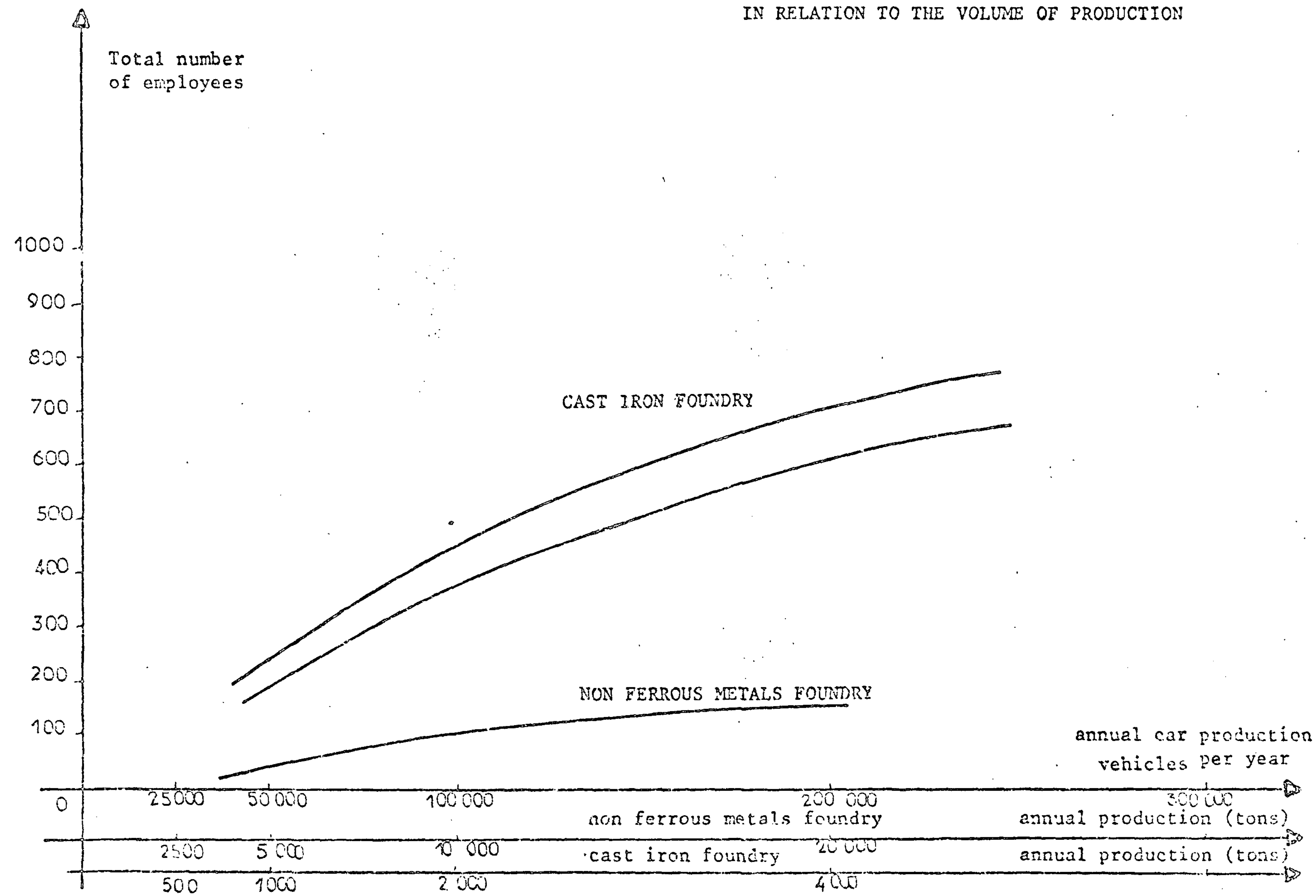
TOTAL INVESTMENT
IN RELATION TO THE VOLUME OF PRODUCTION




- chart n° 2 -
NON FERROUS METALS FOUNDRY
(GRAVITY DIE CASTING
& PRESSURE DIE CASTING)
TOTAL INVESTMENT IN RELATION
TO THE VOLUME OF PRODUCTION
investments
(millions French francs)
6
5
4
3
2
1
0
annual car production
vehicles per year
25 000
50000
100 000
200 000
300 000
500
1000
2000
4000
6000
annual production of
non ferrous metals castings

- chart n° 2 bis -

TOTAL EMPLOYMENT IN A FOUNDRY
IN RELATION TO THE VOLUME OF PRODUCTION



In the case of low volumes, each on the foundries will also work for several other different industries. In other words, for low volumes of automobile manufacture, foundry operations will be sub-contracted to local foundries.

The limit for the integration of foundry operations may be set at 50,000 vehicles a year. This would correspond to a foundry shop producing about 5,000 tons of cast iron and about 1,000 tons of non-ferrou alloys.

5.3.2 Cast iron foundry (Chart No. 1)

This is a foundry shop using the sand-moulding technique.

A) For low volumes of production between 25,000 and 100,000 vehicles a year, investment is almost proportional to the capacity installed. The scale-up factor is about 0.75 to 0.90. To double the capacity of production, the investment must be multiplied by 1.7 or 1.9.

B) For large-scale automobile production of more than 10 ,000 vehicles a year, investment rises more slowly. This means that investment is less than proportional to capacity. The scale-up factor is about 0.40 to 0.50; thus, to double capacity, investment must be multiplied by 1.30 to 1.45.

5.3.3 Non-ferrous alloy foundry (Chart No. 2)

The non-ferrous alloy foundry studied produces aluminum alloys by the die-casting and pressure die-casting processes.

A) For 10,000 to 100,000 vehicles a year, that is, an output of 200 to 2,000 tons a year, the scale-up factor is 0.64; therefore, investment must be multiplied by 1.53 to 1.62 to double the production.

B) For an output of more than 100,000 vehicles a year, that is, more than 2,000 tons of non-ferrous alloys a year, the scale-up factor is 0.58; therefore, to double the output, investmen must be multiplied by 1.48 to 1.52.

When calculating the production of a foundry on the basis of the weight of the cast parts used in a vehicle, nobs and wastes must be taken into account. Therefore, the weight of liquid cast iron will be about 1.4 to 1.5 times greater than the weight of rough cast iron, the latter being about equal to the sum of the gross weight of the cast parts ready to be machined.

However, for an aluminum foundry, the weight of the liquid alloy will be about 1.1 times greater than the gross weight of the parts made of non-ferrous alloys.

As an indication, the following investment amounts are given for tooling which is specific to a model of vehicle in the foundry shop of a European manufacturer:

- iron castings : about 3 million French francs
- non-ferrous castings : about 2 million French francs

This example refers to a medium sized vehicle, the engine block of which is made of cast iron.

5.4 Analysis of the cost of manufacturing a casting

The cost of a casting is the sum of the price of the raw material plus the cost of processing. Therefore, the processing cost corresponds to the value added by the foundry shop.

5.4.1 Analysis of the value added by the foundry

In order to determine which part of the cost of a casting corresponds to the value added, the price of the main castings has been studied. The results of this study are shown on Table No. 1

Table No. 1

Example of an analysis of the value added by a foundry shop

		Price of raw Materials %	Value Added %	Cost Price %
iron castings	Engine block	5.01	20.29	25.90
	Cylinder liner	0.57	6.18	6.75
	Exhaust manifold	0.55	2.05	2.60
	Clutch driving disk	1.98	6.57	8.55
	Cam shafts	0.36	1.21	1.57
	Brake disks	1.06	3.37	4.43
non-ferrous alloys	Cylinder head	16.07	9.65	25.72
	Intake manifold	1.72	1.23	2.95
	Pistons	1.12	1.28	2.40
	Gearbox	11.76	7.37	19.13

The parts representing the highest percentages of cost price are, in particular, the engine block, the cylinder head and the gearbox.

The value added by the foundry shop represents, in the case of the parts under consideration, about 60% of the price of the castings; the price of the raw materials thus accounts for about 40% of their cost.

However, the difference between the iron foundry and the non-ferrous alloy foundry must be clearly distinguished.

The price of raw materials for the non-ferrous alloy foundry is high. Roughly speaking, a kilo of non-ferrous alloy costs about 10 times more than a kilo of cast iron. This is why non-ferrous alloy parts represent half of the cost of the castings though they do not even make up for a fourth of their weight. Therefore, the price of the non-ferrous alloy castings is high due to the high cost of the raw material.

On the contrary, the cost of raw material for the iron foundry is low and processing costs, that is, the value added, are high.

The above facts are brought out on Chart No. 2, in order to illustrate the relative importance of the iron and non-ferrous alloy foundries in the cost price of the cast parts.,

Table No. 2

Relative importance of the iron and non-ferrous foundries

%	Cost of raw materials	Processing cost (value added)	Cost price
Non-ferrous castings	30	20	50
Iron castings	10	40	50
Total cast parts	40	60	100

5.4.2 Variation of foundry operation costs in relation to production

It has been stated that an increase in the annual volume of castings produced by the foundry shop is accompanied by an increasing mechanization of the equipment. Manufacturing time, and in particular, the time needed for casting and finishing will be considerably reduced, with a consequent reduction in labor costs.

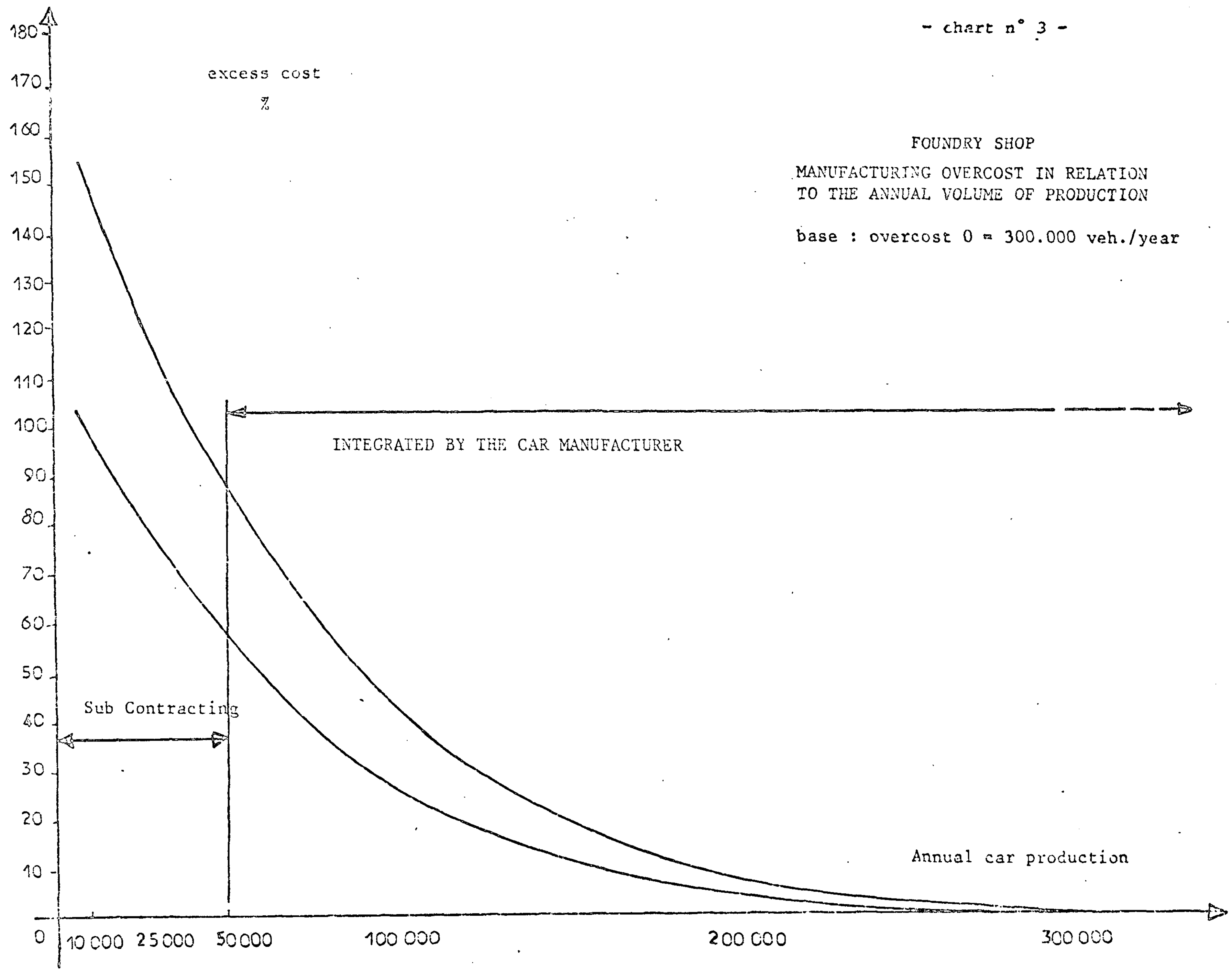
Furthermore, those tools which are specific to a vehicle model (patterns of parts, core boxes) will be depreciated over a larger number of castings.

Therefore, the cost of foundry operations will be lower in the case of high outputs than in the case of low outputs.

Variations in the cost of foundry operations are shown on Chart No. 3. The ordinate shows the overprice as a percentage of the zero overprice for different levels of production.

The minimum cost or zero overprice corresponds to an entirely integrated foundry producing only automobile parts for a manufacturer producing 300,000 vehicles a year.

- chart n° 3 -



excess cost
%
FOUNDRY SHOP
MANUFACTURING OVERCOST IN RELATION
TO THE ANNUAL VOLUME OF PRODUCTION
base : overcost 0 = 300.000 veh./year
INTEGRATED BY THE CAR MANUFACTURER
Sub Contracting
Annual car production
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10 000
25 000
50 000
100 000
200 000
300 000

A) Small series

For low rates, the overprice is very high, about 100 to 150% for a volume of 10,000 vehicles a year.

This overprice drops rapidly, but is still 50 to 85% for 50,000 vehicles a year.

B) Large series

In the case of large series, the overprice becomes negligeable only for an output of 200,000 vehicles a year. It may thus be concluded that the critical mass of the foundry shop is high.

Furthermore, notice should be taken of the fact that for rates as high as 100,000 vehicles a year, the overprice is still 25 to 40%.

C) Limit for the complete integration of foundry operations

Due to the high overprice in the case of low volumes of production, casting operations are normally sub-contracted for volumes of less than 50,000 vehicles a year. This corresponds to a production of about 1,000 tons of castings a year. For higher volumes, manufacturers usually decide to integrate the foundry operations even though the overprice is still high.

When sub-contracting, the manufacturer resorts to the local foundry industry which produces castings for many varied industries, including:

- passenger cars
- industrial vehicles
- wheeled tractors
- caterpillar tractors
- heat engines
- pumps
- railroad material
- hand tools
- spare parts for the maintenance of cement plants and iron and steel works
- machine tools
- etc.

Some of these are related industries, in particular, the industrial vehicle industry, the heat engine industry, and the tractor industry. The parts that have to be manufactured and the casting operations for these industries are quite similar.

Therefore, the production overprices of castings may be limited, if the country concerned has a sufficiently developed tractor industry or heat engine industry.

Chapter 6

The forge shop

The forging shop like the foundry shop, constitutes a complementary manufacturing unit which is of relatively little importance as far as investment goes, especially compared with the machining shops. The forge shop supplies the machining shop with rough forgings.

Forged parts represent about 2.5% of the cost of a vehicle, and the value added by the forge shop is only 1.5% of the cost price of the vehicle, that is, about 3.3% of the total value added by the automobile manufacturer. Under these conditions, forging operations will frequently be sub-contracted, because they concern only a few units.

However, these units are fundamental to the safety of the vehicle and therefore the manufacturer will have to supervise closely the techniques employed and the quality of the products supplied by the sub-contractors, if he decides to sub-contract instead of doing the work in his own shops.

This chapter will first describe briefly the forging operations and estimate the amount of investment required by a forge shop. As for the main manufacturing units of an automobile plant, the variation of manufacturing costs in the forge shop in relation to the volume produced will be studied. Thus it will be possible to determine an approximate critical mass for the forge shop.

6.1 Description of the forge shop

6.1.1 Definition of drop-forging

Drop-forging is a hot-forging operation done by machine with a tool consisting of two parts: male and female.

Drop-forging operations are done in two or sometimes three steps.

First, the metal is heated to the forging temperature. At that temperature the metal is sufficiently malleable to be deformed by shock or pressure; strictly speaking, this is the drop-forging operation.

In order to make sure that the forged part has the right dimensions, the excess metal or the fins are driven into the lateral dies.

The forged part which has thus been formed is sent to a press which cuts off the fins.

Two forge techniques are mainly used:
- drop-forging with multiple dies usually with 3 dies (extrusion, roughing, finishing) for compact parts;
- forge with the forging and upsetting machine

for cylindrical surfaces (shaft, axle, ...).

A forge shop for the automobile industry must therefore use both types of technique.

6.1.2 Diagram of drop-forging operations

Outline of operations:

```
sawing   )
shearing ) -- heating in a furnace ---
cutting  )
                                ( heat treatment
drop forging --- cutting -- ( shot blasting
                                ( gauging
```

In order to show the sequence of forging operations in detail, a complete outline of drop-forging operations is given below.

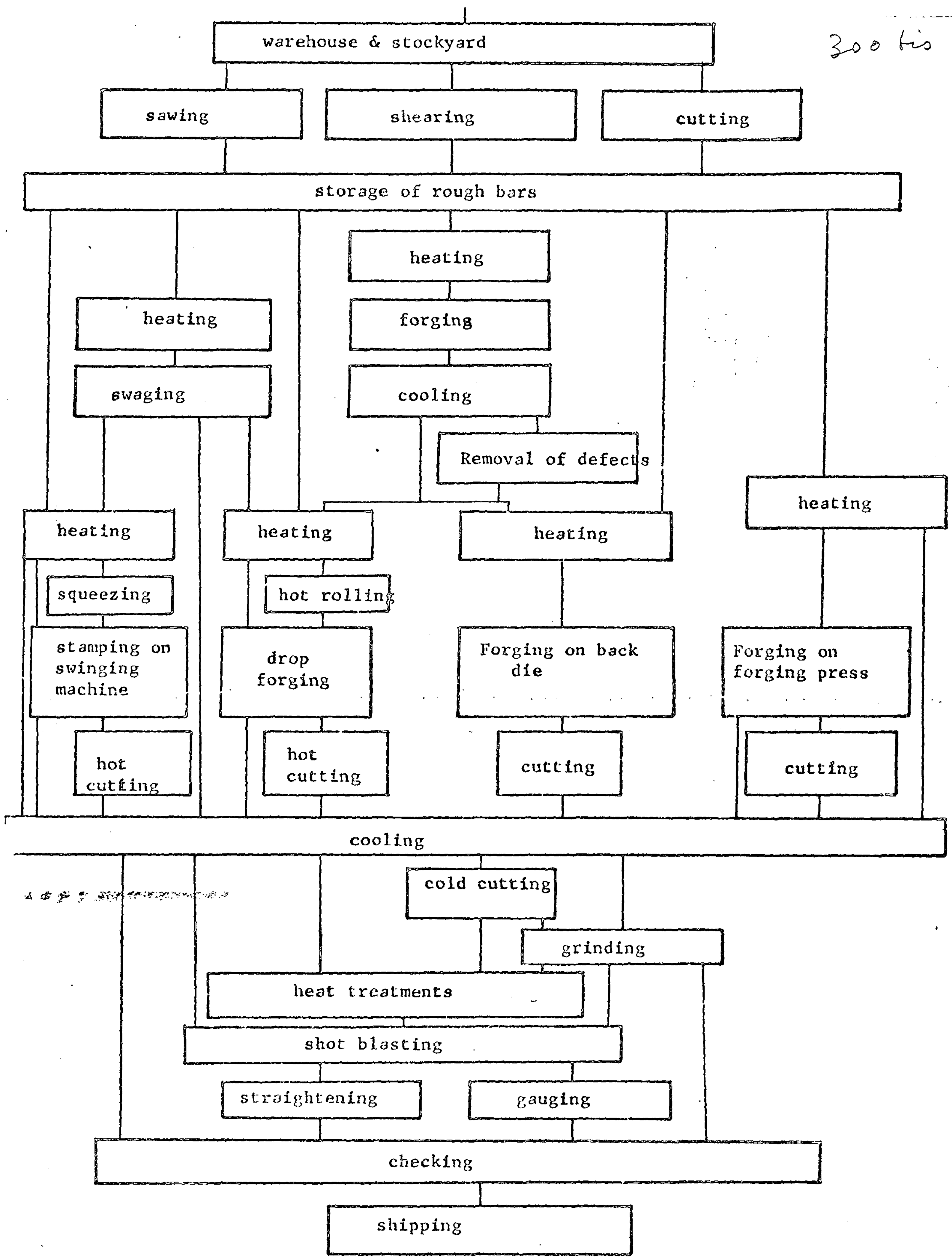
6.1.3 The drop-forging shop

A) Preparation of raw materials

a) Storage of materials

These are the raw materials needed for the manufacture of forgings and toolings; in particular, alloy steels and ordinary non-alloy steels.

300 bis


warehouse & stockyard
sawing
shearing
cutting
storage of rough bars
heating
forging
cooling
Removal of defects
heating
swaging
heating
heating
heating
heating
squeezing
hot rolling
stamping on swinging machine
drop forging
Forging on back die
Forging on forging press
hot cutting
hot cutting
cutting
cutting
cooling
cold cutting
grinding
heat treatments
shot blasting
straightening
gauging
checking
shipping

Raw materials are stored, according to the category of steel and size, in an open yard equipped with a travelling crane.

b) <u>Checking and control</u>

The steel comes in bars and checks are made upon arrival of the weight, the size, the sections and the types of steel.
A visual inspection comes first, then a sample is sent to the control laboratory which measures the hardness with a Brinell Hardness Tester. A chemical analysis is then performed.

Furthermore, mechanical tests are carried out in order to control the resistance to tension and measure the resilience.

c) <u>Cutting to size</u>

The raw materials are transferred from the stockyard to the section responsible for cutting the slabs lengthwise in order to prepare the bars for the drop-forging operation. This is done by sawing, shearing and cutting on appropriate machines

B) Drop-forging

This operation requires a special work station with additional machinery and equipment:

- a heating furnace;
- a machine, for example, a drop-hammer on which the two dies are mounted;
- a deburring press whose capacity corresponds to the drop-hammer on which the deburring dies (male and female) are mounted.

In general, the following machines will be found in the forge shop:

- heating furnaces,
- forging hammers, possibly a maxipress,
- horizontal forging machines,
- deburring presses,
- gauging and straightening presses.

C) Finishing and heat treatment

The drop-forged parts are stored in a special yard for in-processing materials where they cool naturally.

a) Heat treatment before machining

After forging, the forged parts undergo a normalizing heat treatment in an annealing furnace.

b) Finishing

After heat treatment, the forged parts are shot blasted and ground. Some of them have to be straightened or sized: this is a forging or cold pressing operation which gives the part more precise dimensions

The finishing process ends with final control, during which hardness is tested.

Forged parts are then ready to be machined.

D) The tool shop

Forging tools are usually very heavy, i.e. from 1 to 3 tons, and therefore must be stored on the ground of the storeroom and handled by fork-lifters or travelling cranes.

Unlike foundry tooling which is made for the life span of a certain model, forging tools have to be renewed periodically. A forging tool can be used for about 10,000 to 20,000 simple parts and for about 2,000 to 5,000 complex parts.

The tool storeroom must therefore have a tool shop responsible for making new tools and renewing worn out tools. This tool shop will need conventional machining

equipment such as:
- planing machines,
- lathes,
- milling machines,
- surface grinding machines.

6.2 Investment in a drop-forging shop

6.2.1 The importance of parts forged for the automobile in the forging industry

Forged parts represent only a small part of the cost price of an automobile. This is why the forge shop also manufactures parts for other industries.

Apart from producing parts for the automobile industry, the forge shop produces forgings for other industries:
- industrial vehicle,
- tractor,
- agricultural machinery,
- heat engine,
- railroad material,
- hand tools, etc.

Drop-forging operations are analagous for all these industries, which makes investment for the manufacture of automobile parts more profitable as the machines may be depreciated over a much larger output.

For these reasons, it is quite difficult to distinguish what share of investment is devoted to the manufacture of automobile parts. Furthermore, certain engine parts may be manufactured either by forging or casting. This is the case of the crankshaft, the camshaft and the rocker arm. The decision will be taken by the engineering office of each manufacturer and will depend on the amount of development of the forging industry in the country under consideration.

In order to give a clearer picture, the following table presents a list of the mechanical parts of an automobile that may be manufactured by drop-forging; obviously, this list is not restrictive and is given only as an indication.

Unit	Part	No. of parts per vehicle	weight of part kg.	weight per vehicle kg.
Engine	Valve	8		
	Crankshaft	1		
	Camshaft	2		
	Rod-body	4	0.490	1.960
	Rod cap	4	0.334	1.336
	Rocker arm	8	0.075	0.600
	Clutch shaft			
Gearbox	Fork axle	4		
	Fork	4		
	Main shaft	1	1.460	1.460
	2nd gear idler pinion	1	0.940	0.940
	2nd and 3rd sliding gears	1	1.820	1.820
	Back sliding gear	1	1.050	1.050
	3rd idler gear	1	0.800	0.800
	4th idler pinion	1	0.950	0.950
	4th sliding gear	1	1.100	1.100
	Driving pinion	1	2.380	2.380
	Conical wheel	1	3.500	3.500
	Planetary	2	0.550	1.100
	Movable cone	1	0.140	0.140
	Synchro-ring	1	0.215	0.215
	Satellite	2		
Front axle	Front wheel hub	2	2.935	5.870
	Left stub axle holder	1	2.950	2.950
	Right stub axle holder	1	2.950	2.950
Steering	Steering coupling rod	2	0.480	0.960
	Rack cap	1	0.150	0.150

The forged parts of an automobile weigh about 50 to 70 kilos. Taking into account wastes and spare parts, this makes an annual total of 6,500 to 8,000 tons for an amount of 100,000 vehicles a year.

6.2.2 Breakdown of investment in a forge shop

It has been stated that tooling has to be renewed regularly, usually several times a year. Furthermore, according to the type of vehicle and manufacturer, certain parts can be obtained by forging or casting.

Under these circumstances, forging tool costs are regarded as manufacturing expenditure and not as investment and they can only be calculated for a given vehicle within the framework of a particular project.

Investment in a forge shop must then be divided into two categories:

- industrial buildings, and
- equipment and machinery.

General facilities, utilities, and administrative buildings are common to all the sections of the die-forging shop and cannot be assigned to the forge unit in charge of the manufacture of automobile parts. Furthermore, the forge shop is often associated with a foundry shop as their productions complement themselves. If such is the case, the chemical analysis and mechanical test laboratory will also be shared.

The investment in a forge shop may be subdivided as follows:

industrial buildings equipment and machinery	20 to 30% 80 to 70%
Total investment	100%

For the sake of information, it may be indicated that a forge shop supplying an automobile manufacturing plant with a production of 100,000 vehicles a year, occupies a roofed surface of about 7,000 to 10,000 m2.

The investment in equipment and machinery for the forge shop represents a small part in the total investment in equipment necessary for a complete automobile manufacturing plant, about 4 to 6%.

6.2.3 Relationship between investment and production

Total investment in a drop-forging shop for different production rates has been studied, but it was not always possible to isolate the part accounted for by the manufacture of automobile parts. Due to this, the information obtained is not really comparable.

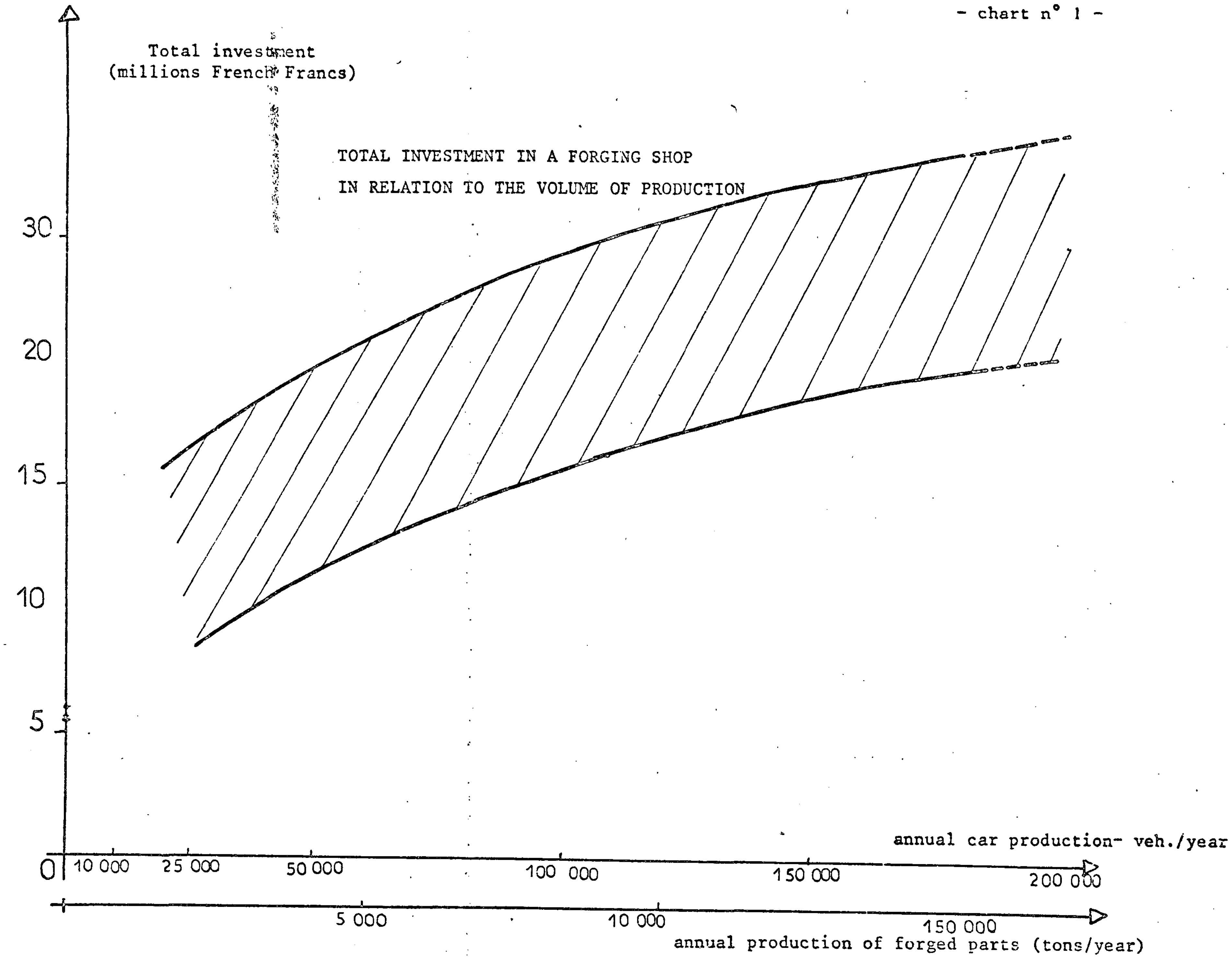
The result of this survey appears on Chart No. 1 which shows total investment in relation to output. Furthermore, Chart No. 2 shows the amount of labor required by the forge shop for different volumes of production.

A) The scale-up factor

Chart No. 1 shows that investment is less than proportional to the volume of production. Therefore, when production is doubled, from 50,000 to 100,000 vehicles a year, total investment is multiplied by about 1.5. This corresponds to a scale-up factor of about 0.58.

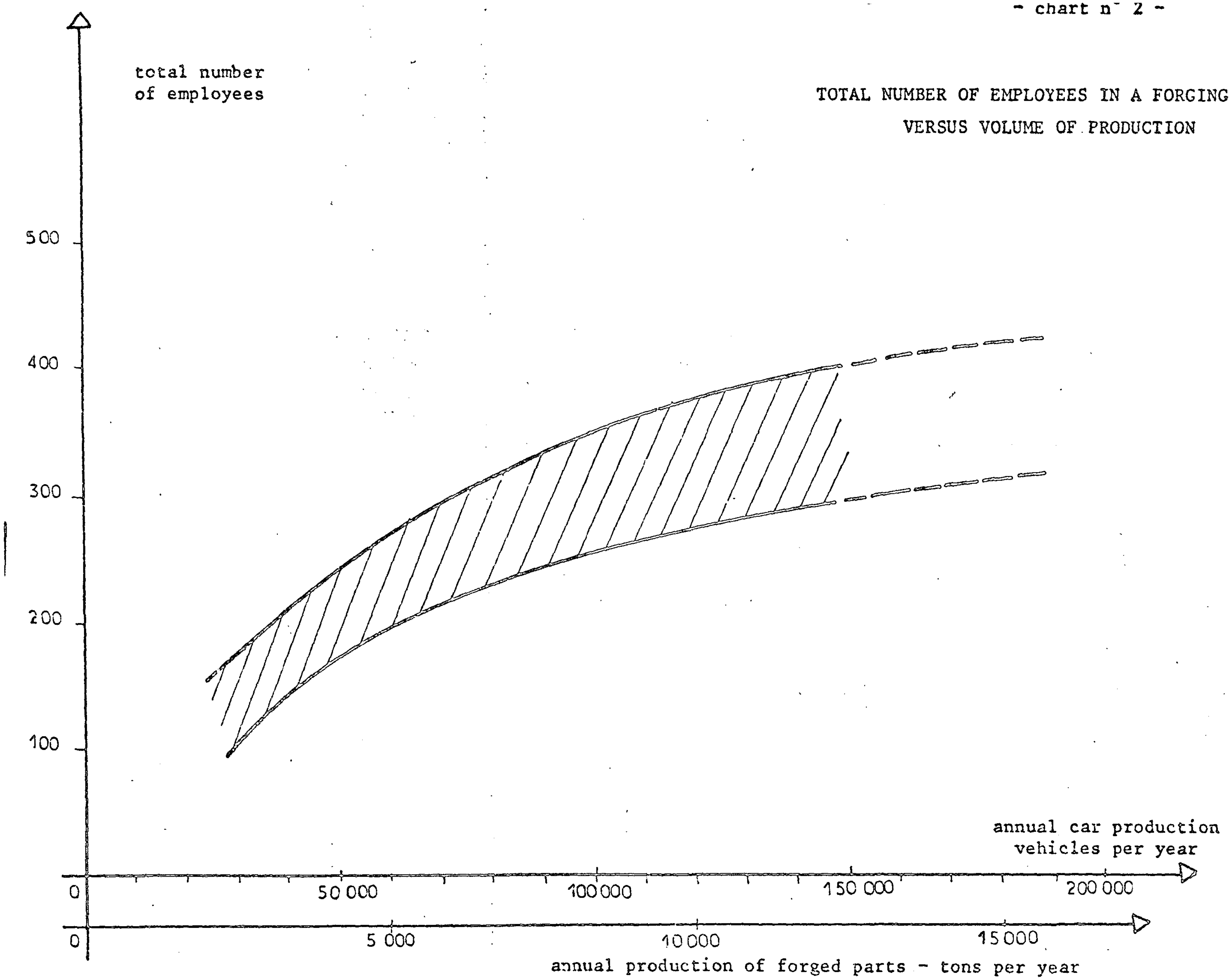
N.B. For the sake of information, it will be indicated that the cost of the forging tools for a medium-sized automobile is about 0.5 to 1 million French francs. However, it should be kept in mind that the tools must be renewed several times in the course of the year, for production in large series.

- chart n° 1 -


Total investment
(millions French Francs)
TOTAL INVESTMENT IN A FORGING SHOP
IN RELATION TO THE VOLUME OF PRODUCTION
30
20
15
10
5
0
10 000
25 000
50 000
100 000
150 000
200 000
annual car production- veh./year
5 000
10 000
150 000
annual production of forged parts (tons/year)

- chart n° 2 -

TOTAL NUMBER OF EMPLOYEES IN A FORGING SHOP
VERSUS VOLUME OF PRODUCTION



B) Effect of mechanization

For production in large series, i.e. about 100,000 vehicles a year, or about 8,500 tons of forged parts, the forge shop is equipped with work stations including:

- a puddle train,
- a vertical stamping press, possibly a maxipre
- a deburring, punching or hot gauging press.

Maxipresses with capacities up to 10,000 tons can manufacture the main forgings at a fast pace: crankshaft, wheel journal, etc. A maxipress may cost about 1.6 to 2 million francs and large-scale output would be required to depreciate this sum which nevertheless considerably reduces the time needed for certain forging operations.

For smaller rates, of about 10,000 to 100,000 vehicles a year, it is usually more economical to employ a forge-hammer machine. According to the type of part, and for levels of production of about 80,000 to 120,000 vehicles a year, either a forge-hammer or a maxipress may be chosen. The forge-hammer machine requires an operating overtime for some forged parts.

6.3 Cost of forging operations in relation to production

If the variation of the value added by the forge shop is analyzed in relation to the volume of production, the cost of drop-forging operations in relation to manufacturing rates may be inferred. The manufacturing price of certain forgings has been determined for the different volumes of production. These results appear on Chart No. 3 which shows the manufacturing overprices on the ordinate, and the volume of production on the abscissa. Base 0 of the overprices corresponds to the manufacturing cost of forgings in a European plant producing 300,000 vehicles a year.

It has been assumed that for output exceeding 100,000 vehicles a year, the forge shop is equipped with a maxipress.

6.3.1 Forging overprice in relation to production

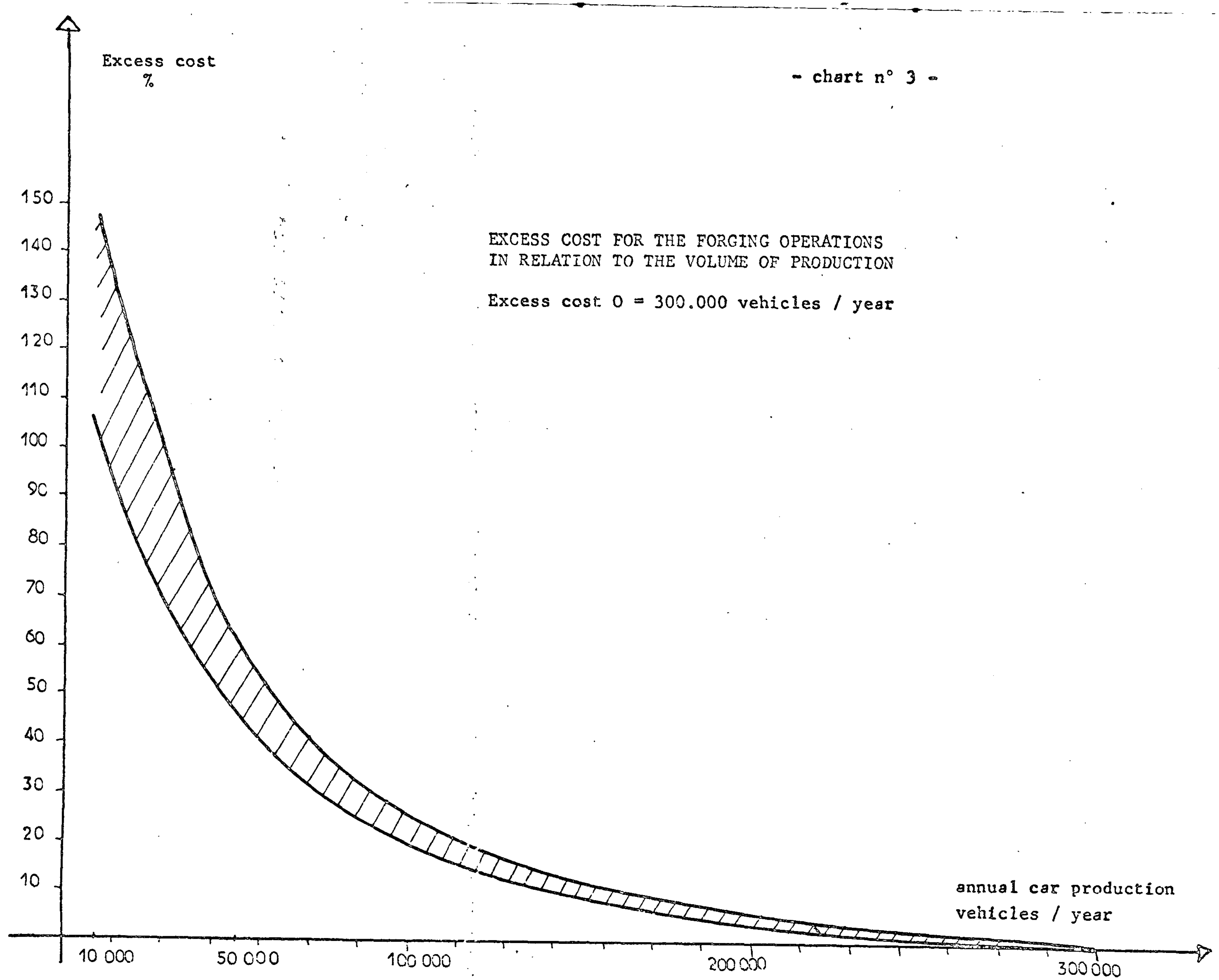
Chart No. 3 indicates that the overprice is very high for low rates, about 100 to 140% for 10,000 vehicles a year.

This overprice rapidly declines as the output increases, but is still at 20% for 100,000 vehicles a year.

- chart n° 3 -

EXCESS COST FOR THE FORGING OPERATIONS
IN RELATION TO THE VOLUME OF PRODUCTION

Excess cost 0 = 300.000 vehicles / year



The minimum cost would theoretically be obtained for 300,000 vehicles a year. However, it may be estimated that for more than 200,000 vehicles a year, the manufacturing overprice of forgings is practically negligeable.

6.3.2 Critical mass of the forging shop

It therefore seems that the critical mass of the forging shop is about 150,000 vehicles a year, i.e. 12,500 tons of forgings a year. For this level of production, the overprice is about 10%.

But if this annual figure of 12,500 is obtained by manufacturing parts for other industries, a higher overprice would have to be estimated because of the variety of the parts manufactured.

However, this overprice would not be very high as where there is a possibility to produce a high annual tonnage, the use of large-scale production equipment is justified; for example, a maxipress, which reduces manufacturing time.

6.3.3 The position of the forge shop in the industry of a given country.

It should thus be noted that a forge shop should not only be seen in the limited background of car manufacturing but, on the contrary, should be seen in relation to the development of all industries which are likely to use forged parts. This is why, in most cases, the forge shop is only integrated in the automobile manufacturing plant when output is higher than 50,000 vehicles a year. For lower volumes, forging operations very often are sub-contracted to the local forging industry. According to the degree of development of other connected industries (such as industrial vehicles, tractors, public work machinery, etc.) the overprice on the forged parts supplied to the automobile industry, will be high or low. However, if local conditions are favorable, the overprice may be relatively low, even where automobiles are produced on a small scale.

Chapter 7

Purchases of raw materials and supplies

Purchases of raw materials and supplies represent about 55% of the cost price of an automobile. Raw material purchases, that is, pig iron, steel, paint, etc. account for 15% of the cost of a vehicle and purchases from the sub-contractors and suppliers are about 40% of the cost price.

As a consequence, the cost price of a vehicle will be particularly sensitive to eventual excess costs in the purchase of raw materials and components, especially if there is a high degree of integration and if the volume of automobile production is small.

In this chapter the different raw materials employed by the automobile industry will be studied and the probable overprice in relation to the volume of automobile production will be indicated.

In a similar manner, the very numerous components purchased from other manufacturers will be reviewed and the overprice due to different volumes of production will be analyzed. In particular, the critical masses of the different industries responsible for supplying the automobile components will be given.

7.1 Purchases of raw materials and semi-finished products

The cost of the purchases must be considered differently in the case of raw materials to be processed by the manufacturer and in the case of components or assemblies that are to be directly incorporated in the vehicle without any further processing.

In the case of rough materials (raw materials and semi-products), the price will depend on how far the basic processing industry of the country under consideration is developed: iron and steel works, chemical industry, glass industry, etc.

For components and supplies that are not to undergo any further processing the price will depend on the level of development of the secondary processing industry in the manufacturing country. The price is then a function of the basic technologies employed in the manufacture of these components: forgings, castings, pressings, processing of plastics, welding, cutting, etc.

7.1.1 Classification of the raw materials used

Purchases of raw materials and semi-products represent about 15% of the cost price of a vehicle.

The following table shows the materials mainly used in the manufacture of an automobile. The example refers to a medium-sized vehicle.

Material	Weight (kgs.)
Cast iron	92
Cast steel	0.5
Steel in bars and wires for forging and machining	80
Alloy steel	25
Steel sheets and steel strips	440
Steel tube	10.5
Aluminum and alloys	20
Copper and alloys (not including electric wire)	1.2
Electric copper wire	98 m.
Glass	2 m2
Rubber	25
Plastics	16.5
Textiles	
Paint	20
Total	730.70 kg.

In addition to this the weight of the materials bought in the form of assemblies and components should be added to this breakdown, for example, zamak, for the carburator, steel for the screws, copper for the starter and the dynamo, lead for the battery, etc. All this represents less than 10% of the total weight of the vehicle, which, as has been seen in the above example, weighs about 800 kgs.

All of these items are not of equal importance. In particular, iron and steel products alone account for about 80% of the total weight of the vehicle. The breakdown of the weight of the raw materials used is given as a percentage of the total weight in the following table:

Material		% of total vehicle weight	
Cast iron		10 to 12%	77 to 86%
Steel	forging-machining	12 to 14%	
	sheets-tubes	55 to 60%	
Aluminum and alloys		2 to 3%	14 to 23%
Copper and alloys		~ 2%	
Lead		~ 1%	
Glass		3 to 4%	
Rubber		3 to 4%	
Plastics		3 to 4%	
Paint		2 to 3%	
Textiles		~ 1%	
Total weight of a vehicle		100%	

7.1.2 Investment in basic industries

Some data on investment and productivity ratios, as regards the raw materials used for the manufacture of a car, are given below.

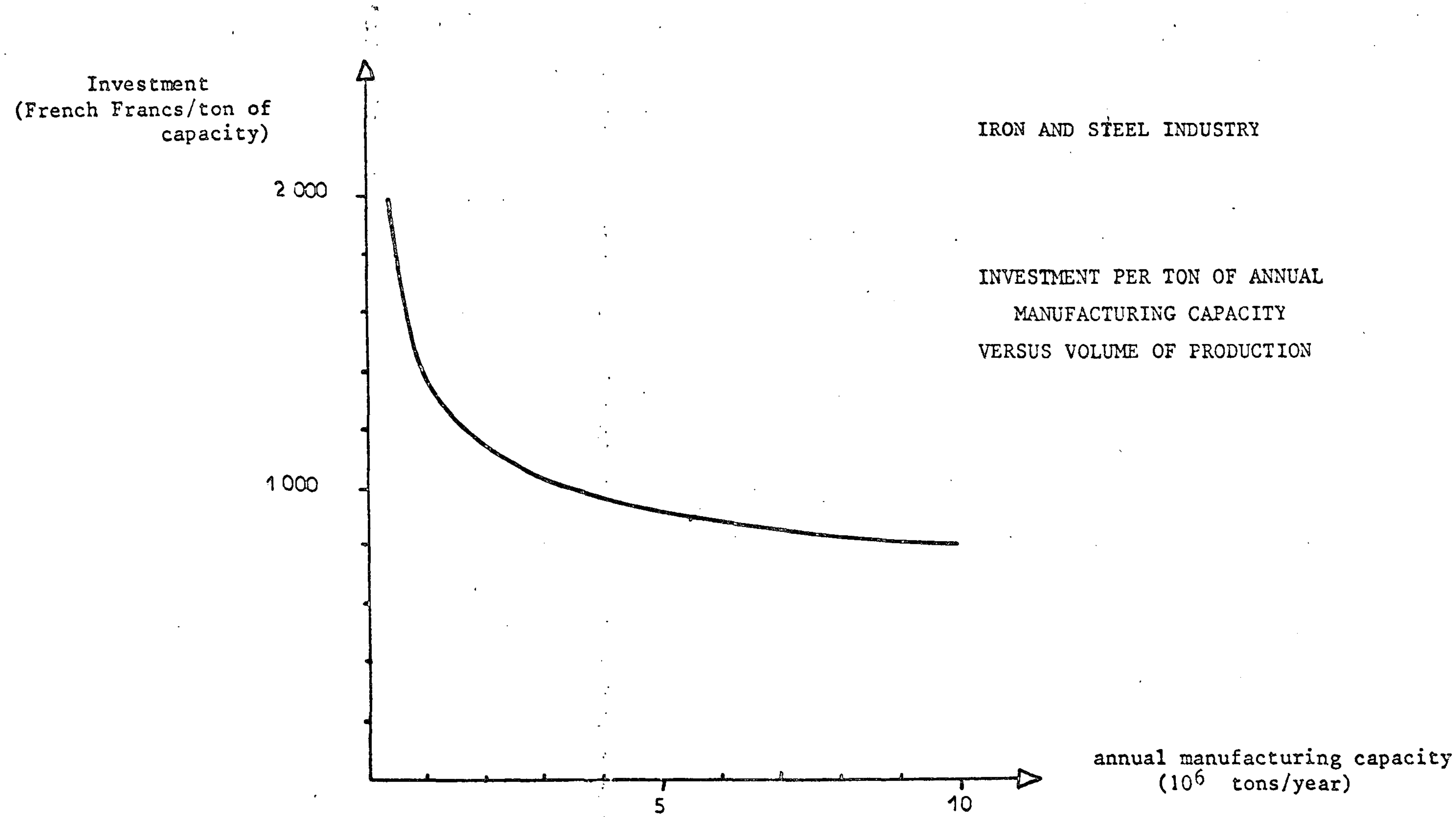
A) Iron and steel

Investment must be estimated at about 1,000 to 2,000 French francs per annual ton of capacity installed. Chart No. 1 shows the ratio of investment per ton in French francs in relation to the annual capacity installed.

As far as productivity is concerned, this may range between 100 and 200 tons per person employed, according to the level of industrial development of the country. For example, in France productivity amounts to 160 tons per employee.

Tubes are considered separately because they are not a direct product of the iron and steel industry; they require additional operations such as rolling and welding. In this case productivity is about 75 tons per employee per year.

- chart n° 1 -


Investment
(French Francs/ton of
capacity)
2 000
1 000
annual manufacturing capacity
(10^6 tons/year)
5
10
IRON AND STEEL INDUSTRY
INVESTMENT PER TON OF ANNUAL
MANUFACTURING CAPACITY
VERSUS VOLUME OF PRODUCTION

B). The production of non-ferrous metals

a) Aluminum

Investment would be equal to FF. 10,000 for each ton of annual capacity installed, in the case of small output. For large scale productions, the necessary amount is much smaller, i.e. 1,000 francs per ton for a total capacity of one thousand million tons, for example. Productivity in the aluminum industry is about 40 to 50 tons per employee a year.

b) Copper

As stated before, the share of copper bars in the manufacture of an automobile is somewhat small. On the other hand, wiredrawn copper continues to be important. Investment in the copper wiredrawing industry is about 50,000 francs per employee. Productivity is about 30 tons a year per person employed.

c) Lead

In the automobile industry, lead is mainly used for the battery (about 10 kgs. per vehicle).

Investment is estimated at about 50,000 francs per person employed and productivity may be calculated at about 20 tons per person employed per year.

C) The glass industry

The automobile industry mainly uses "Triplex" sandwich glass and tempered glass.

Investment in the glass industry is about 2,000 to 3,000 francs per ton of annual capacity. However, it must be stated that modern methods of producing flat glass require the use of float glass processes. In this case, investment is very high, about 200 million francs for the basic unit. When the conventional methods are used, productivity totals about 30 kg/per productive hour.

D) The chemical industry

Reference will be made to rubber and plastics which are of interest to the automobile industry. It is somewhat difficult to distinguish between the share of rubber and plastics and the other products of the chemical industry such as acids, spirits, etc.

Plastics probably represent 10% of the total production of the chemical industry. This industry usually demands very high investment and the labor force is rather small.

In order to give a few orders of magnitude, it may be considered that the investment in a steam cracking chemical plant is about 250 million francs.

For second generation products, such as plastic bars, paint, etc., investment in a manufacturing plant would be about 50 million francs.

These sums do not concern only the automobile industry, they will serve to supply most of the industries in a country. For example, the chemical industry could produce the necessary bases for the manufacture of the lacquers and varnishes used in the automobile industry. The latter would require additional investment of about one million francs for a capacity of 2,000 tons a year. Productivity in this sector is about 40 to 6o tons per person employed per year.

7.1.3 Variation of the cost of raw materials in relation to automobile production

A) Factors affecting the cost of raw materials

Considering the important share of ferrous products (cast iron and steel) in the purchase of raw materials (an average of 80%) it may be concluded that any variation in the cost of ferrous products will considerably influence the cost of raw materials in relation to output. Therefore, the overprices corresponding to iron and steel works, will be highly representative of the overprices of raw materials in general.

The price of ferrous products, in particular that of steel has been studied in several countries which have different levels of automobile production. By annual automobile production is understood the total production of automotive vehicles manufactured in a country in one year. Therefore, the number of models is not relevant in this case, as the raw materials used are identical.

However, it should be noted that the iron and steel industry of a given country cannot always manufacture all the varieties of steel used by the automobile industry; special steels for forging, or pressing sheets for the outer body parts, for example, have to be imported.

B) Purchase overprice for raw materials

The result of this analysis is found on Chart No. 2; the excess cost of the raw materials is shown on the ordinate and the annual automobile production on the abscissa.

a) Steel

Overprice 0 corresponds to the price of steel in Europe, that is, a minimum automobile production of 300,000 vehicles a year, whatever the number of vehicle models. It is not possible to give an overprice for an output of less than 10,000 vehicles a year because at this level there is usually no iron and steel industry in the country.

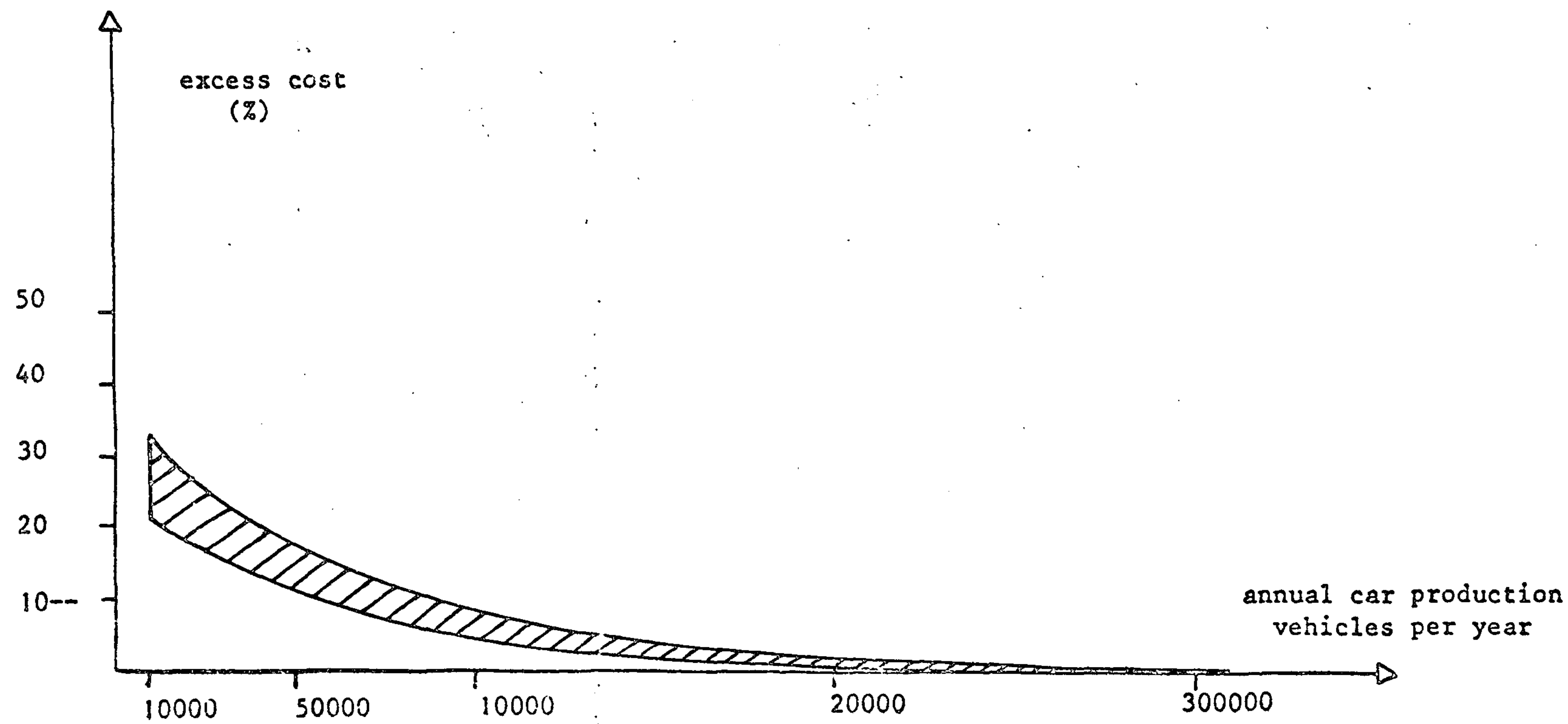
At a level of 10,000 vehicles a year, the overprice for raw materials is moderate: no more than 20 or 30%. The overprice falls rapidly and is only about 5% for a level of 100,000 vehicles a year.

b) Other raw materials

In addition to steel, the following overprices have been noted in the case

- chart n° 2 -

EXCESS COST ON THE PURCHASES OF RAW MATERIALS (STEEL)
IN RELATION WITH THE VOLUME OF AUTOMOBILE PRODUCTION



basis : excess cost 0 = European cost

of a country producing about 10,000 vehicles a year.

steel	15 to 25%
aluminum	20 to 25%
plastics	50 to 120%
paint	20 to 50%

7.2 Purchase of supplies, sub-contracting

7.2.1 The importance of sub-contracting in the automobile industry

The automobile industry is characterized by:

- increasing concentration of production;
- horizontal integration being preferred to vertical integration;
- the growing specialization of its sub-contractors.

A distinction should be made between the supplier who delivers a component in the form of an industrial product (dynamo, carburator, headlight) and the sub-contractor who sells a service (small machinings, small pressings, ...). A finished product is bought from the first one while in the second case, the manufacturing equipment of the sub-contractor is used.

Sub-contracting offers the automobile manufacturer certain advantages that may be summarized as follows:

- Satisfactory products at a lower price (specialized tooling, smaller overheads);
- Better return on capital invested which may be directed to other more profitable uses or devoted to operations more directly connected with automobile manufacturing (machining of mechanical units, pressing);
- Competition between the sub-contractor and the automobile manufacturer on the one hand and between the subcontractors themselves on the other.

In these conditions, the sub-contractor who supplies units or components is always a specialist producing a particular product. In order to give some additional information, Table No. 1 shows the main suppliers of components in Europe; they all hold an excellent position on the world market for automobile supplies, directly or through their network of subsidiaries, or through their authorized dealers.

Table No. 1

Main world suppliers of components for the automobile industry

Country	West Germany	France	Italy	Great Britain	United States
Piston	MAHLE	FLOQUET	BORGE	ASSOCIATED ENG.	
Carburator	SOLEX	SOLEX	WEBER		
Radiator	BEHR	CHAUSSON	FIRA IPRA	PRESSWORK	BORG-WARNER
Battery	BOSCH VARTA	DUCELLIER FULMEN TUDOR			
Electric equipment	BOSCH	PARIS-RHONE DUCELLIER	MARELLI	LUCAS	MOTOROLA PRESTOLITE
Clutch		FERODO		BORG & BERG	
Transmission				SPICER	BORG-WARNER
Steering					THOMSON RAMCO
Brakes	PERROT	BENDIX LOCKHEED	FERODO	LOCKHEED	BENDIX
Ball bearings	SKF	SKF SNR	RIV SKF		BORG-WARNER TIMKEN
Wheel	KRONPRINZ	DUNLOP MICHELIN		DUNLOP KELSEY SANKEY	FIRESTONE KELSEY
Tires	CONTINENTAL	MICHELIN	PIRELLI MICHELIN	DUNLOP	GOODYEAR GOODRICH FIRESTONE
Shock absorber	BOGE	ALLINQUANT			GABRIEL MONROE
Dashboard instruments	V.D.O.	JAEGER	BORLETTI	SMITH & SONS	
Air control temperature		SOFICA		SMITH & SONS	
Windshield window panes		B.S.N. ST. GOBAIN	ST.GOBAIN	TRIPLEX	

7.2.2 Classification of the main components purchased from suppliers

A wide variety of techniques are used in the production of the components that an automobile manufacturer purchases from local industry.

For further information, Table No. 2 shows the different techniques used to make the main components. If each technique used in the production of a component is studied from the point of view of its effect on the cost price of the component, the result will be a classification of those techniques according to their share in the total purchases. These results are shown on Table No. 3

Table No. 2

Classification of the Techniques Used in the Manufacture of the Main Purchased Components

Component	Cost of Production (approx. % of vehicle price)	Foundry	Forge	Machining	Cutting Pressing Welding	Rubber or Plastics	Observations
Piston	∼ 0.5	x		xx			
Piston ring	≪ 0.5	x		x			
Chain	< 0.5		x				
Belt	< 0.5					x	rubber coating
Pinion	< 0.5		x				
Pulley	< 0.5				x		
Carburator	0.5 to 1	xx		x			

Component	Cost of Production (approx. % of vehicle price)	Foundry	Forge	Machining	Cutting Pressing Welding	Rubber or Plastics	Observations
Gasoline pump	< 0.5	xx		x			
Filter	≪ 0.5				x		
Radiator	2 to 2.5				x		
Battery	1 to 1.5					x	⌿ lead
Starter	1 to 1.5	x		x	x		⌿ coiling
Dynamo/alternator	~ 1	x		x	x		⌿ coiling
Igniter	~ 0.5			x		x	
Ignition coil	< 0.5					x	⌿ coiling
Spark plug	≪ 0.5		x				⌿ ceramics
Electric wire	~ 0.5		x			x	wiredrawing
Wheels	1 to 1.5				x		
Trimmings	< 0.5				x		chromium plating
Tire	4 to 5					x	
Tire tube	~ 0.5					x	
Shock absorber	~ 1			xx	x		
Suspension springs	~ 0.5		x				
hboard truments	0.5 to 1			xx			
light [illegible]	< 0.5					x	
& temperature trol	~ 1			x	x	x	
dlight	~ 0.5				x		⌿ glass
rn	< 0.5				x	x	
Windshield wiper	0.5 to 1				x	x	
Windshield washer	~ 0.5			x		x	

›mponent	Cost of Production (approx. % of vehicle price)	Foundry	Forge	Machining	Cutting Pressing Welding	Rubber or Plastics*	Observations
ndshield	1 to 1.5						glass
ndow panes	$\sim$0.5						glass
oor mat	< 0.5					x	≠ textiles
at stuffing	0.5 to 1					x	
mper	1 to 1.5				x		≠ chromium plating
:ks	$\sim$ 0.5				x		
ɔl kit	< 0.5		x		x		
l1 bearing	2 to 3		x	xx			
ıll spring	< 0.5						wiredrawing
:al wire	< 0.5						wiredrawing
:s & bolts	0.5 to 1		x				
.p	$\sim$ 0.5				x		
.ls and rubber .ips	$\sim$ 0.5				x	x	
ıi- ducts (Sheets) (Tubes) (Bars) erials (cast iron) (steel) (aluminum)	12 to 14						

Plastics will be analyzed in detail in Chapter 8.

Table No. 3

Classification of purchases according to the technologies to make them

Technology	% of the total value of purchases
Iron and steel works (raw materials and semi-products)	25
Non-ferrous castings (aluminum and zinc alloys)	5
Forging	4
Machining	18
Cutting, pressing, welding	20
Processing of plastics	10
Chemical industry and processing of rubber	10
Processing of glass	8
Total value of purchases	100

7.2.3 Overprices in the purchase of components

From Table No. 3 it is clear that the majority of the components or units made of metal are the result of machining or cutting-pressing techniques. The price of the components will then depend on how far these techniques are developed in the country under consideration.

Following this concept, the overprice curves for the components purchased may be plotted in relation to the volume of production. This is shown on Chart No. 3.

This Chart shows the average overprice in the purchase of supplies according to the volume produced.

It will be noticed that the manufacturing techniques studied, that is, those necessary for the manufacture of the different components of a vehicle, may have different critical masses. This means that the overprices caused by low output for given components do not modify in a similar way the overprice for all the components of a vehicle, in relation to automobile production.

A) Low rates

For less than 10,000 vehicles a year, the overprice of the purchases is very high, about 70 to 120%.

B) Medium rates

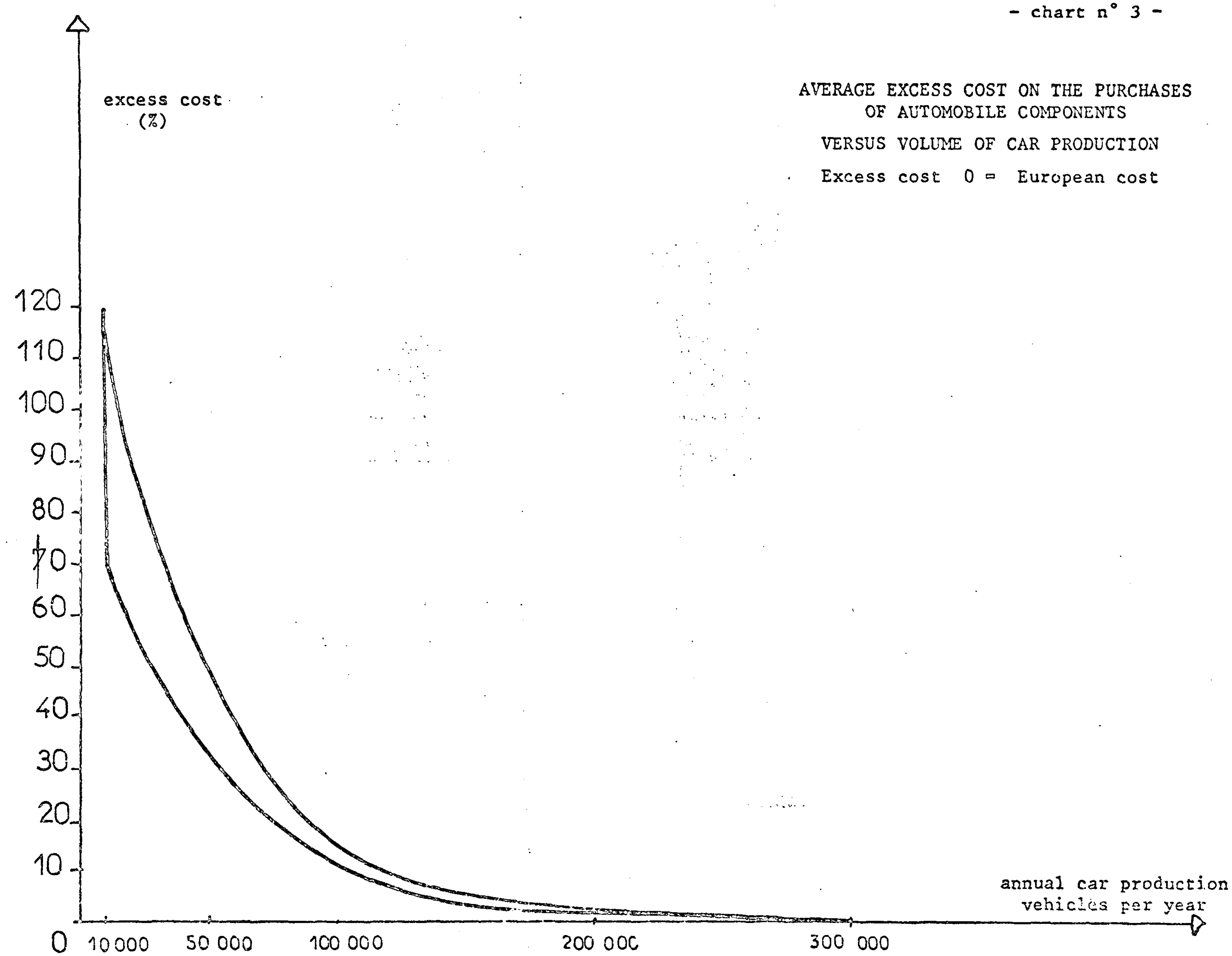
For about 50,000 vehicles a year, the overprice is still 40%.

- chart n° 3 -

AVERAGE EXCESS COST ON THE PURCHASES
OF AUTOMOBILE COMPONENTS

VERSUS VOLUME OF CAR PRODUCTION

Excess cost 0 = European cost



C) <u>High rates</u>

For 100,000 vehicles a year, the overprice of the purchases is small, about 10%; it then decreases rapidly and becomes negligeable for about 200,000 vehicles a year.

7.2.4 Critical production masses for the main components

It has been observed that according to the techniques used, the overprices of a given component in relation to the volume produced may be considerably different. In order to bring this out more clearly, Table No. 4 shows the critical masses for the main components of a vehicle.

Table No. 4

Order of magnitude of the critical masses of different components purchased by the manufacturer

Components	Critical production mass units/year
Piston	200,000 to 250,000
Radiator	15,000
Clutch	60,000
Brake lining	500,000
Wheel	150,000
Tire	300,000
Suspension spring	100,000
Shock absorber	80,000
Seat framework	15,000 to 20,000
Battery	30,000
Dyanamo	100,000
Starter	100,000
Ignition coil	30,000
Horn	30,000
Windshield wiper	120,000
Headlight	120,000
Spark plug	500,000
Dashboard	120,000

7.3 Importance of the local manufacture of components for the automobile industry

7.3.1 Advantages found in the local manufacture of components

The local manufacture of components for the automobile industry opens up many opportunities for diversification in the industry of a country. Very often, there is a wide variety of techniques used which are not peculiar to the automobile industry. Therefore, a two-fold return on investment may be expected, both as regards the training of the labor and the equipment installed which makes parts for several industries other than the automobile industry.

The classification of the components according to the manufacturing techniques used for them may be modified in order to show the products which rely on the same techniques and which could be manufactured in a parallel manner, so offering a good chance to diversify. This new classification is shown on Table No. 5.

Table No. 5

Diversification opportunities offered by the industry of automobile components

Techniques required	Products	Examples of possible parallel manufactures
Casting of non-ferrous alloys	Pistons	Hardware, household apparatus, housings and bodies for household appliances, electric motors (flanges and castings) housing for sewing machines, office machines, scales, electric hand tools ...
Powder metallurgy	Gears for oil pump, shock absorber, pistons locksmith parts self-oiling rings	Polar parts for electric motors, parts for office machines, household appliances, locks, fire arms
Light forging, upsetting	valves	Clack valves,
Extrusion	shock absorbers	Hydraulic jacks, bottles of compressed gas
Cold rolling	rocker arm impeller, spark plug socket	Standard nuts & bolts
Cold cambering	on wire: valve springs on tube: brake circuit, seat framework	All ordinary coil springs Tube circuits for boilers or domestic refrigerators, Office furniture made of tubes
Hot cambering	helicoidal springs	Wagon springs

Techniques required	Products	Examples of possible parallel manufactures
Cutting, pressing forming, welding	body locks hinges window mechanism	Household appliances, locks for appartments, and furniture, parts of electric motors, electriccontacts, metal furniture
	radiator	refrigerator
	fuel tank, air and oil filter, muffler	barrels and small containers packaging
	wheels	barrels and drums, gas bottles, fire extinguishers
Cutting, coiling	starters, dynamos, windshield wipers, air and temperature controls, horn	¼ and 1 HP electric motors small hand tools, household appliances
Coiling, moulding of plastics	igniters, coils, tension regulators	electric transformers
Cutting, delicate work assembly	dashboard brake, clutch	Precision mechanical work Industrial clockwork, meters Hoisting material (winch)
Processing of plastics	<u>injection</u>	Industrial parts for household appliances; radio and electricity, especially.
	<u>Extrusion</u>: electric cables <u>Blowing</u>: brake fluid container, windshield water tank, gasoline tank	electric insulation bottles, containers

Techniques required	Products	Examples of possible parallel manufactures
Processing of plastics	Heat forming: door lining	Inside lining for refrigerator door
	Calendering, coating: floor mats seat, roof and door lining	Carpets coated textiles rain coats, tablecloths, curtains
	Foam: seat stuffing	Foam mattresses seats
Rubber	tires tire tubes	
	rubber parts: seals	Industrial rubber parts
Flat glass	Cutting and tempering of glass Bent windshields	Bent and tempered glass for industrial and domestic uses

Table No. 5 indicates that the making of a certain component might further allow the development of another product, but this does not imply that the same machines or tools are used; it only means that the same techniques are used, and that they could therefore be adopted for the manufacture of other products.

In addition to this, although the automobile industry promotes the manufacture of new products in a developing country, the opposite is not true, therefore, if such manufactures exist they cannot always be used by the automobile industry. For example, an automobile locksmith shop can easily enlarge its activities and manufacture locks for appartments and furniture, whereas a locksmith for the building industry will not be capable of manufacturing car locks because he will not be up to the specifications required.

The existence of an automobile industry in an industrializing country may be a springboard for many other activities: in particular (although this list should not by any means be considered exhaustive) the following:

- non-ferrous castings,
- forged tools,
- household appliances and cooking apparatus made by pressing,
- furniture and seats made of tubes,
- electric motors,
- nuts & bolts, etc.

7,3.2 Problems arising from local manufacture of components for low rates of production

A) Prices

The prices of the supplies which are purchased are the result of two factors:

1) the national output of all types of vehicles: automobiles, trucks, tractors, motorcycles and bicycles;
2) the quantity consumed by automobile production.

It has been observed that for 100,000 vehicles a year, the overprice was only 10%.

However, as far as the parts produced by casting, forging, machining and processing of plastics is concerned, the overprices are high for outputs of 10,000 vehicles a year.

In the case of glass or plastics, an economical level of production is attained with a figure of 100,000 vehicles a year. But at this level electric equipment is still expensive, especially if the household appliance industry is not very developed.

B) Quality

Local suppliers can produce quality goods, but this is not always certain in the case of low rates of production as certain control facilities may be lacking.

C) Delivery terms

It is extremely important to keep up with delivery dates and this is not always true of local production and so the assembly plant is forced to keep large stocks.

Furthermore, there is often only one manufacturer of a certain component. This situation is acceptable in the initial period but in order to ensure a regular supply, it is preferable to diversify the purchases between at least two suppliers. Would it not be the case then stocks have to be built up with a consequent increase in the cost price of the vehicle.

Chapter 8

New Techniques in the Automobile Industry

8.1 New possibilities: plastics

8.1.1 General uses and tendencies

A) Specific average consumption

Every European vehicle produced in large-series contains about 30 kg. of plastics (*) distributed among several hundreds of parts (200 to 500; 540 in the FIAT 128).

This weight only represents 2 to 3% of the total weight of the vehicle, but lightens it of about 200 kg. of metal; it is well known that every kilo represents an average saving of 3 francs on the size of the mechanical part (engine and suspension).

Furthermore, in terms of volume, plastic parts represent 10 to 15% of the volume of a vehicle.

Finally, a study of the chart in Annex 1, showing the progress of plastics in the American automobile, will reveal that the European manufacturers are well ahead of the

(*) Only the main categories of plastics have been considered, so that synthetic fibers, elastomeres, paints, varnishes, adhesives and mastics are excluded.

Detroit manufacturers, especially as the average USA vehicle is twice as heavy as its European counterpart.

However, the following annual consumption per vehicle has been calculated for the future in the USA:

Year	Kg/automobile
1970	45
1975	100
1980	150
1985	200

Therefore, considering this specific future consumption, automobile manufacturers are expected to integrate in their manufacturing processes part of their own requirements for plastic parts. As the weight of plastics per vehicle increases and, as a result, the corresponding share in turnover, it is only natural that the manufacturers first want to learn a technique with which they are not familiar (this is the stage at which the pilot shop controls the supplier's cost prices), and then regain control of the percentage of turnover they would lose for the parts which they do not wish to sub-contract (body, radiator, grille, gasoline tank, even the dashboard).

CHRYSLER, FORD, and GENERAL MOTORS in the USA, and FIAT, RENAULT, and VOLKSWAGEN in Europe, thus have their own plastic manufacturing plants.

B) Plastics and the automobile

There are certain obstacles that prevent the use of plastics in the automobile, in particular:

- the fact that the training of project engineers and designers is oriented mainly towards metals (there are no or very few courses on the technology of plastics in the engineering schools);
- the large sums invested by the manufacturers in the processing of metals (machining and pressing, for example);
- the time needed to elaborate a model, about 5 or 6 years, as is shown in the following example:

Beginning of 1963	Specifications
February to end September 1963	Preliminary draft
October 1963 to April 1964	Study of the scale model
February 1964	The first blue-prints are worked out
November 1963 to January 1965	Scale-models are manufactured and assembled
March 1964 to March 1965	Technical tests of the units
February 1965	Preparation of the second detailed blue-prints to make the proto-type
September 1965 to February 1966	Static tests of the first proto-type
October 1965	The endurance tests of the 5 proto-types begin
Between March 1966 to June 1968	35 more proto-types are built
December 1966	Decision to enlarge the body
June 1967	Preparation of the toolings
May 1968	The test series comes out
July 1968	Final specifications
March 1969	Production of the first standard vehicles
June 1969	Mass production begins
October 1969	Marketing begins

Because of this, the cost prices which determine the choice are established on the basis of data which, in the case of plastics, are no longer valid when marketing begins.

- marketing campaigns favor inappropriate applications which trigger off anti-plastics reactions or confuse the user who is torn between several brands of the same family of plastics;
- the need to use materials which must hold good until the vehicle becomes obsolete (10 to 20 years) and can, for export reasons, withstand different climates (temperature, dampness, ...)

The temperature requirements, in particular, cannot be disregarded in the case of plastics used in the automobile, as is shown on the following table:

Unit	Part	Maximum Temperature (C)
Mechanical	top of water radiator	115
	carburator	100
	main cylinder	100
Outer body	top hull, hood	75
	side panels	65
Interior of passenger compartment	dashboard	105
	sun visor	100
	seat	85
	steering wheel	80
	inside of doors	70
	pedals	55

These maximum temperatures may be obtained in hot countries after switching off the engine in the case of the mechanical units under the hood, and after 8 hours in the sun in the case of the body parts and passenger compartment. One must also bear in mind that certain manufacturers have touch-up paint lines through which a fully equipped vehicle may pass. All of the components of the vehicle must then be able to support a temperature of 80 to 90 deg. C. during approximately 30 minutes. In spite of the disadvantages mentioned, the choice of a synthetic material is necessary for the automobile in many cases, for example in order to:

- reduce its weight and price: as far as weight is concerned, this the general case, due to the low density of plastics and also as regards prices, as it may be possible to design complex parts which can be manufactured in a very short time.
- improve the performance:
  - . diminution of sound level: gears of the mechanism of the speedometer and the windshield wiper, locks;
  - . comfort of foam seats;
  - . better appearance: dashboard, radiator grille, trimmings;

- greater safety: stuffing of dashboard elbow rest, steering wheel, gasoline tank;
- improvement of the friction coefficients of the bearings, as indicated below:

Material	Friction coefficient	
	Dry	Oiled
High density polyethylene	0.21	0.1
Polyacetal	0.10 to 0.30	0.1
Polyamide	0.15 to 0.40	0.06
Polyfluor	0.04	0.04

C) Usual applications

The average distribution of plastic applications for the automobile in Europe is roughly as follows for 1970:

Materials		% (weight)	Evolution (tendency ↗ or -)
Styrenic:	Polystyrene-PS, copolymere SAN and ABS	5 to 10	↗
Polyvinyl:	Plastified PVC especially	30 to 35	
Polyolefines:	Polypropylene-PP and high density polyethylene PE hd	5 to 10	↗
Acrylics:	Methyl polymetacrylate PMM	2 to 3	
Polyacetals:	PAC	0.5 to 1	
Polyamides:	PA-6 and PA-11	2 to 4	↗
Cellulosic:	Cellulose acetobutyrate ABC	3 to 4	-
Phenolic plastic:		2 to 8	-
Polyurethanes:	PU	30 to 35	↗

Preferential applications are given in outline form in the following tables:

a) <u>Mechanical and electric driving units (the engine and its related parts)</u>

Parts	Materials								Observations
	PS	PVC plastified	PE hd	PP	PAC	PA	PFE	Phenolic	
Fan box				x					
Fan				x	/	x			
Transmission gear					x	x		/	
Water pump parts						x			PRO possible
Gasoline pump parts						x			
Gasoline pipe						x			PA-11 mainly
Carburator parts						x			
Air filter			/	x					
Filter cartridge		x							PVC rigid
Windshield water container		x	x						(flexible:PVC (rigid: PE
Brake fluid container			x						
Gasoline tank			x						
Gears for the speedometer and windshield wiper					x	x			PPO also
Pedal parts				x					for accelerator (PP
Shock absorber bellow			x						
Battery housing	/			x					inside: PS possible; outside: PP
Top of igniter								x	
Ignition coil cover								x	
Fuse box				/				x	
Wire insulation		x							
Miscellaneous rings and bearings						x	x		

b) Outer body parts

Parts	Materials											Remarks
	PS	SAN	ABS	PVC plastified	PE hd	PP	PMM	PC	PA	Phenolic	Reinforced polyester	
Hull, hood, and fender parts			x								x	*(1)
Radiator grille			x			x						
Monogram	x	x	x				x					
Licence plates			x									
Hub-cap			x									
Horn						x						
Headlight rim			x									
Headlight reflector									x			*(2)
Rear lights		x	x				x	x				
Parking light		x										
Joints, seals sections				x								
Locksmith parts									x			* (3)
Tank cap					/					x		
Miscellaneous rivets and clamps									x			

*(1) ABS "Mehari", polyester: sports car

*(2) TPX possible for parabole shape

* (3) or PAC

c) Inner body parts

Parts	Materials											Remarks
	PS	SAN	ABS	PVC plastified	PE hd	PP	PMM	PA	ABC	Phenolic	PU	
Steering wheel						/			x		/	
Miscellaneous housings			x		x	x						
Dashboard			x			x						*(1)
Headlight switch			x			x				x		*(2)
Dashboard visor			x			x			x		/	
Sun visor				x							/	
Glove compartment					x							
Lower part of door					x	/						
Rear mirror					x	/						
Inside light	/						x					
Ash tray										x		
Knobs, levers	/	/	x			/			x			
Air regulator casing						x				x		
Hot air pipe					/	x						
Deflector			/		x	x						
Seat											x	
Safety belt								x				*(3)
Handle			/					x				*(4)
Elbow rest				x							x	
Floor mat				x	/							
Underneath of roof				x							/	
Door lining				x							/	
Hood of convertible				/								

*(1) or PVC /ABS thermoformed

*(2) PTE for printed circuit

*(3) PA buckle

*(4) or PAC

The plastics which are to be developed on a large scale in the automobile industry include:

- ABS particularly as appearance and body parts;
- high density polyethylenes especially as hollow blown bodies;
- polypropylenes whose behavior when heated is up to automobile requirements in satisfactory economic conditions;
- polyamides moulded by injection which can be substituted for non-ferrous alloys cast under pressure, especially if they are reinforced by fiberglass;
- polyurethanes because of the confort they provide thanks to their honeycomb shape and the possibility of obtaining a rigid skin with a cellular core.

D) New and future applications

There are many potential applications of plastics in car manufacturing, but we shall consider only those which, because of the quantity of plastics used, may strongly influence the development of the processing industries of those materials. They include utilizations for the following parts:

Part	Weight (kg.)
Tank	2 to 4
Battery housing	1 to 1.5
Dashboard	0.8 to 1
Inside of door (2 or 4)	0.5
Radiator grille	0.7 to 0.8
Body	50 to 100

a) The gasoline tank

Apparently the material chosen is high density polyethylene and the procedure selected is blowing.
This tank would allow flexible adaptation of forms unlike the metal sheets, and could be placed in "dead" and protected spots (following the shape of the rear axle or of the suspension, under the seats, in the luggage trunk ...). The risk is lessened in the case of an accident: this material has good shock resistance and is deformed while the welding of a metal tank tends to give way so that the gasoline flows out. Furthermore, in the case of fire, plastic melts thus avoiding the blowpipe effect or the explosion caused by a metal tank. Finally, the reduction in weight must be mentioned, i.e. about 40 to 60% of the weight of a tank made out of leaded steel sheets, of similar capacity. In the future, costs may be reduced (the blowing technique takes less time than the pressing of two shells followed by roll welding).

The following examples may be mentioned:

Procedure	Vehicle
Blowing	Trucks in the USA CHEVROLET "Corvet" FORD "Thunderbird" PONTIAC 70 CITROEN S.M. PORSCHE submitted to tests in France: CITROEN 3 HP PEUGEOT RENAULT SIMCA
Rotation is also possible	KAISER "Jeep"

In these applications the weight saving is about 10 kg. in comparison with the steel sheet.

b) <u>Battery housing</u>

In this case the following conditions are sought: an excellent resistance to sulphuric acid and to shock, absence of deformation resulting from temperature, satisfactory behavior in the face of gasolin and oils, lightness, and, possibly, visibility of the electrolyte. All this at a reduced cost.

Thus two materials have been selected to meet these requirements (in the injected form):

- polypropylene when the battery is under the hood or in the luggage trunk;
- polystyrene when the battery is in the passenger compartment.

Present achievements:

Material	Brand names or countries
Polypropylene	United States and Italy starting in France (Compagnie Française d'Electrochimie)
Polysterene	NSU "Prinz" VOLKSWAGEN

The weighted gain is about 1.5 to 2 kg. For a 6V battery and with ordinary materias the weight would be as follows:

Material	Weight (Kg.)
Pitch	4.5
Ebonite	2.7
PS or PP	1.2

It has been estimated that 15% of all battery housings will be plastic in 1970 60% in 1975.

c) <u>Dashboard, inside of door, radiator grille hub cap</u>

Plastics are used for these parts mainly because costs can be reduced, shapes diversified, and considerable attractiveness achieved. Two materials have been chosen due to their effective resistance to shock and because theycan be chromium-plated for radiator grilles and hub-caps: the ABS and the polypropylene:

- dashboard: for example, CITROEN "Dyane", RENAULT 4, ...;
- inside of door: CITROEN "Dyane";
- radiator grille: see the following table:

Materials	Brand Names
ABS painted (*) or black pigmented	American vehicles BMW 2500 DAF 55 PEUGEOT 504 RENAULT R6
ABS chromium-plated	DODGE Barracuda FORD 20
POLYPROPYLENE	American and Japanese vehicles RENAULT R12

(*) There is no point in painting the radiator grilles. It would be a much better idea to give them a color which sharply contrasts with the body.

- hub cap: beginning in the USA and Italy

d) Body

The specific consumption rates indicated above only refer to conventional vehicles because for many years some vehicles have had bodies which are entirely plastic: ALPINE, CORVETTE, MATRA, OPEL GT ... These are made out of plastic reinforced with fiberglass containing more than 100 kg. of thermosetting resin plus fiberglass. More recently, there have been vehicles made with heat formed thermoplastic bodies. But up to now these vehicles have been manufactured on a small scale.

The following table gives the details of these products:

Brand Name	Material	Group	Procedure	Body weight	Production vehicles/year
ALPINE	polyester/glass	Thermosetting	contact	120	400 to 500 (France and Mexico)
MATRA	epoxy/glass	Thermosetting	(manual)	-	2,000 to 2,500
CHEVROLET "Corvet" roof for CITROEN DS	polyester/glass	Thermosetting	pressing (machine)	100 6 to 7	about 20,000
CITROEN "Mehari"	ABS	Thermo plastic	heat forming (machine)	65	about 15,000 (an increasing production)
VW "Beetle"	AAS	Thermo plastic		60	starting

It is now estimated that the threshold of economic production would represent the following number of vehicles/day:

- Contact reinforced plastic	10 to 20
- Pressed reinforced plastic	50 to 100
- Heat formed plastic	20 to 200
- Pressed steel sheet	200

Thus, in the intermediate area there may be competition between a body made out of pressed reinforced plastic and a body with heat formed parts. But the former requires more expensive moulds than the latter and more time is needed for its manufacture. Furthermore, standard colors are not so sun-resistent as those obtained with thermoplastics, so that the former have to be painted while the latter will keep their own color. Therefore, it is quite possible that in the future heat formed plastics will be preferred, as in the case of CITROEN (there was a precedent in the USA, a small amphibious engine for hunting and fishing, the "Amphicat"). Recently, VW launched a somewhat similar vehicle and others -about ten- are now being prepared in Great Britain, the United States (AMERICAN MOTORS "Forma Car"), Japan (the HONDA vehicle already has some body parts in thermoplastics) and France.

Because of the importance of this possible application of plastics in automobile bodies, further details of these techniques will be furnished in part 8.1.2.

8.1.2 Technology - Investment and manufacturing costs

Plastics can be divided into two main categories: thermoplastics (cold set and with a certain plasticity at room temperature) and thermosetting (hot set and very rigid).

The processing of each type is very different. Basically, the differences may be summarized as follows:

Type	Mould	Reaction during moulding	Moulding time	Wastes
Thermoplastic	cold	none	a few seconds	reusable
Thermosetting	hot	polymerization	about a minute	lost

Consequently, each category will be examined separately but it becomes immediately apparent that thermoplastics will always be preferable -when this is functionally possible- if only because of cost prices.

A) Thermoplastics

a) Injection (Sketch 2-a in the annex)

Under the two-fold effect of pressure (piston or screw) and temperature (heating resistance), the plastic granules are melted and plasticized in the transfer chamber of the injection press. Then, the piston (or the head of the screw) pushes the plasticized material through a feeding duct in order to fill in the imprint of the mould as quickly as possible. As soon as the plastic comes into contact with the relatively cold walls of the mould it coagulates and the part may then be withdrawn.

i - advantages:

. considerable homogeneity and precision of finished products;

. high output and therefore low prices for manufactured products.

ii- disadvantages:

. expensive moulds and therefore a high threshold of production because of depreciation.

An injection press is similar in technology to a pressure casting machine for non-ferrous alloys.

Its characteristics are as follows:

iii-capacity

From a few grams up to 20 kg., although machines of more than 5 kg. are an exception (for example, in France there are no more than 10 machines of 10 kg. or more.

iv- rates

They obviously depend on the thickness of the part to be manufactured. For usual thicknesses, the rate would be about 3 to 4 cycles/min.

Of course, the number of parts obtained is equal to the number of imprints in the mould so that several imprints in a single mould are made for the small parts, while the larger parts are made one by one.

Example of the cost of the moulds:

- standard average mould (parking light) 2 or 4 imprints 20,000 F.
- large mould (dashboard) per unit 80,000 F.

These prices are high because the moulds are machined in the mass (resistance to millions of manipulations, and to pressures of about 1,000 kg/cm2) and have an inner cooling system by ducts.

Skilled workers are needed and the equipment is highly sophisticated (jig boring machine, electroerosion machine).

v.- materials used in injection

- copolymeres - ABS
- polypropylene
- methyl polymetacrylate
- polyacetal - polyamides
- cellulose autobutyrate

vi- typical applications

Fan, battery housing, small gears for meters ...

Radiator grille, parking lights, locksmith parts ...

Dashboard, air control switches, door handle ...

b) Extrusion (Sketch 2-b)

With the help of a revolving screw in a sleeve, the plastic which has been previously softened by heat, is pushed through a die which gives it the shape that is then fixed by cooling.

i - advantages

- continuous production
- inexpensive tooling (die) whence great flexibility in use (many different shapes obtained by simply changing the die).

ii- disadvantages

- the break-even point is calculated in kilometers of products manufactured.

The plastics extruding machine is derived from the rubber extrusion press. For automobile parts, machines with screws of small diameter: 60 to 90 mm are used. They produce from 40 to 100 kg/hr.

iii-materials used and typical applications

PVC : insulation of electric cables, joints, framework sections, tubes and sheaths.

Polyamide 11 : gasoline pipe

c) Blowing (Sketch 2-c)

A thermoplastic sheath of sufficient thickness is extruded and then gripped at both ends in a cooled metal mould of an appropriate shape. One of these ends is then welded on itself and the other receives a blow pipe through which enough air is sent with light pressure to deform the hot sheath and put it in contact with the inner walls of the mould whose shape it will assume upon cooling.

i - advantages

. satisfactory rate of output

ii- disadvantages

. the thickness of the product is difficult to control.

The blowing machine is obtained by associating an extrusion press and a blowing press. As the work of the former machine is continuous and the work of the latter discontinuous, the mould must move back and forth (the mould hooks on to the rough sheath then withdraws, blows out the product and releases the extrusion axis.

iii-capacity

Casting volume up 200 liters of content (for higher volumes the rotation method is preferred).

iv- rate

From 20 to 50 containers/hour for volumes of 10 to 60 liters of content.

v - materials used and typical applications

. high density polyethylene: water

containers for windshield washers, brake fluid containers and gasoline tanks.

.polypropylene: hot air pipe, radiator pipe

d) Coating (Sketch 2-d)

This technique consists in the spreading of a plastic in the form of a paste or solution (on a textile). The textile is thus directly impregnated continuously without letting the plastic pass through it

A transfer roller is used to spread the plastic over the textile and a scraping system is used to regularize the thickness of the deposit.

This type of machine is used to impregnate widths of up to 2.5 m. at a speed of 10 to 100 m/min.

i - Material used and typical applications
Plasticized (flexible) PVC for example, is used for seat and inside of door upholstery.

N.B.: - This technique is never done in the car manufacturing plant which prefers to buy the coated products at about 8 to 10F/m (for the standard thicknesses required for a car).

- The seat cover designed with these products is now made with a high frequency welding technique which has gradually replaced the sewing machine .

e) Summary of the technical and economic data

i - capital outlay

Techniques	Machine	Cost of machine (FF.)	Cost of tooling (FF.)
Injection	press (processable (weight (100 to 150 grs. (~ 1 kg. (~ 5 kg.	60,000 to 80,000 ~ 200.000 ~ 800.000	(10,000 standard (20,000 high ~ 50,000 very high ~ 100,0
Extrusion	extrusion (60 mm. press (90 mm.	~ 60,000 ~ 120,000	draw-plates (simple ~ 1,00 (medium ~ 2,00
Blowing	extrusion press blowing machine	60,000 to 80,000 120,000-160,000	10,000 to 20,00

ii - <u>cost of the material</u> (in granules)

Material	Price (F/kg.)
Polystyrene - PS	1.3 to 1.5
Polystyrene shock - PSC	1.8 to 1.9
Styrene - acrylonitril - SAN	3.6 to 3.8
Acrylonitril - butadine	4.0 to 4.8
High density polyethylene - PEhd	2.2 to 2.4
Polypropylene - PP	2.2 to 2.4
Methyl polymetacrylate - PMM	3.8 to 4.2
Polyacetal - PAC	9 to 10
Polyamide - (PA6	7.5 to 8.5
(PA 11	13 to 15
Polyfluor - PFE	∼ 50
Cellulose acetobutyrate -ABC	7 to 7.5

iii - <u>Price of finished products</u>
(order of magnitude)

Injected part	2 x cost of material
Extruded section	1.5 to 2 x cost of material
Hollow body	2 to 2.5 x cost of material
Textile coated with PVC	8 to 10 F/m2

(*) All prices are French market prices for 1970 without taxes (the cost of the material is practically identical in all industrialized countries).

f) Thermosetting (Sketch 3)

This method is somewhat similar to metal pressing because the process starts with a semi-product (in this case, a sheet cut out in plastic which is the blank).

This sheet is gripped in a rigid framework, then heated with infra red. When the plastic has been sufficiently softened it is sucked by vacuum into a mould of an appropriate shape or pushed by a suitably shaped piston or by a combination of both.

i - advantages

- the moulds which are not submitted to high pressures are relatively inexpensive, so that small series can be manufactured.
- the base sheet can be thin, and in order to make the manufactured product stiffer sunken ribs are formed (increased moment of inertia).

ii- disadvantages

- the part held by the gripping frame will have to be cut off later and will become a non-usable scrap.

. the thicknesses are not uniform in the finished product, although air heating or blowing may be used to harmonize them.

The basic machine has been described above but the rates may be considerably improved by using a roundabout device with 2 or 3 stations, in order to distribute more effectively the direction of the processing cycle.

iii-capacity

At present it is less than 10 m2 of formed surface; 20 m2 and more will be possible in the future. For thicknesse the thickest sheet is 8 mm.

iv- rates

(small: 300 cycles/h (elbow rest, sun visor)
parts (medium: 80 to 100 parts/h (dashboard component)
(large: 5 parts/h (complete body: (experimental

The material used for the moulds depends on the series to be manufacture for example:

Material	Scale expected
Plaster	prototype for a few dozen parts
Wood	small series from 10 to 500
Reinforced polyesters	medium series, up to 10,000
Aluminum	large series, more than 10,000

A mould for large series, for a surface of 2 to 4 m2, may cost from 5,000 to 30,000 FF. depending on how complex it is. It would cost about 300,000 FF. for a complete body.

Chart No. 4 in the annex will give an idea of:

- first, capital outlay in relation to the formed surface and the type of machine used.
- second, hourly costs, in the same conditions.

v - Basic materials used and applications

The most important application hoped for automobiles is the car body though examples are still rare. The following materials would be used (supplied in sheets):

Material in sheets	Price (F/kg)	Remarks
ABS	7 to 8	is now used
PVC	5 to 7	
High density polyethylene - hd PE		possibility of low prices but longer processin
Polypropylene - PP		
Polymetacrylate - PMM	6 to 8	transparent for glasses
Polycarbonate - PC	higher price	

It is difficult to give the exact prices of existing vehicles, as the only vehicle of a small series throughout the whole world is the CITROEN ,"Mehari" to which we have already referred. The cost of its finished body would be about 10F/kg.

This model has a chassis and framework made with sections onto which 11 plastic thermo-formed parts are screwed. The general thickness of these parts is about 3 mm (3.5 mm for the wheel housing and 5 mm for the frame and the radiator grille). The photograph in annex 5 will illustrate this idea.

It would seem that this technique can be developed and improved as will be seen from the sketches in annex 6 which show developments in body making.

In the early days of the automobile, vehicles were made with a steel chassis on which was screwed a body, first made out of wood and later out of metal. Certain American vehicles and trucks are still built in that way.

Just before the Second World War, the self-supporting body, or chassis-body was born in Europe. It was assembled by spot-welding. This design is now widespread but as plastics have appeared on the scene it may well be that one day recourse will be had to a chassis on which a thermoplastic body would be placed, and its different parts would be fitted together by ultra sound welding.

As a medium steel body weighs between 400 and 500 kg. and needs about 6,000 spot welds (electric) it could be reduced to less than 100 kg with only a few spot welds (ultra-sound) because the forming of the large surface parts is very straightforward. Furthermore, the body does not need any paint as the mass is colored (as we know the cost of the painting cabins is very high).

The advantages of an ABS body as compared with the conventional body made out of steel sheets could be summarized as follows (less expensive propylenes could also be used for this application with similar characteristics):

- smaller costs
  . cheaper tooling and material
  .. no painting tunnel
- saving in weight
  . lower cost for the engine and the suspension
  . lower consumption of fuel
- no painting (colored mass)
- high rate of output and less welds
- improved appearance of the welds (ultra sound: no marking)
- possibilities of using more complex shapes and improved finishing
- no damage in the event of a mild accident and comparatively easy repair of tears: gluing (methylethylcetane) or hot air welding of parts of the same material.

vi- Summary of technical and economic data

Investment:

machine - 50,000 to 300,000 F for forming surfaces of 1.5 to 5 m2.

tooling - 5,000 to 30,000 F (for a complete body about 5 or 10 times this amount would be necessary)

Cost of the material

Sheets	(ABS	7 to 8 F/kg	
	(PVC	5 to 7 F/kg	
	(PP	-	(4 to 5 F/kg in the future)
	(PMM	6 to 8 F/kg	

Price of the finished products
(order of magnitude)
1.5 x cost of the sheet material

B) Thermosetting

The materials reviewed above were all thermoplastics which means that they are manufacture at high rates of output without any chemical processing. The materials which will be examined now are of the thermosetting type which means that their processing is slower, as polymerization is necessary. Furthermore, they are always reinforced with wire or fiberglass for use in the automobile. In particular they are used for body parts.

Plastic

Usually unsaturated polyester is used, and less frequently, epoxy. The resin is prepared by mixing an accelerator (0.33% in weight) and a catalyzing agent (1% in weight); the accelerator may be mixed beforehand but as soon as the catalyzing agent is added the setting of the material begins (polymerization); the useful time is then of about 20 minutes.

Glass

It is used in the form of glass felt or textile glass according to the resistance desired (textile glass is best for this purpose but cannot be impregnated as easily). The textile glass or glass fabric is cut in different shapes with patterns and the waste is used to increase local resistance.

The snare of plastics in a "sports" car manufactured today is about 500 or 600 F per vehicle.

Cost of basic materials

Material	Price without taxes F/kg
Polyester	1.6 to 1.9
Epoxy	8 to 12 "gel coat" (resin surface): 8F/kg white, 12F/kg red
Glass (glass felt)	5.2 to 5.6
(textile glass)	6 to 8 and more

a) Techniques used

Initially the shape of the body is made out of wood, plaster, metal or polyester. On this shape which is suitably coated with a stripping agent, a reinforced resin will be deposited and this will become the mould for all the parts that have to be made. Two different methods may be used for the casting:

i - Contact (7a in the annex)

After coating the mould with a strippinc agent, the first coat of resin (gel-coat is deposited; this coat insulates the product from the atmospheric agents. A reinforcement of fiberglass (glass felt or textile glass) followed by a coating resin are then alternatively deposited on the mould. A brush is used to completely impregnate the reinforcement with resin and eliminate residual air (otherwise there would be bubbles which might expand and burst the material). Once this has been done the operation is renewed until the requisite thickness is obtained.

In short, the moulding is done from the outside to the inside. The first coat is the "skin" and therefore needs greater care.

This method produces structures with excellent mechanical resistance. As the moulds can be taken to pieces, large structures can be made in one block. This is how the "Dinalpine" is made in Mexico.

There is very little waste after moulding, about 2%, but it cannot be recovered.

ii- Projection (Sketch 7b)

A faster method may be used: a spray gun simultaneously projects onto the mould:

- cut fiberglass
- accelerated resin
- a catalyzing agent.

This is a faster but less flexible method. It is also necessary to remove the bubbles and the structure has less mechanical resistance. Furthermore, to make it profitable several moulds are required and they are expensive.

Pressing techniques may also be used; in this case the resin penetrates the glass reinforcement by pressure. But this requires:

- higher investment (hydraulic presses)
- the body must be built with a large number of parts which then have to be glued together (although there are obvious differences, this is comparable to the assembly of a metal body by the welding of different pressings).

It is then necessary to make a medium pressing between hot tools on a hydraulic press (about 50 kg/cm2 at about 120 degrees C.)

iii-Preform

A cut fiberglass framework is made on a grid by aspiration. This is then coated with resin and taken to the press in the same conditions as above. The characteristics have been very much improved in this case because the framework is in one piece (e.g., the roof of the CITROEN DS and the CITROEN "Ami", the roof of the RENAULT "Estafette").

iv- Premix or Compound (Sketch 7d)

A mixture of 1/3 resin, 1/3 fiberglass, and 1/3 limestone charge is made. This forms a putty which is then pressed into shape (e.g., engine hood for the RENAULT "Estafette"). The mechanical characteristics resulting from this method are not excellent. It is best suited for hoods or housings not submitted to stresses.

v - Preimpregnation

This method would probably be preferred by mechanical engineers since the basic product is ready to be used and includes the reinforcement and the resin. It can be cut out in the shape desired and is then sent to the press where it is treated in a similar manner as above (e.g., the back shelf of the R 16 RENAULT). Its characteristics are quite good and preimpregnation comes in the form of a bobbin which can be kept for 6 months (under 10 deg. C.) before use.

Thus it would only be necessary to have a hydraulic press and create tools which can be heated ; this can be done by a large number of pressing shops.

Capital outlay:

Method	Machine	Cost of Machine (F.)	Cost of tooling (F.)
Manual	Tool (roll (brush	negligeable	according to production
Spray-gun	Projection spray gun	10,000 to 15,000	10,000 to 100,0 average
Premix	Hydraulic press	80,000 to 200,000	
Preforming	Preforming machine +	50,000	20,000 to 50,0
	Hydraulic press	80,000 to 200,000	in average
Preimpreg-nation	Hydraulic press	80,000 to 200,000	according to size

B) Application to the body

Complete bodies produced in small series (ALPINE) are already entirely made out of reinforced polyester (sometimes in reinforce epoxy:MATRA). Furthermore, vehicles whose body is not of the self supporting type could perhaps be made in such conditions for small series.

The method used is the contact technique (mainly manual sometimes with a spray gun). Investment in material is fairly small but 20 to 40 moulds will be necessary for a body that can only be manufactured in small series.

Since this application may be interesting for production is small series (countries in the early stages of production, or manufacturing of heavy trucks) a detailed description will be necessary:

i - Structure

The thickness of a sports car body ("Dinalpine" type) may vary between 1.5 mm (parts which are not submitted to stresses) to 10 mm. (support of door hinge). Average thickness is 2.5 mm.

The percentage of glass/resin used may vary according to the parts, i.e., between 35 and 45% (of glass).

The weight of the complete plastic body is about 120 kg. The biggest moulding weighs 35 kg. (body) and the smallest about 100 grs.

Approximately 60% of labor and 40% of raw materials go into the structure.

ii- The assembly of the complete structure

First, the two main moulds: the hull and the platform are made simultaneously. They are then sealed together on a chassis.

The other parts are moulded separately and are assembled on a jig which connects the different parts.

It should be noted that some of these parts are glued together before they are extracted from the mould (front hood and its internal reinforcement, door and reinforcement). The bumper may also be made out of reinforced plastic.

iii-Paint

The base resin (gel-coat) could be colored as for plastic boats but as atmospheric conditions affect the color it is very difficult to touch up the paint after an accident.

Therefore, cellulosic paints are used (which are more expensive than the glycerophtalics used to paint a body made of metal); polyeurethane paint may also be employed (it is less expensive but the finishing is less satisfactory).

iv- Tooling

A complete body needs about 50 moulds but only two of them are especially important: the hull and the platform.

Investment in moulds is about 300,000 to 500,000 F. for a body. This tooling which is made out of charged polyester can be used for at least 500 bodies.

If pressing systems were used in order to increase productivity, about 2'ooo,ooo F. would have to be invested in pressing tools.(plus the cost of the presses). This equipment could then be used to mould about 10,000 parts. Apart from the moulds, investment in a plastic body is fairly small.

v - Labor

There are no specialists in this field but a certain amount of professional consciencíousness is necessary (no bubbles can be left in); therefore supervisory personnel are also neeeded.

About one week is necessary for the training of a contact moulder for internal parts, and about 3 months for a moulder of "skin" parts. A foreman should be hired for every 6 moulders.

vi- Buildings

It is preferable to work at a temperature of 20 deg. C. to obtain satisfactory polymerization. A higher temperature is acceptable as it speeds up polymerization but in this case the amount of accelerator and catalyzer must be reduced. For a production of 200 to 300 bodies a year, 1,000 m2 of roofed surface are needed. In tropical and equatorial countries, the roof is not indispensable.

vii-Possible applications

Technically, any existing automobile body could be converted into plastic. particularly if it has a rigid floor.

-Economically, a minimum annual output is required:
.300 to 400 for a sports vehicle
.1,000 to 2,000 for a conventional vehicle.
These values, of course, will depend on the sales price of the vehicle.
.For larger quantities, it might be necessary to press and glue the parts on to a dummy.

-Apart from complete bodies spare parts may also be manufactured: door, hood, fender or complete body parts such as the cabin of industrial vehicles and buses (this is well developed in the USA and in Europe).

viii-Summary of technical and economical data

. labor: about 2.5 to 3 kg of finished product per productive hour.

Labor accounts for about 60% in the making of a car body.

Materials		Cost (F/kg)
Thermosetting	(resin: polyester	∼ 1.8
plastics	(epoxy (less frequently)	∼ 8
(55 to 65%)	(accelerator (0.33% of weight)	∼ 10
	(catalyzer (1% of weight)	∼ 10
Fiberglass	(glass felt	∼ 5.5
(35 to 45%)	(textile glass	∼ 6 to 8

Stratified structure (average thickness 2.5 mm (1.5 mini, 10 maxi)

=Reinforced plastic (body weight 120 kg (smallest part 100 grs.)

=Plastic + glass (cost of material (F/body) 500 to 600

The share of the material in a car body is about 40%

. Investment

Type of mould	Number of moulds for type of body	Life span of moulds (number of parts manufactured)	Cost of moulds (F per type of body
Contact	≥50	≥ 500	300,000 to 500,000
Spray gun	>50 (same type)	≥ 500	Higher than contact require more moulds to make it profitable
Pressing	50 (different types)	5,000 to 10,000	2'000 000

ix- Break-even point (critical mass)

- contact (300 to 400 sports vehicles
  (1 000 to 2,000 conventional vehicles
- pressing 10,000 vehicles
- price of finished products (order of magnitude)

Part obtained by contact	8 to 12 F/kg
Pressing (Premix / Preforming / Preimpregnation)	6 to 15 F/kg

c) Tools for forming

This is another interesting application of reinforced plastics.

Pressing tools may be made out of plastic. A metal concrete or premix core is used, it is coated with charged epoxy which receives the shape desired for the pressing.

This is how the male and female dies are made. They are then mounted on hydraulic presses which have variable speeds, for the pressing of the sheets.

i - Advantages

The cost of the tools may be reduced by 25 to 30% compared with metal tools. Example: automobile fender

Part	Price of metal tooling (F)	Price of plastic tooling (F)
Left and right fender	∿ 700,000	∿ 90,000

However, metal is necessary for the whole range and for large scale production; plastic is only used for small-scale pressing.

In the above example, complete large-scale production tooling has 5 work stations:

- pressing
- cutting
- finishing (3 stations: hammering of edges up or down, ...)

It is designed for the making of about 500,000 parts while plastic tooling could only be used for 10,000 parts and replaces only the pressing station.

If the depreciation of tooling is considered, the costs would be as follows

Part	Price of metal tooling (F/part)	Price of plastic tooling (F/part)
Fender	1.4	9.2

Plastic tooling for large series would then be 6 times more expensive than metal tooling; therefore it must only be used for small-scale production of small series or of components subject to fluctuations in shape (fashion).

The advantages are thus:

- perfect adaptation to small series: li~~fe-~~span of 5,000 to 10,000 parts

- easy repair of tools by recharging (gluing)
- no problem s for conventional pressings usual depths, thickness of sheets between 0.6 to 1.5 mm.

Very suitable for pressing without blank holders.

ii- Disadvantages

- Need to use a hydraulic press which is always more expensive than a mechanic press for any given operation. But mechanical presses used on a large scale are also expensive (more so because of their size).

  Example of the price of a hydraulic press:

Capacity (tons)	Size of table (mm.)	Price (F.)
150	1,000 x 750	80,000 to 100,000
800	2,000 x 2,000	500,000

- With these tools only the pressing is done. The cutting and the hammering of the edges have to be done with a conventional method (manual hammering or machine forming).

- The bending radii are higher than for steel tools
- The "blank holder line" is difficult to find, so that a specialist is needed to design the tooling (at least in the first stage).

The Italian firm OSI is at present the European specialist in this type of tooling.

iii-<u>Examples of parts that can be pressed according to this method</u>

- Miscellaneous housings and floors, side panels, roofing and door components, door mouldings, fender and fender flanges, container compartment, exhaust muffler...

iv- <u>Conclusions on plastic bodies</u>

In order to give a clearer idea of the different techniques to manufacture body parts, a comparison of investment in tooling, material and labor is shown for the three possible techniques:
- steel sheet pressing
- reinforced plastic by contact or pressir
- hot formed thermoplastics.

. <u>tooling</u>
- for the whole body

Material	Technique	Price millions F.
Steel	pressing	30 to 40
Reinforced plastic	contact	0.3 to 0.5
Reinforced plastic	pressing	∾ 2
Thermoplastic	hot formed	0.2 to 0.3

- for certain parts:

Injection (dashboard 80,000 to 100,000F
(average part 20,000 to 50,000F

. material, labor, finished product

Body	Density (kg/dm3)	Material (cost in %)	Labor (cost in %)	Finished (F/kg)
Steel sheet welded and pressed	7.8	35 to 40	60 to 65	2
Contact reinforced polyester	1.6 to 1.8	40	60	10
Heat formed ABS	1.0 to 1.1	80	20	10

d) Polyurethane foam (Sketch 8)

The polyurethane foam is obtained by making isocianates react on polyester or polyethers. The basic products are mixed in liquid state and expansion begins immediately. If it is controlled in a closed mould, it takes the shape of the mould by developing a certain pressure which will depend on the amount of density desired. If not, the result is a free foam in a block which can be cut.

The following equipment is used:

- dosing and mixing machine which makes 4 to 5 mouldings/min.
- cast aluminum moulds (resisting pressure) in order to accelerate the reactions, moulds are baked. At least 150 moulds are needed per model to obtain an effective manufacturing cycle.

Typical applications: seat, stuffing of dashboard and elbow rest.

Basic economic data:

Investment	20,000 (low pressure) to 150,000 F (high pressure) machines + mould + oven + roundabout installation
Cost of materials	basic resins (polyoles) 2.5 to 3 F/kg.
Price of finished products	about 200 F/m3 in the usual densities (about 30 kg/m3 for flexible foam)

8.1.3 Recent developments in the processing of plastics

A) Injection of reinforced thermoplastics

By the use of granules of thermoplastics reinforced with fiberglass, the mechanical characteristics of virgin plastic are doubled; its behavior under temperature is also considerably improved. The parts injected with those materials may then be substituted for the non-ferrous metals (polyamide and polyacetal in particular).

B) Injection of lightened plastics

By adding a porogeneous agent to the thermoplastic granules, cellular products of strong thickness at relatively low cost may be produced.

C) Cold forming

Certain materials may be deformed by shock (mechanical press), no softening is necessary as for heat forming. ABS and polypropylene have undergone experiments of this type but no practical achievements have been obtained. If this technique develops, plastic coils could be used in the same way as steel sheet rolls. Thus, this technique would be within easy reach for the pressing shops.

D) Reaction moulding

Polyurethane resins are used; by reaction they give to the moulding a foam with a rigid skin, (the wall of the mould), but the inside remains alveolar. An effective combination of resistance and lightness is thus obtained. This technique is particularly appropriate for large parts made on a small scale.

Dashboards and elbow rests are already manufactured by similar procedures, but body parts could also be made, particularly as polyurethane can be reinforced with fiberglass.

E) Ultrasonic welding

This type of welding is used to assemble very thick thermoplastics. It may play an important role in the assembly of automobile plastic body parts (possible substitution of steel sheets welded by spot-welding).

F) Electro-plating

Styrenic plastics (PA - SAN - ABS) are chromed electrolytically since a few years ago. Recently polypropylene has also been chromed (USA, Japan). Nickel-plating -Kanigen type- has also been obtained directly without any prior copper-plating. It is likely, therefore, that radiator grilles and trimmings made of ABS or polypropylene could be chromed and manufactured in series. The latter being cheaper would be used even more in an automobile.

G) General Conclusions

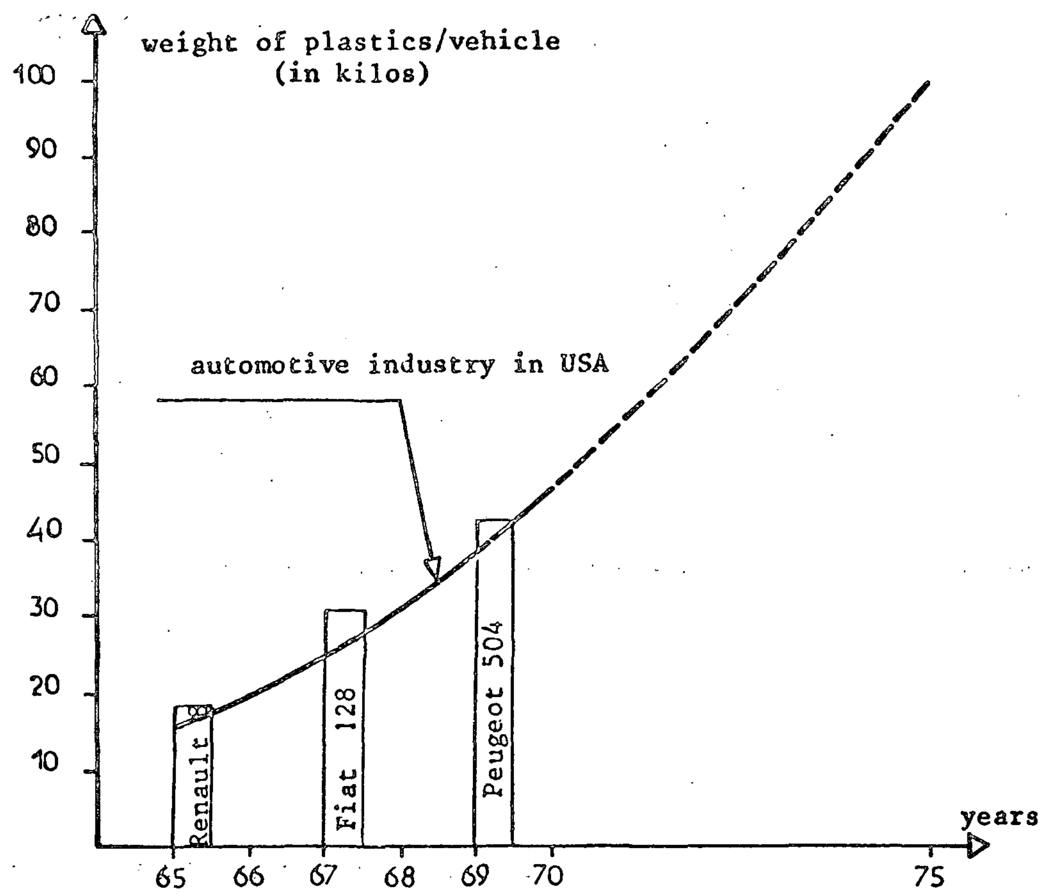
Plastic applications provide considerable openings for the developing countries. At a small cost, plastics allow a more rapid approach to national integration with a better prospect of profitability.

Furthermore, plastics should allow certain countries to by-pass certain stages in industrial development which are traditionally based on the use of metals.

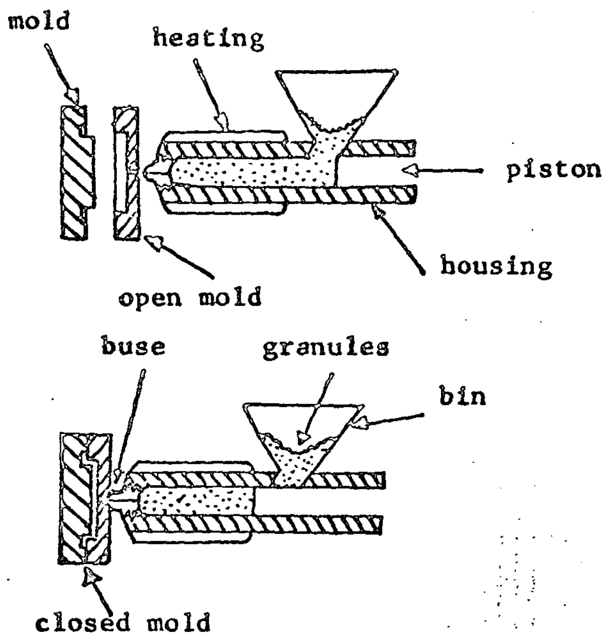
As it is expected that in 1985 the output resulting from the processing of plastics will be equivalent to that of the processing of metals, it is important to give thought to this problem and to be ready to face the future.

ANNEX I
- chart n° 1 -

AVERAGE CONSUMPTION OF PLASTICS PER CAR

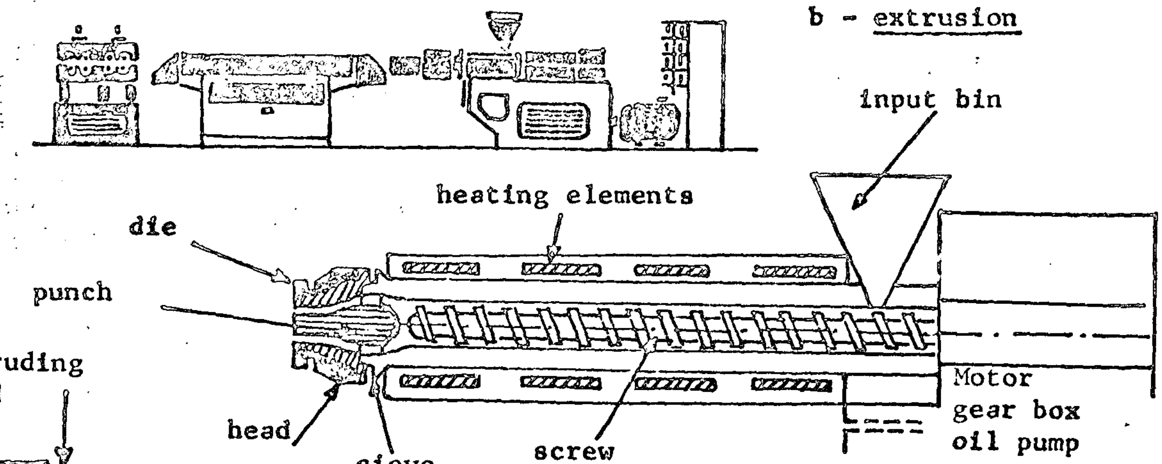


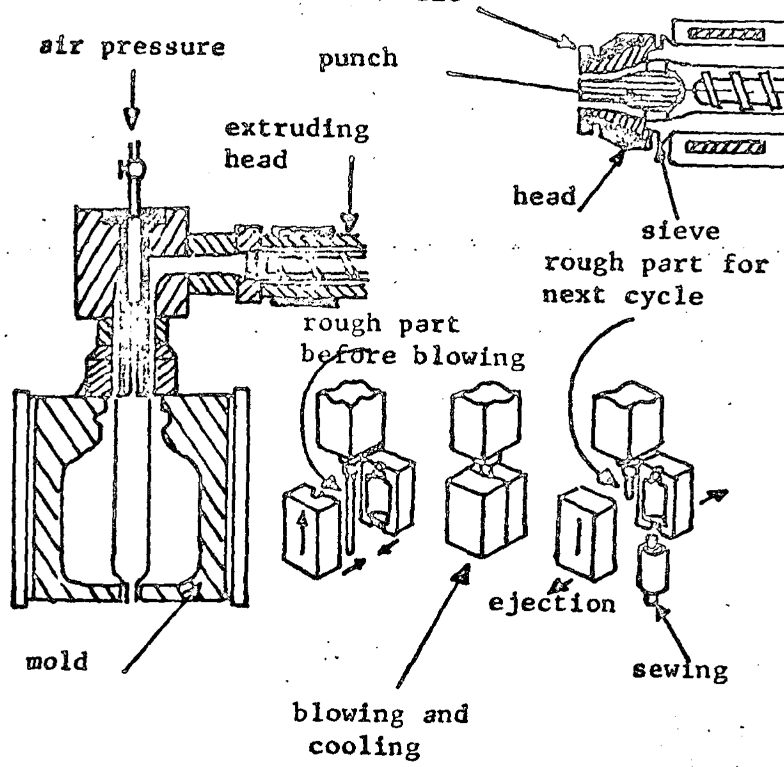
- Chart n° 2 -



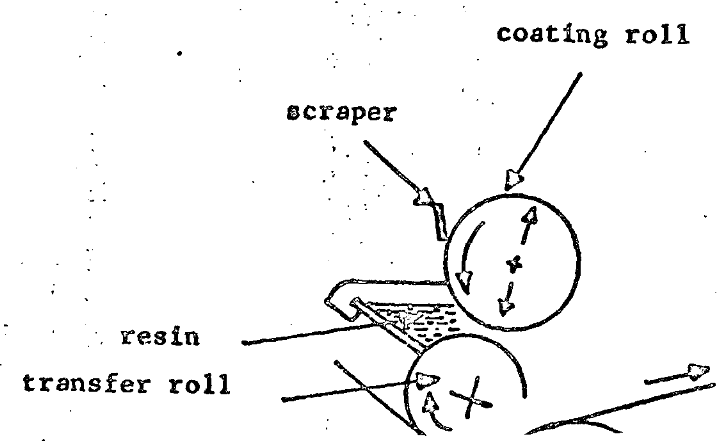
a - injection

b - extrusion

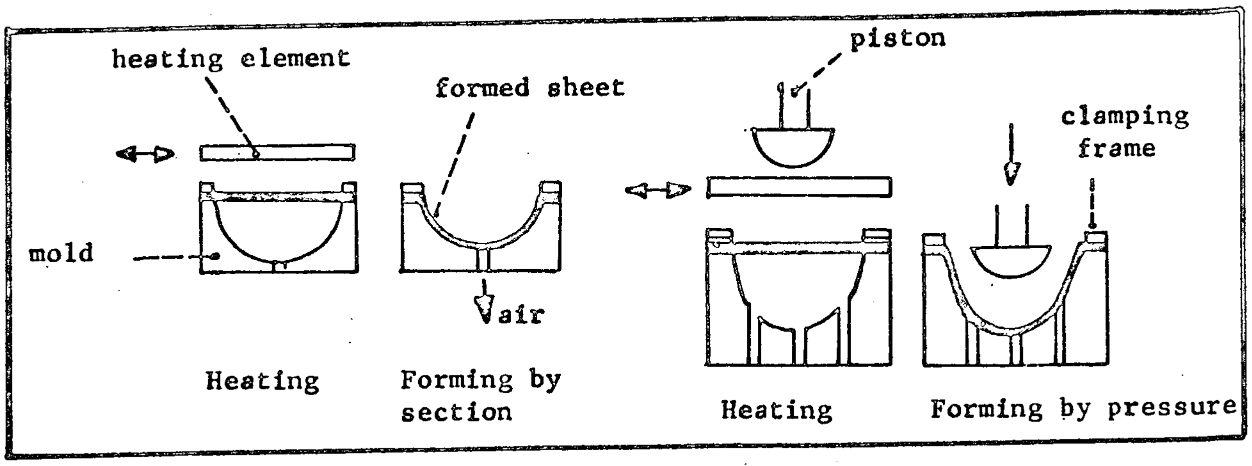


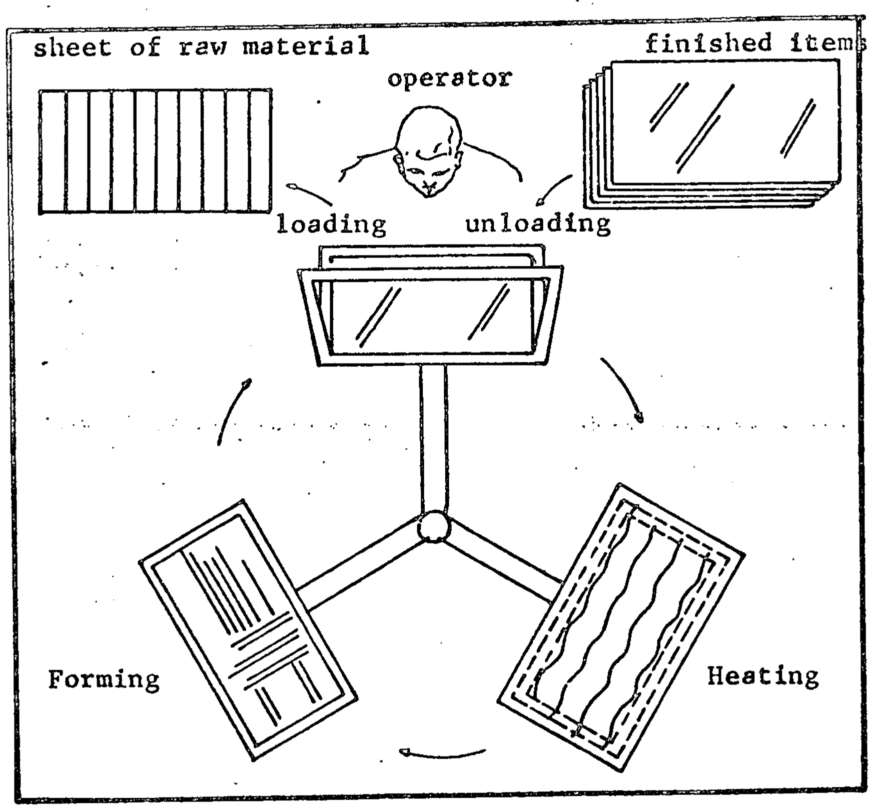


· Blowing

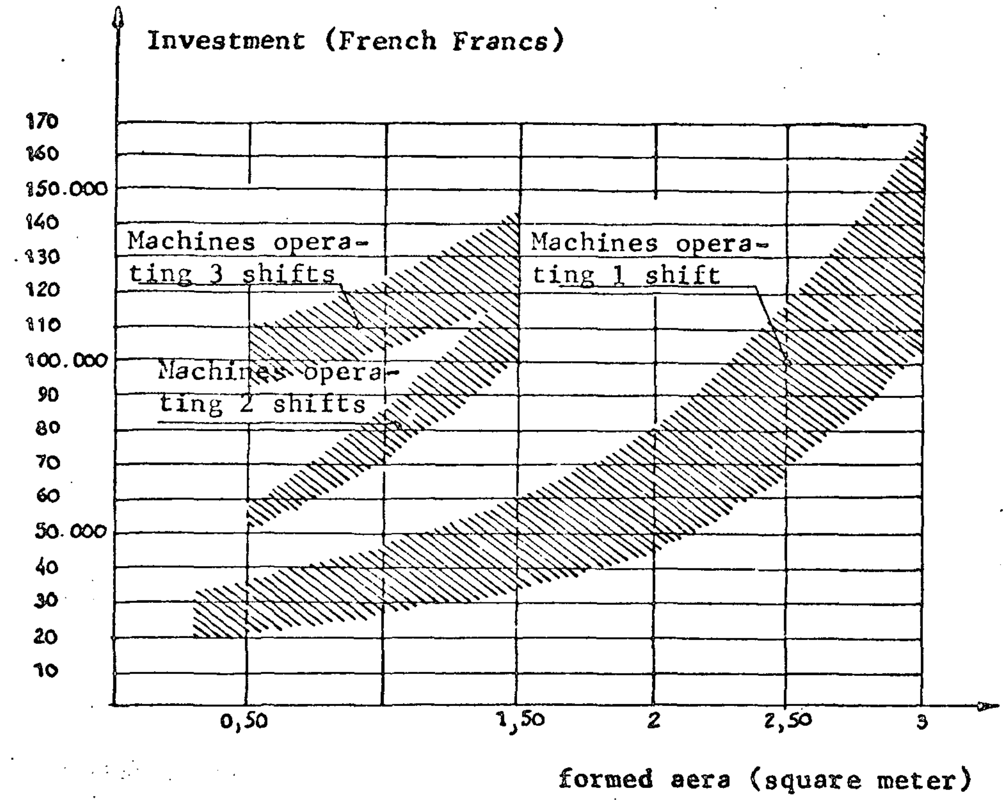


- chart n° 3 -

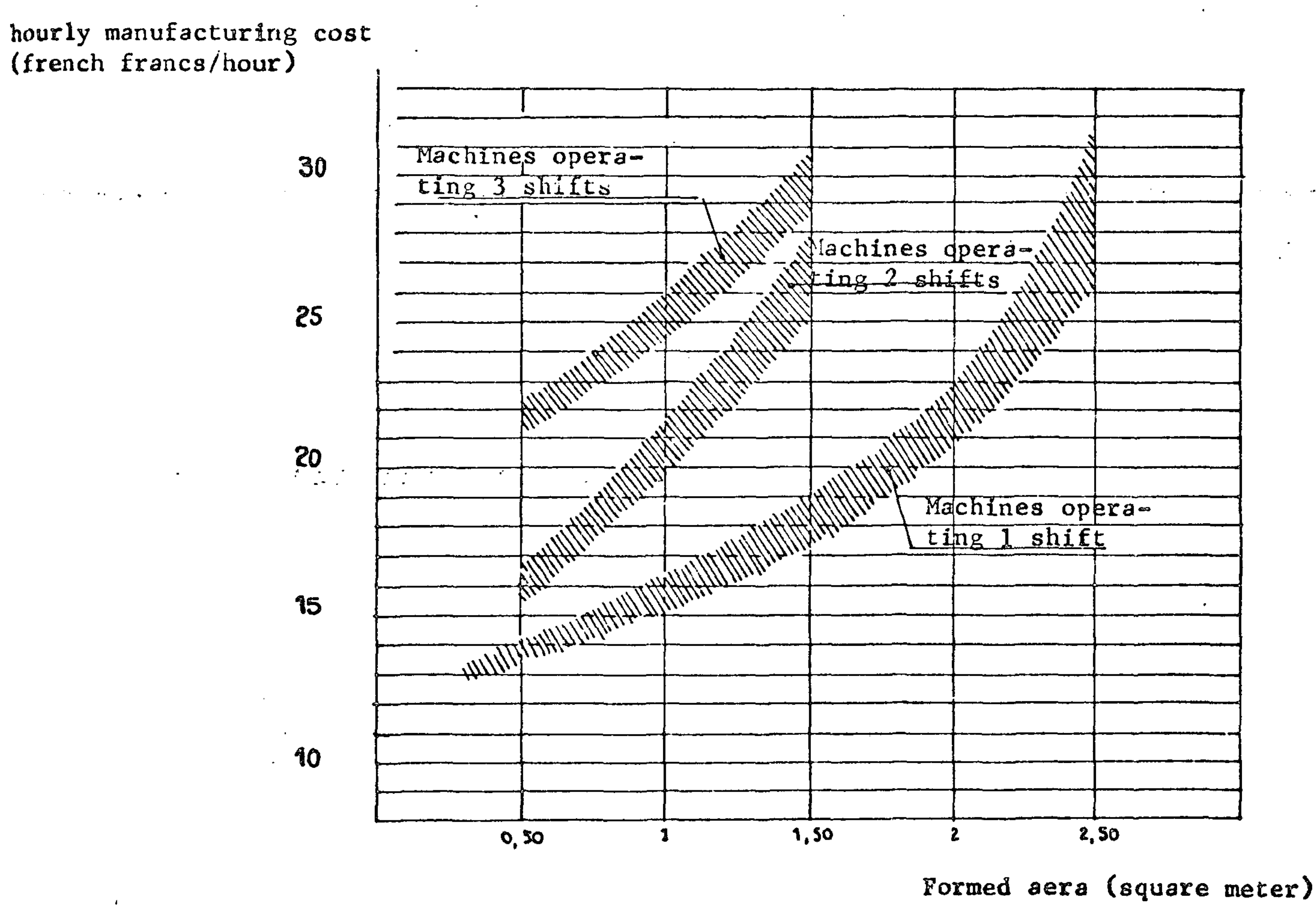

heating element
formed sheet
piston
clamping frame
mold
air
Heating
Forming by section
Heating
Forming by pressure


sheet of raw material
operator
finished items
loading
unloading
Forming
Heating

- chart n° 4 -


Investment (French Francs)
170
160
150.000
140
130
120
110
100.000
90
80
70
60
50.000
40
30
20
10
Machines opera-
ting 3 shifts
Machines opera-
ting 2 shifts
Machines opera-
ting 1 shift
0,50
1,50
2
2,50
3
formed aera (square meter)

408

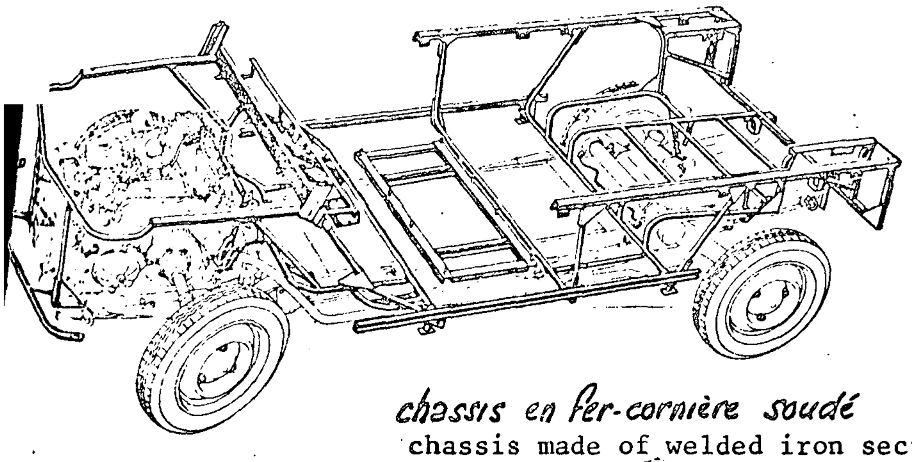

hourly manufacturing cost
(french francs/hour)
30
25
20
15
10
Machines opera-
ting 3 shifts
Machines opera-
ting 2 shifts
Machines opera-
ting 1 shift
0,50
1
1,50
2
2,50
Formed aera (square meter)

ANNEXE - 5

- chart n° 5 -

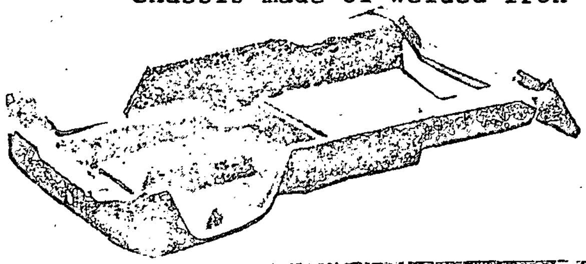
exemple : CITROEN "Méhari"

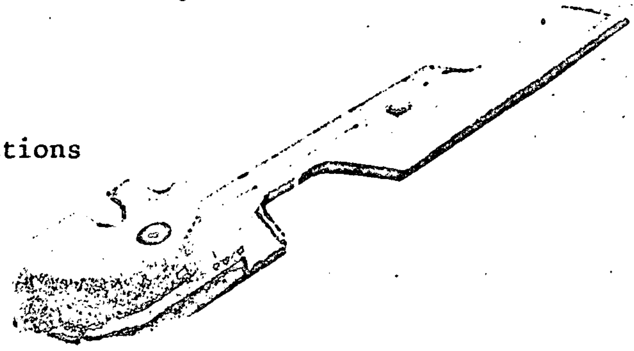
example : the CITROEN "Mehari"

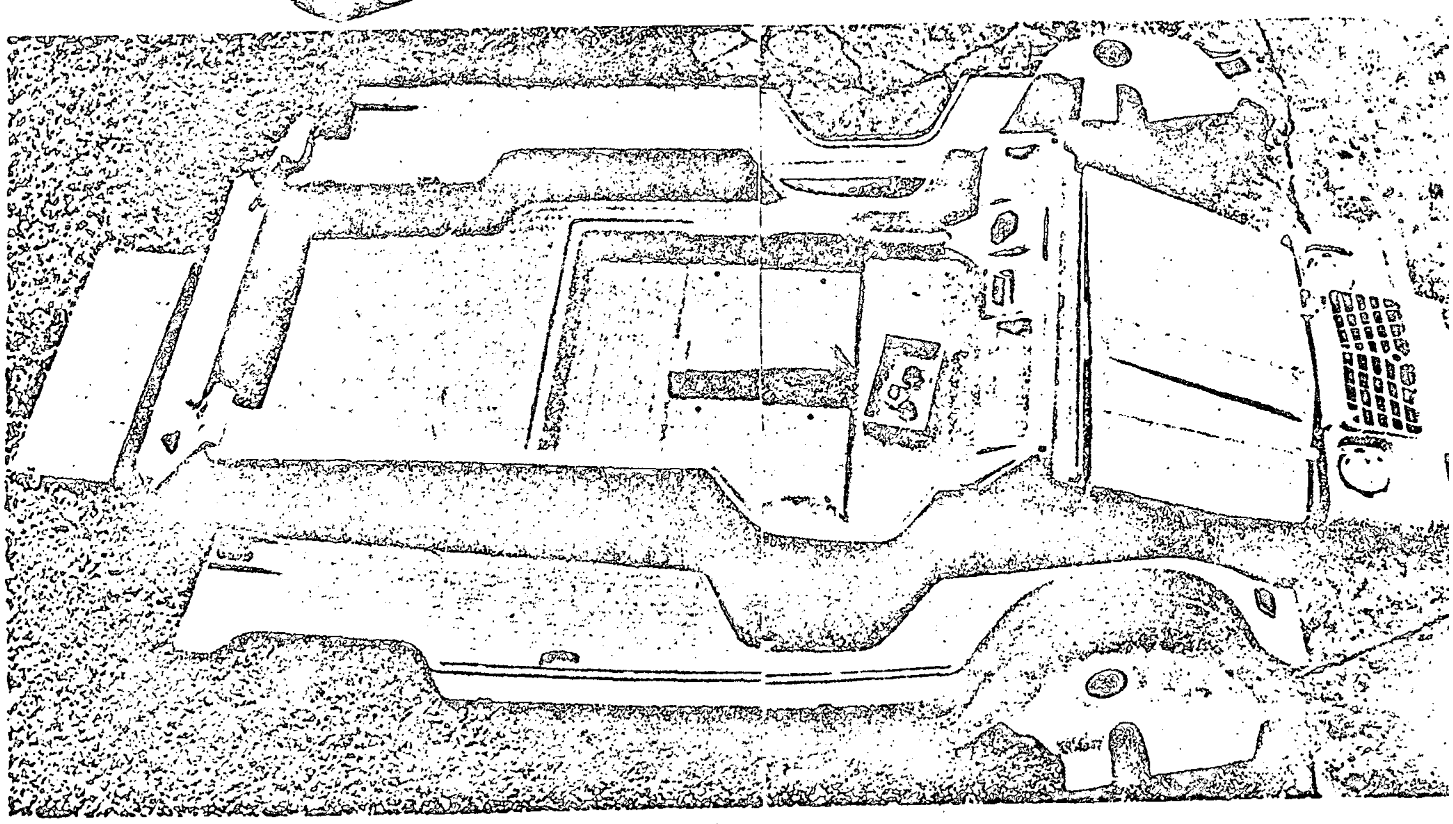


chassis en fer-cornière soudé

chassis made of welded iron sections

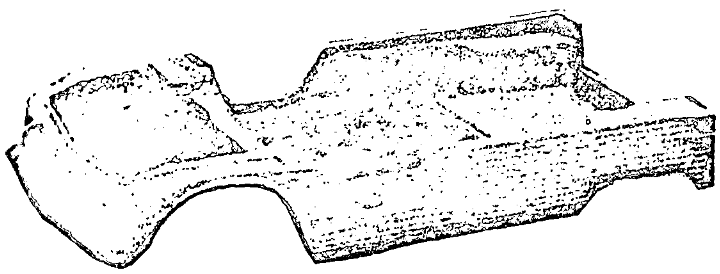


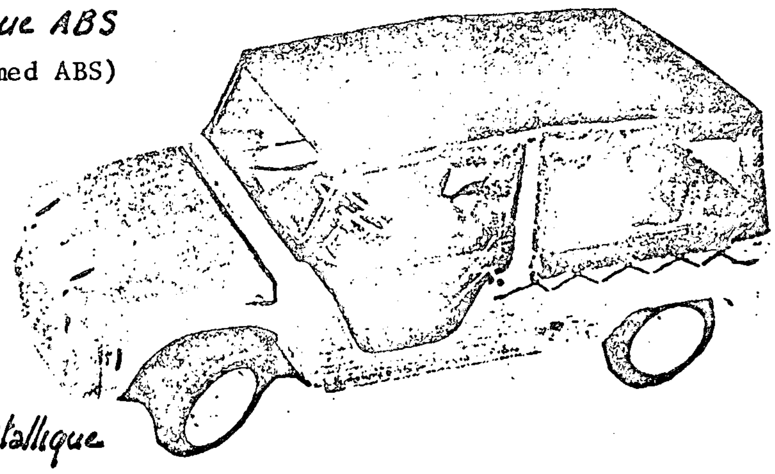




carrosserie 11 éléments thermoformé en plastique ABS

body made of 11 plastic parts (thermo formed ABS)



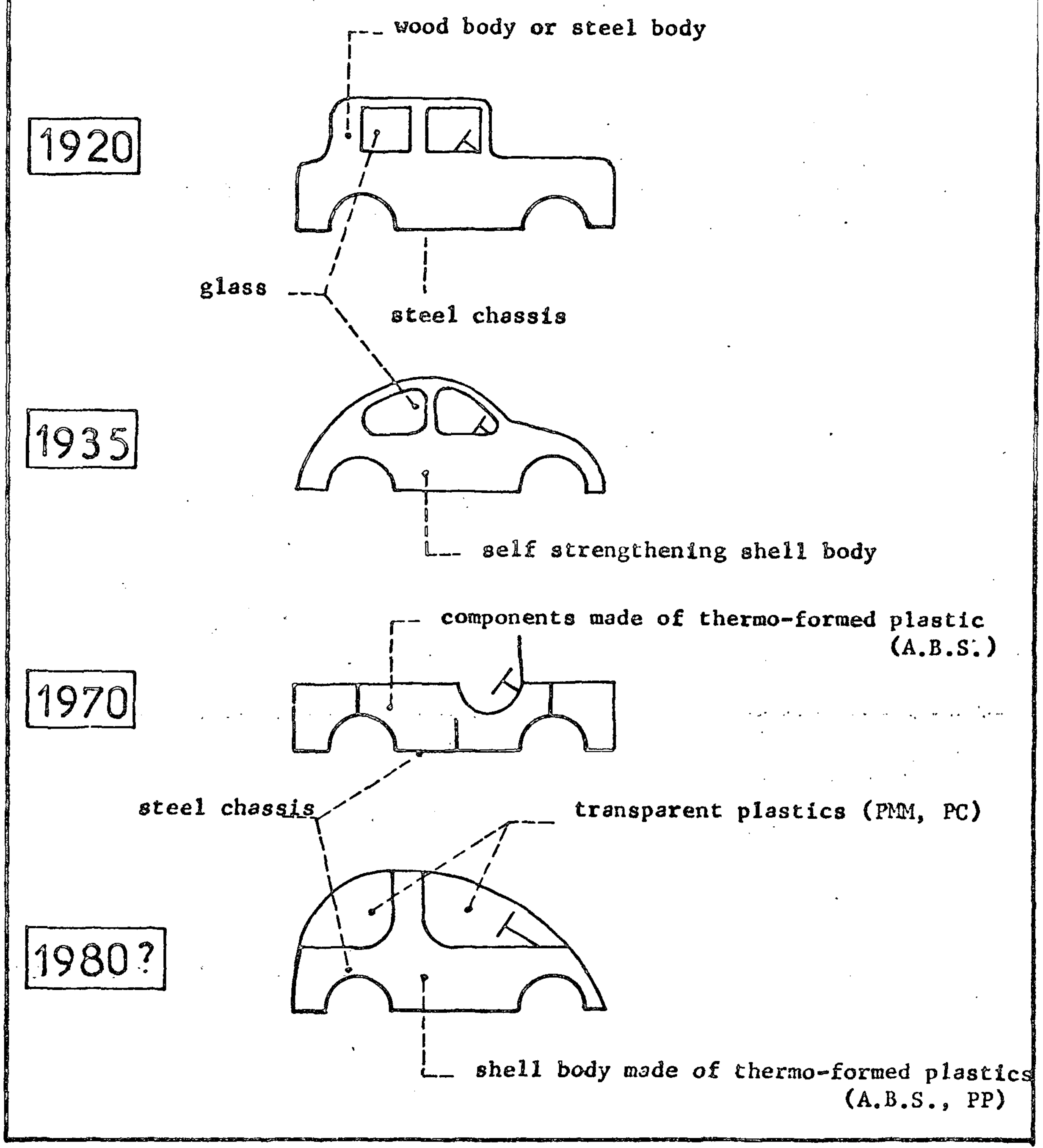


les éléments en plastique sont vissés sur le châssis métallique

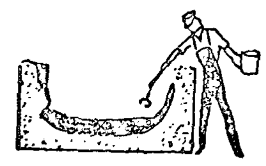
The plastic parts are screwed on the chassis

- chart n° 6 -

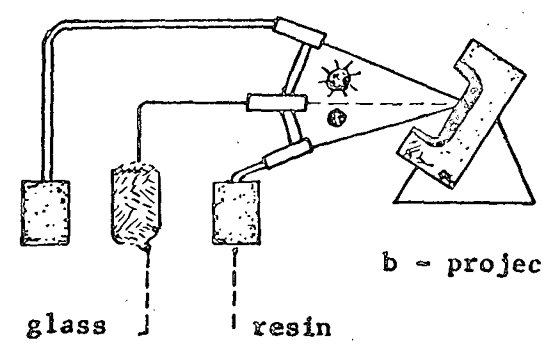
EVOLUTION OF THE DESIGN OF AUTOMOBILE BODIES



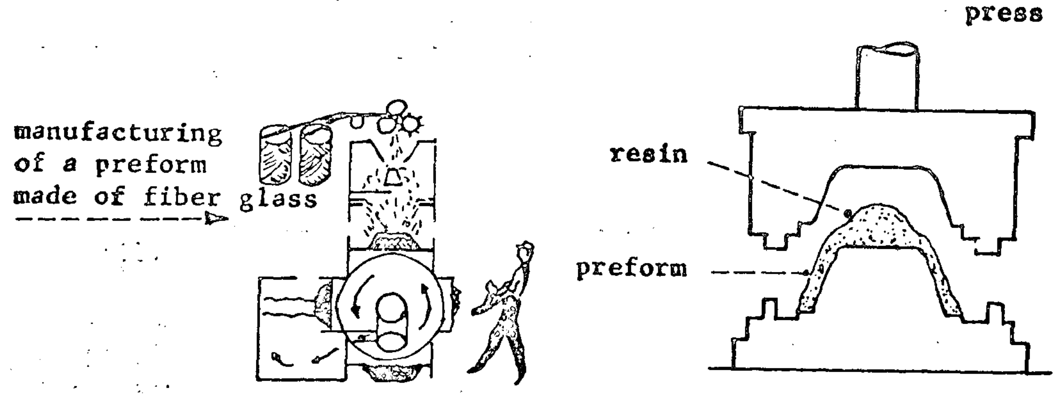
- chart n° 7 -



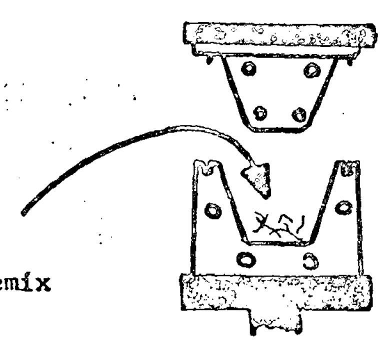
a - contact



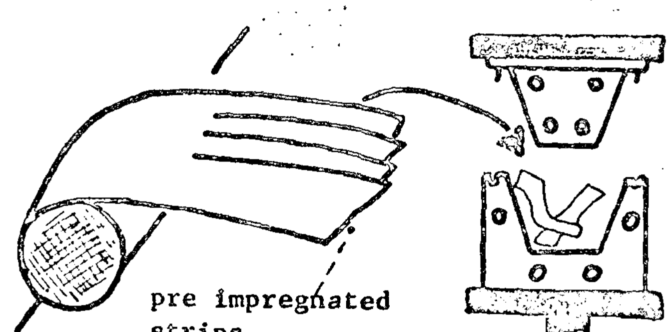
b - projection



c - preform process

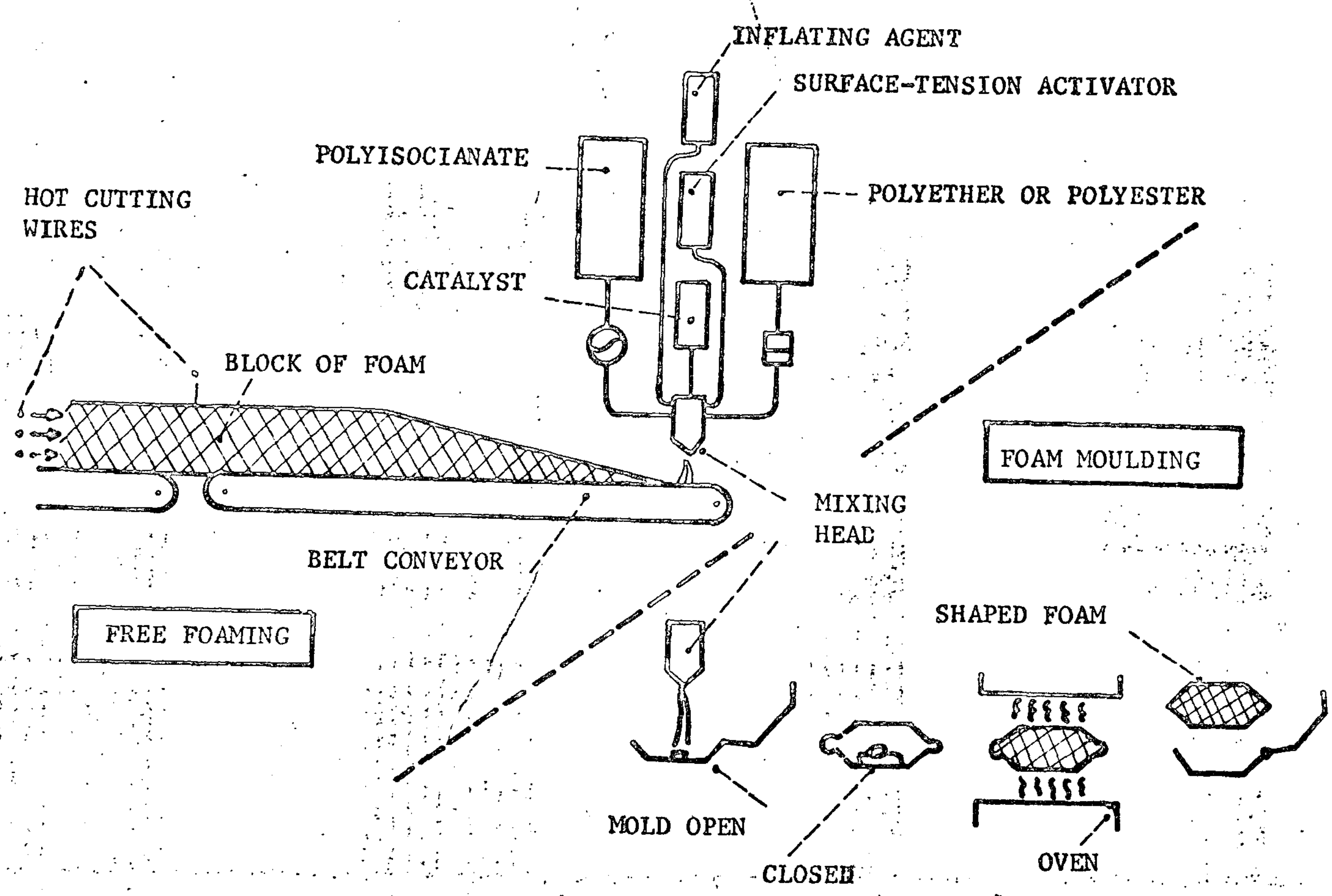


d - premix or compound



e - pre impregnate

- chart n° 8 -


INFLATING AGENT
SURFACE-TENSION ACTIVATOR
POLYISOCIANATE
POLYETHER OR POLYESTER
HOT CUTTING WIRES
CATALYST
BLOCK OF FOAM
FOAM MOULDING
MIXING HEAD
BELT CONVEYOR
FREE FOAMING
SHAPED FOAM
MOLD OPEN
CLOSED
OVEN

8.2 Prospective insight of automobile techniques

In order to ascertain future developments, consideration will first be given to the past and then a separate analysis will be made of possible progress in processing techniques and the finished product, i.e. the automobile and its components.

8.2.1 Retrospective look or past developments

As far as automobile techniques are concerned apart from output the last 30 years do not show, on the face of it, any spectacular development. It will thus be worthwhile to review these developments.

In 1931 an engine with a cylinder capacity of 2.4 L. had a power of 47 HP at 4200 revolutions per minute. Today, a 950 cm3 engine, that is, with a cylinder capacity which is only 47% of the above, is more powerful, i.e. about 50 HP under the same conditions.

These results may be attributed to the new materials to the surface finish of the parts and to the improvement of the octane index. Formerly, an engine had to be run in before being used, that is, it had to be worn, in order to work properly; today this is no longer necessary ("running in" by the manufacturer in 1938 = 1 hour, 1965 = 8 min.)

The "damp" engine block has replaced the machining of the block, segmentation and,therefore, sealproofness has been improved, and the specific pressure has been reduced by a better geometry of the pistons.

The change of gears has been synchronized, even automated. At the same time the gearbox has become more compact.

The old transmission with a suspended and powerful shaft has been abandoned in Europe. The single gearbox-transmission case is preferred either for a front drive or a rear drive (the USA still use the conventicnal transmission system though it is more expensive).

The suspension has been improved in two ways: the replacement of the flat spring by a helicoidal spring; and the use of a telescopic shock absorber (also the torsion bar). This has been made possibl by the progress made in the quality of the surface finish and sealproofness.

The development of the body is less spectacular. However, in 1938, the vehicle had a chassis (side members - cross members) on which was placed a case which did not contribute in any way to the mechanical resistance of the vehicle. After the war, the design was changed in favor of a self-supporting body: a floor panel on which a shell which contributes to the resistance of the vehicle is welded. In the future, it may be possible to turn back to the idea of the chassis, but this time fitted with a plastic body.

Simultaneously, the development of the iron and steel industry has made it possible to use steel sheets allowing deeper pressings, and to reduce the thickness of the sheets, reducing thus the weight of the vehicle also. In some extreme cases the thickness has been reduced from 95/100 mm to 6/10 mm. But it seems that this trend will change because the strength of the vehicle has been weakened (8/10 is a good average).

Furthermore, reference must be made to the quantitative development of production: 1938, about 4 million vehicles manufactured in the world; today, 25 million.

Naturally, this has not happened without a parallel development of techniques and labor. Productivity has practically doubled in the same period. Therefore, two types of development should be be distinguished:

- those concerning basic techniques (with repercussions on the whole industry;
- those concerning the vehicle itself or its main components.

8.2.2 Technical developments in the processing of metals

The automobile has developed new techniques. It has even invented new manufacturing techniques.

A) Processing of mass metals

. Casting of ferrous metals

New sands have permitted greater accuracy which has been further improved by the shell moulding technique (or croning process). However, an old technique has been recently improved: precision casting with scrap wax where the wax has been replaced by plastic. With this technique, resistant and highly precise parts are made: the rocker arm, for example.

For the making of tooling, dies, or machine frames, an innovation has been introduced with the development of the "EXPORIT" technique. The iron or steel is cast on an extruded polystyrene pattern, the imprint of which has been taken in foundry sand. The pattern vaporizes during the casting leaving room for the casting (easy making of the pattern).

. Non-ferrous casting

Gravity die casting and pressure die casting together with aluminum and zinc alloys have shown spectacular development. Pistons, cylinder heads and even engine blocks are made by gravity die casting and carburators, gasoline pumps and all housings even large size (gearbox, steering, axle ...) are made by pressure die casting.

. Sintering

This technique which involves the compression and sintering of metal powders is used in the automobile industry to manufacture oil pump gears, shock absorber pistons and guides, suspension swivels, miscellaneous bearings and locksmith parts. This technique eliminates the machining operation which is very expensive Important applications are anticipated with this technique for the clutch, the brakes, and in particular for the automatic gearboxes. (5 to 7 kg of sintered products in a C-G FORD).

The average rate of consumption of sintered products in an automobile is 1.5 kg in Europe and Japan, and 2.5 kg in the USA. A 50% increase is expected for 1980.

. Forge

The maxipress together with prior rolling has replaced in most cases the conventional hammer head (connecting-rod, stub-axle, pinion) Forging machines by upsetting and swaging can make complex and very resistant assemblies (wheel shaft). Furthermore, tools with numerous dies insure longer life (new alloys and better machining).

New forging techniques have also appeared: high energy forging whereby highly complex parts are made with precision and shock extrusion of steel which starting from a rough part enables the production of an important range of cylindrical parts (i.e., shock absorber tube) to be made.

Finally, the cold techniques have been greatly developed. Thus, quality nuts and bolts are no longer machined but cold forged from steel wire.

B) Processing of sheet metal

a) Cutting - pressing

It is the size of the machines that has made it possible to manufacture large surface parts (body). The rate of production of the double action presses has also been very important. For the small parts the continuous tool has been developed which cuts and presses with precision at high rates. Hydraulic pressing has been developed for very deep pressings.

b) Folding

The most spectacular progress has been obtaine through the use of profiling roller machines which manufacture complex sections or tubes at very high speeds.

These techniques should be associated, naturally, with the progress achieved in the iron and steel industry in reference to the steel sheet itself (quality and appearance).

c) Machining

The most important progress in the removing of particles was in the definition and the making of adequate surface finishes and, therefore, greater precision in the machinery employed. The development of transfer machines is well known but in a parallel manner broaching and gear cutting, conic in particular, have made important progress.

New procedures have developed in particle removal: machining by electroerosion, electrolytic machining, chemical machining and even electronic beam.

D) Assembly techniques

a) Welding

Resistance welding has developed as far as rate of production is concerned by the use of multi-spot machines for the body; the embossing technique is used increasingly. Arc welding in a neutral atmosphere is also applied for the thicker sheets. New procedures are being tested or developed: for example, friction welding or welding by electronic bombing for the wheel shafts.

But new assembly techniques are also appearing:

b) Gluing

Thanks to epoxy type glues used for body parts (doors, hood, ...).

c) Fastening

Direct fastening of a flexible sheet on a rigid sheet.

Finally, constant progress is made with small assembly devices of the clipping type. A series of very keen systems exist.

E) Treatments

a) Surface treatments

New coating techniques have appeared: painting by dipping and electrophoresis and the use of prepainted sheets. Furthermore the conventional techniques have made progress, in particular, hard chromium-plating (KANIGEN procedure). Plasticization by fluidization (rilsanization) is also used.

b) Heat treatments

Here, the main features are the automation of existing procedures and the perfect control of the atmosphere (cementation, nitriding).

F) Automation

a) in the foundry: moulding machine, automatic charging and stripping of moulds (only the placing of the cores and the casting are done manually).

b) in forging: The hot billet comes directly from the furnace to the rolling-mill and then to the press with a minimum of manual work.

c) in machining: the transfer machine limits human intervention to the adjustment of the machine.

d) in cutting and pressing: the feeding of the sheets as well as the passing from one press to another is done automatically. For small parts, the machine is fed with coils; both the feeding and the extraction are automatic The sections are done in the same way.

e) in welding: multi-spot machines limit the intervention of personnel to the positioning of the sheets.

f) in assembly: there already exist automatic machines for small assemblies (parts of the rear or front axle, for example).

g) Finally, heat and surface treatments are done in a continuous manner; the manual operation is limited to the feeding and the extraction of the manufactured units.

G) New techniques

What will be the techniques of the future and how will metals be processed tomorrow, The following may be considered valid and developabl new techniques:

a) Moulding

- "exporit" (expanded polystyrene)
- precision moulding (/ centrifugation and vacuum).

b) Forging

- high energy forging
- steel shock extrusion

c) Forming

- continuous tool
- hydraulic and rubber pressings
- magnetic forming or forming by electric discharge
- forming by explosive (this type of energy which is easy but dangerous to use deserves a better application)
- electroforming

d) Machining

- chemical
- electrolytic
- electroerosion
- impulsion
- ultra-sounds
- photonic or laser
- electronic beam

e) Assembly

- welding by friction
- welding by cold pressure

- welding by ultra-sounds
- welding by electronic bombing
- welding by explosion
- welding by plasma and laser
- gluing
- new clippings
- automation of assembly

8.2.3 Vehicles and components

A) Rotary engine

This type of engine has been developed by the German firm N.S.U. since 1960, but up to now it has not gained much support.

Very briefly, its characteristics may be described as follows:

Advantages	Disadvantages
Compactness	Higher consumption
	High atmospheric pollutior
Diminished vibration (in normal working conditions)	Lower sealproofness
Lower cost price (a priori)	Irregular couple when slow

The main automobile manufacturers have studied this solution by taking out a license or by doing their own research.

. Patent purchase

The following firms have signed licencing agreements with N.S.U.:

. CURTISSWRIGHT - USA (tourism airplane) engine)
. PERKINS - Great Britain (Diesel engine)
. ROLLS ROYCE - Great Britain (gasoline engine)
. M.A.N. - Germany (Diesel engine)
. MERCEDES - Germany (Diesel engine)
. ALFA ROMEO - Italy (gasoline engine)
. MAZDA - Japan (gasoline engine)
. CITROEN - France (gasoline engine)

At present, it seems that Diesel engine manufacturers are abandoning this type of production both because of the difficulty of the manufacture (sealproofness) and the progress in the research on gas turbines.

As far as the gasoline engine is concerned, N.S.U. and MAZDA are developing a small series (a few dozen vehicles a day) but N.S.U. expects to launch a bi-rotor model at a rate of 100 vehicles a day. Furthermore CITROEN is testing a protoype vehicle equipped with this motor. Three hundred vehicles have been built.

In short, it may be concluded that so far the rotary engine has attracted little enthusiasm from the automobile manufacturers and that its success seems doubtful for large series. Furthermore, the recent anti-pollution campaigr tend to further slow down its development.

B) Gas turbines

Studies and protoypes have been made by CHRYSLE in the USA, and ROVER in Great Britain for passenger cars, but it is mainly in heavy truck applications (FORD and GM) that the most spectacular results are expected.

The European Diesel engine manufacturers are closely following these problems (MAN, SAVIEM, ...).

In short, the characteristics of such an engine would be as follows:

. Approximate turbine capacity: 400 HP
. Working conditions: 40,000 RPM
. Automatic speed reducer and transmission (already well developed in USA).

These characteristics will surely mean a higher cost price than the conventional engine, althou the gas turbine would still be adapted to heavy road transportation for long distances.

—

In short, the gas turbine engine will probably be developed for heavy trucks in countries having a long distance road infrastructure that is well developed.

It should be noted that the manufacturing technique differs from that of the conventional Diesel engine (blade made out of a refractary alloy, ceramic regenerator of hot gases, automatic transmission).

A much higher price than for the Diesel engine should be expected and at least 10 or 20 years should be necessary for a general application.

N.B.: Automatic transmission for passenger cars will be well developed in Europe at that time. A price increase of about 10 to 15% should be expected.

C) Electric energy

Here, research is still in the laboratory but automobile manufacturers are following its development closely. It will probably be accelerated as part of the anti-pollution campaign. (*)

(*) Automobile traffic is the most important pollution agent (50% of air pollution).

Apart from its autonomy, it shows a poor performance (maximum speed 60/80 km/h) and a short life span.

a) Batteries

Other types of batteries whose qualities are summarized below have been tested (all of them are more expensive):

Type	Weight (as compared with lead batteries)	Life span (number of recharge
zinc-silver	1/3	100
zinc-gold	1/6	30 to 40
(zinc-air in preparation)	1/10 to 1/15 (but at 300 deg.)	
sulphur-sodium		
lead (as reference)	1	600 to 700
cadmium-nickel	More expensive and heavier than the lea battery but permits better acceleration	

b) Fuel cells

In this case, chemical energy is converted directly and with excellent efficiency into electric energy. Furthermore, these are non-consumable batteries fed with fuel.

The development of astronautics has favored their development, but still only low capacity and very expensive products are manufactured. The use of such fuel cells is completely out of prospect for the automobile, at present.

To date, the hydrogen/oxygen type with 1 kw power (at the beginning) to 32 kw power in one protoype (160 kw maximum) has been studied. Its specific weight is still very high (about 20 kg/kw; a heat engine only weighs 2 to 3 kg/kw).

Hydrogen/air and fuel/air types with a platinum catalyzer may be manufactured but then prices are 100 times higher than the price of conventional engines.

Studies are being done however to improve its characteristics:

- in France: ALSTROM (with PEUGEOT)
  C.G.E. (with CITROEN)
  I.F.P (with RENAULT)
  C.N.I.A.
- in the USA: ALLIS CHALMERS, GENERAL ELECTR
  (Gemini project), PRATT and
  WHITNEY (Apollo project),
  UNION CARBIDE.

In short, here again weight and costs are too high. The purely technical problems have not been all solved (clogging of electrodes). Also, hydrazine fuel will not be marketed for a long time. At the best, the assumption must be that it could only b developed at the end of the century, around 1990!

Engine: an engine using the above energy ma be continuous or alternate. In the latter case, an engine without a collector (rotating very rapidly) is used but it is necessary to create an ondulating current (additional expensive device). Another type of engine: an electronic variable reluctance engine has been created.

Vehicle: electric propulsion thus defined is especially convenient for city delivery vehicles. If the Administration should lay down strict regulations against pollution (in the USA the percentages of released carbon monoxide and unburnt fuel have been strictly defined), it would be possible to manufacture an electric vehicle with a lead battery, of small size and limited speed. However, this would be a city vehicle of limited range and would require an "electric refuelling" infrastructure (electric stations) which has not yet been worked out.

In short, conventional batteries are heavy and have a limited life span. Fuel batteries are expensive and too big for normal capacity. Their development is therefore uncertain and requires a refuellin infrastructure which has not yet been planned.

Therefore no revolution is expected in this field. At the best: an application of this type will not be seen before 20 years.

D) Air cushion

Strictly speaking, there is no application for cars but only possibilities for special vehicles (train, "overcraft" vessel, military engine). The distance above the floor level is proportional to the weight of the vehicle (2 cm. for a 6o T. engine, 1 cm. for a 1 T. vehicle); it still needs a suitable infrastructure.

E) Reaction

The poor performance at low speeds of this method of propulsion excludes for the moment being its use in passenger cars.

F) Nuclear

. The prohibitive weight needed for reasons of protection eliminates this type of propulsion for automobiles.

CONCLUSIONS

Evolution rather than revolution should be expected. In particular, the fiscal system for automobiles in Europe may change, thus permitting the production of more powerful and therefore better balanced (more cylinders) and safer engines. This together with the probable imposition cf speed limits on the motorways will mean that a certain amount of power will be held in reserve.

The example of the U.S.A will confirm this point of view, i.e. the use of more conventional solutions.

In related fields, Europe will probably adopt the automatic gearbox but perhaps not the oleopneumatic suspension since road conditions will no longer make it necessary.

Chapter 9

Cost-volume relationships in a complete manufacturing plant

9.1 Analysis of the investment in relation to the volume of production in a fully integrated plant

In the preceding chapters the investment required for the different techniques used in the automobile industry is indicated in relation to the volume of production. It is observed that certain techniques require large investment, as is the case of machining and the "units" pressing and assembly shops.

In order to have a complete picture of this question we shall now calculate the total investment necessary to set up a complete manufacturing plant integrated at 100% in relation to the output.

Thus a complete manufacturing plant will comprise the following shops and installations:

Foundry;
Forge;
Mechanics: machining, heat treatments, gear cutting;
Bodywork: pressing, welding assembly of "units";
Assembly: final assembly and painting;
Others: utilities: electricity, water, compressed air, gas, heating,
General services and administration: offices, social services.

9.1.1 Classification of investment in a totally integrate plant

Investment will be broken down as follows:

- land and land grading, roads;
- industrial buildings;
- equipment, installations, machines, tooling;
- administrative buildings, offices utilities, general facilities.

The share of each one of these items in total investment is approximately as follows:

Land, land grading, roads	1 to 3%
Industrial buildings	15 to 18%
Equipment	74 to 80%
General services and facilities	5 to 8%
Total Investment	100%

This table shows the importance of the investment in equipment since it represents 74 to 80% of the total investment in a complete plant. This percentage is typical of the engineering industries.

9.1.2 Investment level in relation to production

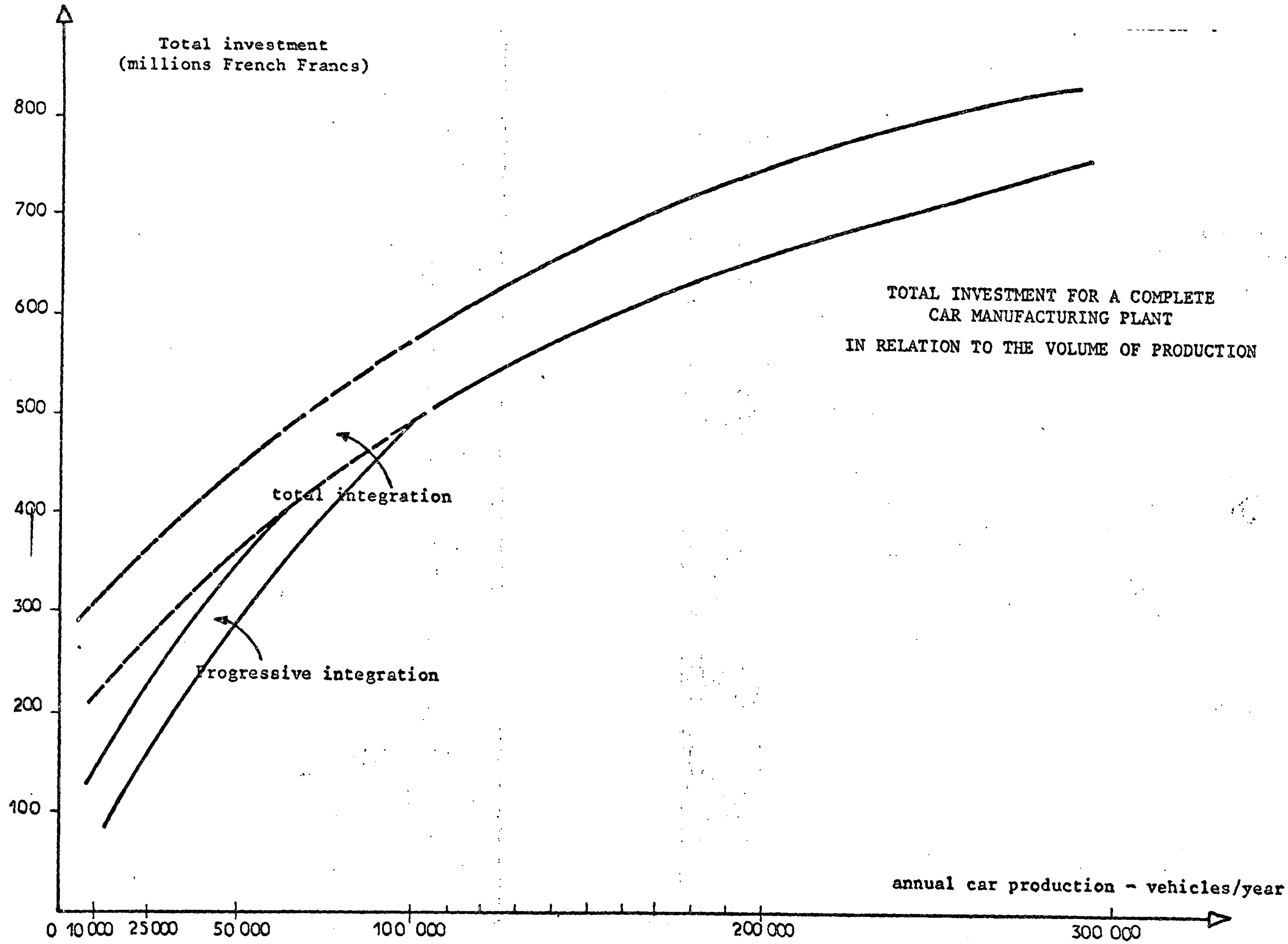
By "totally integrated plant" is meant a plant using all the manufacturing techniques of the automobile industry as is the case of the main international manufacturers. In these conditions, it should be recalled that the value added by the automobile manufacturer is only equal to 45% of the vehicle's cost price, and that the purchase of components or sub-assemblies represents 40% of the cost price of a vehicle.

Therefore, this chapter will survey the investment corresponding only to value added.

The total investment for a complete plant in relation to the volume of production is shown on Chart No. 1.

For rates of less than 100,000 vehicles a year, the investment curve refers to a case of progressive integration. It is well known that for such levels of production, the complete integration of certain manufactures such as pressing is not economical due to the high overcosts. As has been indicated previously, there are different minimum economic levels of production for the different techniques used.

Complete integration for small series is very rare. High production overprices are incurred though they vary according to the techniques used. Therefore, the left part of the investment curve shown in a dotted line and referring to complete integration is theoretical. It is only given for information. It should also be carefully noted that in the case of partial integration the investment will, for a given rate, differ according to the techniques which have been integrated. Thus, there is a rational order of integration generally used by the


Total investment
(millions French Francs)
800
700
600
500
400
300
200
100
TOTAL INVESTMENT FOR A COMPLETE
CAR MANUFACTURING PLANT
IN RELATION TO THE VOLUME OF PRODUCTION
total integration
Progressive integration
annual car production - vehicles/year
0
10 000
25 000
50 000
100 000
200 000
300 000

manufacturers. However, distorsions could exist in different industries in the developing countries (forge and foundry,especially) that might mean faster or slower integration. The decision depends, in this case on the level of development of the industry under consideration in a particular country and the overprices that the automobile industry would incur.

For all these reasons, the investment figures given in Chart No. 1 are approximative.

It will also be observed in the chart that in the case of complete integration, the scale-up factor is fairly constant, about 0.38. This means that when the production is doubled, investment is multiplied by about 1.3.

9.1.3 Breakdown of total investment according to the techniques used

A) The following table shows the different manufacturing shops according to their importanc in total investment of a complete plant:

Forge	2.5 to 3%
Foundry	4 to 5%
Mechanics, machining and mechanical assembly	33 to 35%
Pressing - bodywork - "units" assembly	32 to 35%
Final assembly and painting	13 to 16%
Utilities	3 to 4%
Administration, social services	3 to 4%
Total investment	100%

This breakdown refers to an output of about 100,000 to 300,000 vehicles a year. For lower outputs the plant will not be integrated 100% and therefore the percentages will be different. For example, in the theoretical case of complete integration for small rates, the pressing shop would represent a very high share of total investment, about 45 to 50%.

B) It is interesting to compare the investment made in each shop with the value added by it. For this purpose, a slightly different breakdown may be adopted for investment: each shop is assigned a share of the investment in "utilities" in proportion to the investment in the shop; and a share of the investment in " administration and social buildings" in proportion to the number of persons employed in the shop.

The following table is thus obtained:

	% of value added	% of total investment			
		rate: vehicles/year			
		10,000	25,000	100.000	200,000
Forge	3.3	3.50	3.40	3.30	3.00
Foundry	7.8	2.50	3.30	5.60	6.50
Machining, mechanical assembly	35.6	30	33	34	35
Pressing, welding, assembly of "units"	28.9	47.50	43	37.50	35.5
Final assembly, painting miscellaneous	24.4	16.5	17.3	19.6	20.0
Value added	100				
Total investment		100	100	100	100

It may be observed in the above chart that for high rates, the pressing, welding and "units" assembly shop demands heavy investment compared with the machining shop as the value added is considerably lower. On the contrary, the assembly shop is of great value because investmen is only 20% of the total whereas the value added is about 24%.

In the case of small scales of production, the assembly shop is even more worthwhile (16.5% of total investment) while the pressing shop representing more than 47% of total investment demands, in comparison with other shops, a capit outlay which is out of proportion with the value added. Furthermore, if investment alone is considered, the machining shop is the most worthwhile for low rates because the value added in this shop is about 35%. This fact must however be corrected in the case of the machining shop by considering the cost of machining: in chapter 3, it has been observed that for small scales of production, this cost was very much higher than the minimum cost obtained by a large manufacturer.

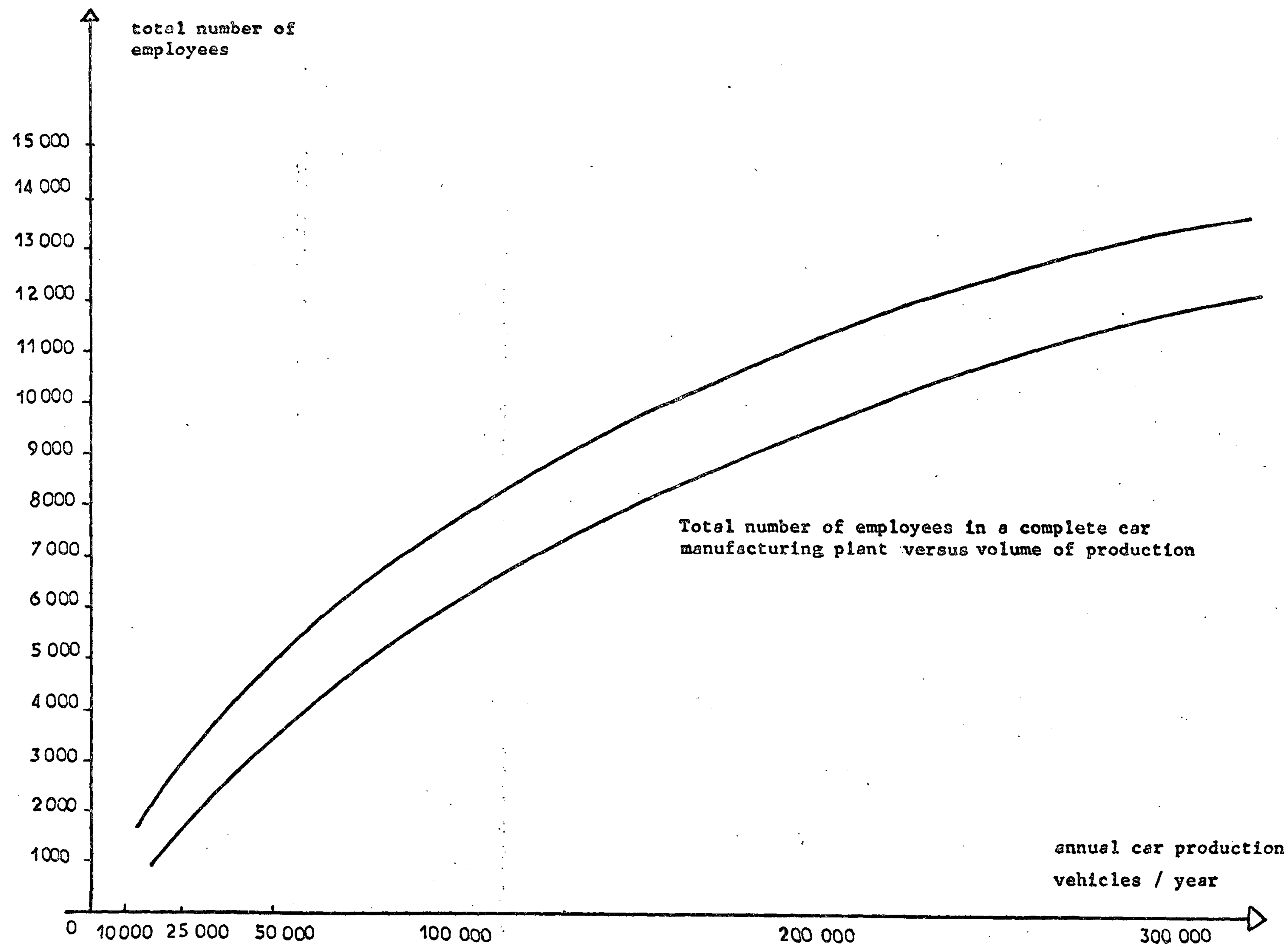
Thus, if one is guided only by the importance of the investment to be made, a theoretical order of integration of techniques for an automobile manufacturer gradually emerges. In a developing country this order would be as follows:

- final assembly;
- machining;
- foundry;
- pressing;
- forge.

C) Analysis of investment according to the number of persons employed, and the technique used

For the purpose of information, Chart No. 2 indicates the number of personnel employed in a complete plant in reference to production.

If this chart is compared to Chart No. 1, it may be observed that the investment per person employed is about 70,000 to 80,000 FF in the


total number of employees
15 000
14 000
13 000
12 000
11 000
10 000
9 000
8000
7 000
6 000
5 000
4 000
3 000
2000
1000
0
10000
25 000
50 000
100 000
200 000
300 000
Total number of employees in a complete car manufacturing plant versus volume of production
annual car production
vehicles / year

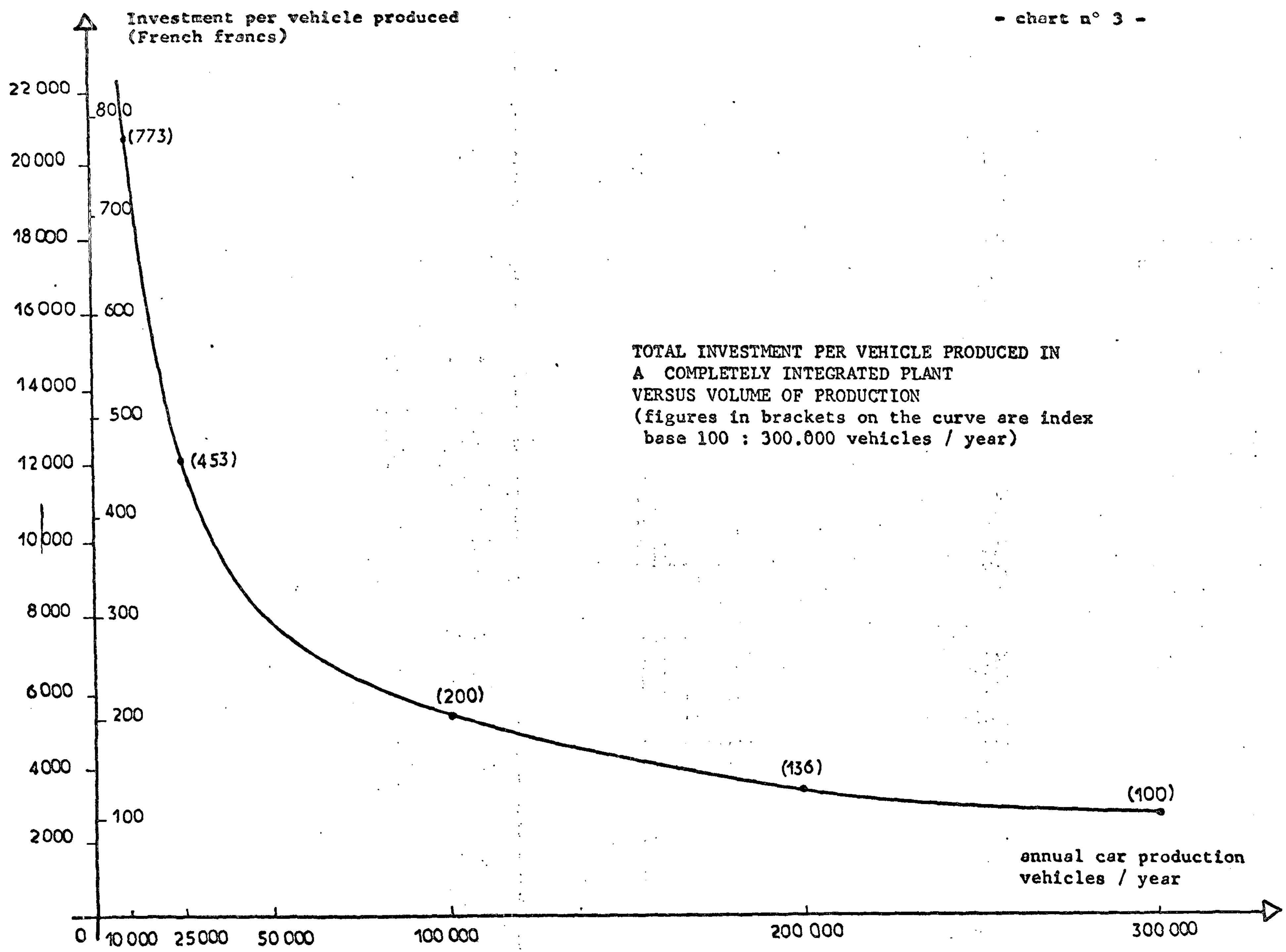
automobile industry for large scales of producti
This is in fact a global figure which does not show the differences between each shop because the investment per person employed varies considerably according to the technique used, as is shown in the following table:

Technique	Investment per person employed (FF)
Forge	70,000 to 80,000
Foundry	50,000 to 60,000
Machining	80,000 to 90,000
Pressing	150,000 to 250,000
Assembly	40,000 to 50,000
Complete plant	70,000 to 80,000

9.1.4 Investment per vehicle produced in relation to volume of production

In order to emphasize the effect of economy of scale in reference to total investment in a complete plant, total investment per vehicle produced annuall according to different production rates has been calculated (Chart No. 3).

This chart shows that twice as much must be invested per vehicle to be manufactured for 100,000 vehicles a year instead of 300,000; and that 4.5 times more must be invested per vehicle if only 25,000 are to be produced a year.


- chart n° 3 -
Investment per vehicle produced
(French francs)
TOTAL INVESTMENT PER VEHICLE PRODUCED IN
A COMPLETELY INTEGRATED PLANT
VERSUS VOLUME OF PRODUCTION
(figures in brackets on the curve are index
base 100 : 300.000 vehicles / year)
22 000
20 000
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
800
700
600
500
400
300
200
100
(773)
(453)
(200)
(136)
(100)
annual car production
vehicles / year
0
10 000
25 000
50 000
100 000
200 000
300 000

Such disparities heavily penalize the developing countries whose production is relatively small and whose financial capacity is always very limited. This fact would tend to prove that developing countries should try to group their automobile production to promote the setting up of large automobile production units. This would be the only type of unit which could economically compete with the main world manufacturers.

9.2 Study of production overprices of a complete vehicle in relation to the volume of production

9.2.1 Definition of manufacturing overprice of a complete vehicle

The manufacturing overprice of a complete vehicle will be equal to the sum of the overprices of each technique used, weighted according to the share of each technique in the cost price of the vehicle. The weighting factors used are those shown in Table No. 2 in Chapter 1 (General Data on the Automobile Industry).

In addition, we investigated the orders of magnitude of the overprice of a vehicle produced by a large manufacturer according to volume that was produced.

The figures thus obtained are in good agreement with the results obtained by the calculation based on the overprices for the different techniques.

All of these observations are shown on Chart No. 4 where the average overprices for a complete vehicle are indicated in relation to the annual automobile production.

9.2.2 Survey of the results

It is important to observe that the overcosts given correspond to a progressive integration achieved in rational order, such as it is usually done by a manufacturer with the manufacturing techniques best adapted to each rate of production.

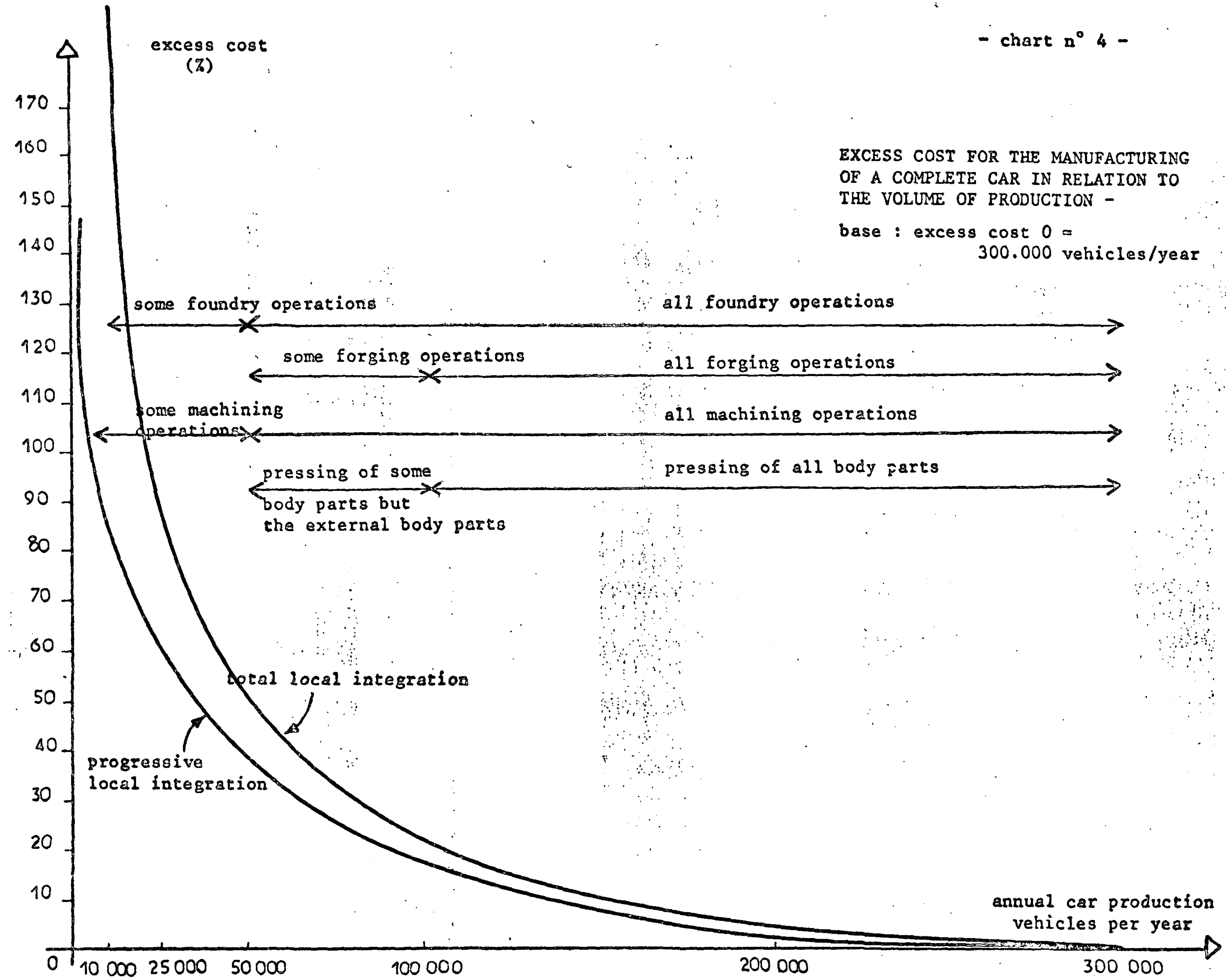
It has been observed that for each rate of productio and for each technique employed there is an optimum method of manufacture which minimizes overprices. This is true in particular of the machining and pressing shops.

It has also been seen that in certain cases it is more economical to sub-contract part of the work and sometimes the whole of the work (forge, foundry, pressing).

It is only in these operating conditions that minimum overprices will be obtained for each rate of production as shown on Chart No. 4.

In order to bring out these facts more clearly the chart shows the manufacturing methods used for each rate of production.

- chart n° 4 -


EXCESS COST FOR THE MANUFACTURING
OF A COMPLETE CAR IN RELATION TO
THE VOLUME OF PRODUCTION -
base : excess cost 0 =
300.000 vehicles/year
excess cost
(%)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10 000
25 000
50 000
100 000
200 000
300 000
annual car production
vehicles per year
some foundry operations
all foundry operations
some forging operations
all forging operations
some machining
operations
all machining operations
pressing of some
body parts but
the external body parts
pressing of all body parts
total local integration
progressive
local integration

Generally speaking, the minimum cost price in automobile construction is only reached for volumes of about 300,000 vehicles a year.

For smaller scales of 10,000, 15,000, 25,000 50,000 and 100,000 vehicles a year, which are typical successive levels of development of an automobile industry, high overprices as compared with the cost prices of large car-builders, must be absorbed. Each level of development correspond to an optimum degree of integration and to manufacturing methods adapted to the rate of production in question (see table below).

Annual rate	Overcost %	Techniques employed					
		Foundry	Forge	Machining	Pressing	Assembly of units	Final Assembly
10,000	80 to 90	partially	no	partially	no	partially	total
15,000	75 to 85	partially	no	partially	no	partially	total
25,000	60 to 70	partially	partially	partially	no	partially	total
50,000	40 to 45	largely	partially	largely	inner parts	total	total
100,000	15 to 20	total	total	total	total	total	total
300,000	0	total	total	total	total	total	total

B) Total integration

In the theoretical case of complete integration for small scales of production, the overprices would be very high.

At a rate of 10,000 vehicles a year the overpric would be about 200% and for 25,000 vehicles a year it would be 90 to 100%.

It is only at a level of 50,000 vehicles a year that the overprice, in the case of total integration, is comparable to the minimum overprice for progressive integration though it is still about 50 to 55%.

9.3 Effect of the degree of local integration on the manufacturing cost

9.3.1 Survey of the problem

It is interesting to see how the cost of manufacturing a complete vehicle varies as the degree of local integration increases in a developing country

It is, however, difficult to establish precisely the relationship between the rate of integration an the manufacturing cost. The only indications that may be obtained in this respect are furnished by th car-builders by comparing the cost price of a vehicle produced on a large scale and the cost price in different countries where output is somewhat low, with all the inaccuracies such a method involves.

The results obtained result from the following factors (taxes are excluded):

- modifications made in order that the vehicle may be better adapted to the working conditions of each country;
- the number of different models and versions, manufactured by the same plant;
- conditions of local manufacture (organization of production and equipment chosen);
- sales price of the C.K.D. collection;
- importance of local integration and quality of the choices made between imported and domestic parts;
- productivity and cost of the labor employed;
- transportation cost of the imported parts delivered by the foreign manufacturers.

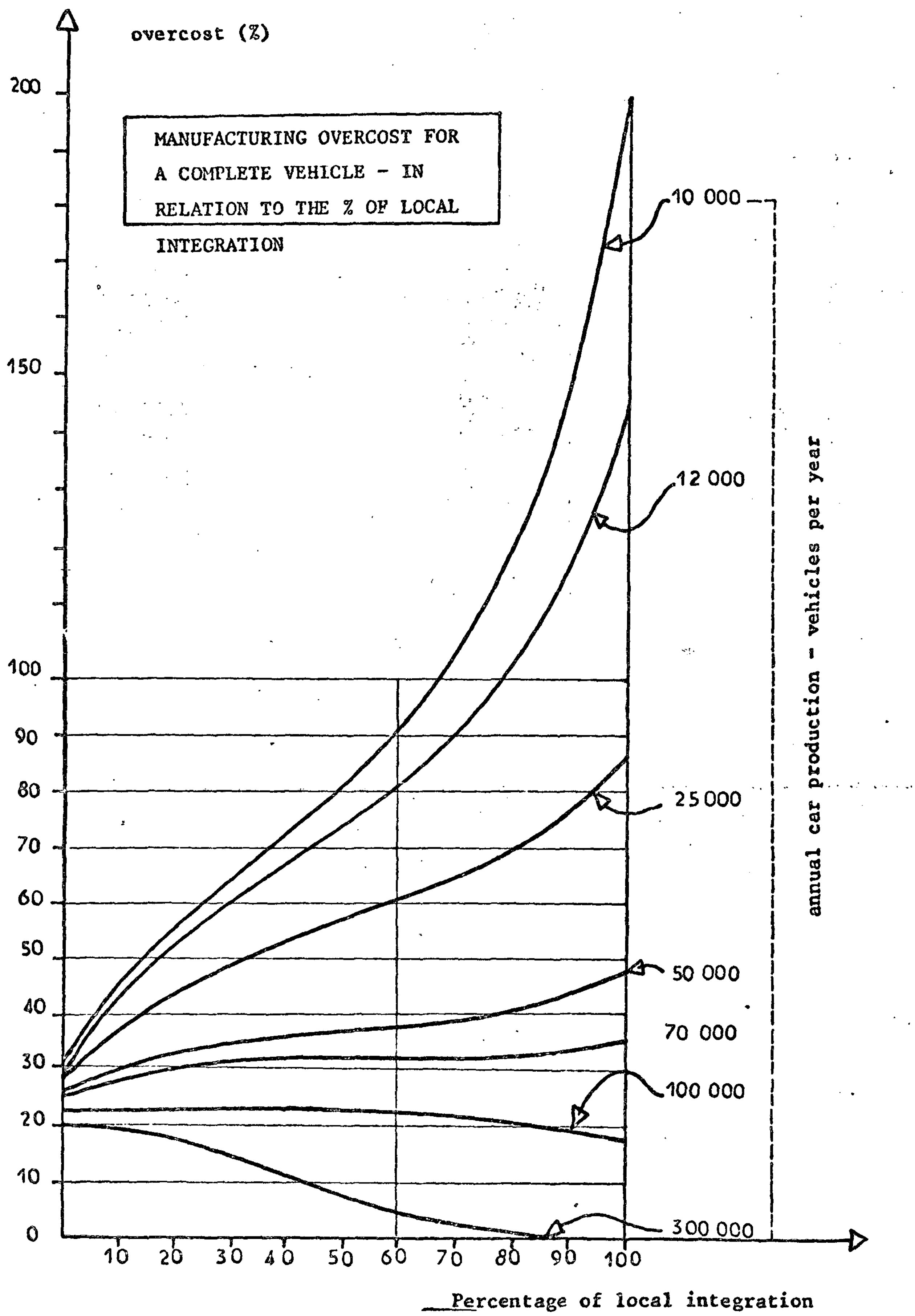
Bearing in mind these factors, the theoretical variation of the cost price of a vehicle in relation to the degree of local integration and according to the different volumes of production, may be ascertained by examining the cost price of the different parts which make up a vehicle, grouped by categories.

All these observations are shown on Chart No. 5

It must be indicated that several important hypotheses had to be adopted in order to establish this chart:

- whole production is based on a single basic model which may have several related versions;

- chart n° 5 -


overcost (%)
MANUFACTURING OVERCOST FOR A COMPLETE VEHICLE - IN RELATION TO THE % OF LOCAL INTEGRATION
200
150
100
90
80
70
60
50
40
30
20
10
0
10 000
12 000
25 000
50 000
70 000
100 000
300 000
annual car production - vehicles per year
10 20 30 40 50 60 70 80 90 100
Percentage of local integration

- the increase of the integration rate is done rationally: the first manufactures considered are those whose effect on the final cost price is most reduced. However, this is not always the case.
- for each rate of production, the most economical manufacturing technique is adopted.

9.3.2 Examination of overprice curves in relation to local integration (Chart No. 5)

A) No integration

This covers plants which only do the final assembly, and no other operation. Table No. 6 in Chapter 2 shows how the cost price of a vehicle (dealer's price) was calculated from the price of the C.K.D. collection, including gathering, packing, and transportation of the C.K.D. set.

In the completely theoretical case of an assembly plant producing 300,000 vehicles a year, it is known that the assembly price is 10% of the price of the C.K.D. collection. In these conditions, the dealer's price would be 130: the price of the C.K.D. would be fixed at 100 and packing and transport expenses would be estimated at 20.

On the contrary, in a plant which is 100% integrated, producing 300,000 vehicles a year, the cost price of a vehicle will only be 110.

Therefore, the assembly plant alone incurs the following overcosts compared with a completely integrated plant of a large car manufacturer.

<u>No integration: Overprice for the dealer's price</u>
(Overprice zero = cost in a completely integrated plant producing 300,000 vehicles/year)

Rate of production vehicles/year	10,000	25,000	100,000	300,000
Overprice %	30	27	22	20

These values will help to determine the ordinat for zero integration of each overprice curve shown on Chart No. 5.

Thus, it may be seen that even in the absence of integration there are fixed charges, so that the minimum overprice is 20% (theoretical case of an assembly plant producing 300,000 vehicles a year). These charges, which cannot be reduced correspond to gathering, packing and tranportati expenses of the C.K.D. collections. Assembly costs must be added to these charges, and assembly costs rise as the assembly rate falls (see Chapter 2).

B) High rates of integration

As local integration rises, the production overprice also rises. And the lower the rates of production the higher the overprices. In particular, in the case of high integration, th overprices are very high because of the effect of the investment in pressing equipment on the cost price (effect of the depreciation charges) However, for a sufficiently high production rat of about 50,000 to 70,000 vehicles a year, the volume effect, due to the number of vehicles produced, considerably reduces depreciation charges per vehicle. Thus the increased rate of integration only causes a small increase in t initial overprice, which is about 30 to 40%.

For outputs of 100,000 vehicles a year or more, the increase in the integration rate reduces , on the contrary, the production overprice. The figure of 100,000 vehicles seems to constitute an important threshold since the overprice is approximately constant (15 to 22%) whatever the integration rate.

It is fairly obvious that in the case of complet integration, the overprice will be similar to those indicated on the upper curve in Chart No.

A production level of 100,000 vehicles a year is the minimum for the making of a completely "national" vehicle in satisfactory conditions. However, it is only for rates of more than 200,000 or even 300,000 vehicles a year that the totally integrated manufacture of a vehicle becomes profitable and competitive at international level.

9.3.3 Factors relating to the development of local integration

The curves on Chart No. 5 show that the fixing of the local integration rate determines the price at which the vehicle will be manufactured. However, this supposes that on the one hand, local incorporation will be done in the most rational order, and on the other, that the industrial development of the country is coherent with the degree of national content chosen.

The curves show that the "last percentages" of local incorporation are expensive, so that the increase of local incorporation must be in line with the development of industries on which car manufacturing relies rather than being uselessly in advance; which would mean that overprices would be very high.

The main concern of a manufacturer in a developing country, must thus be to integrate locally in the most convenient order and at a careful rate.

It is well known that the first points or percentages of national content are achieved easily with the manufacture of batteries, tires, seats, bumpers, exhaust manifolds, ... etc. However the setting up of assembly and machining shops for a given unit (engine, gearbox, steering, ... etc.) requires large investment which is only worthwhile if this allows important local incorporation. This is one of the most difficult problems in a developing country.

Also, for an identical installed capacity, investment is higher in a less industrialized country than in Europe, mainly because of:

- the cost of transporting the equipment;
- the relatively high construction costs for buildings;
- the cost of creating industrial areas;
- the cost of the training of workers;
- the cost of foreign technical assistance.

For these reasons, the figures indicated for the curves in Chart No. 5 will be probably much higher.

In order to reduce overprices, and at the same time have a relatively high local incorporation rate, one or more of the following solutions could be considered:

- <u>optimal localization of the plant</u>;
- <u>purchase of second-hand pressing tools</u>;

The conventional pressing tools necessary for the manufacture of a model represent an investment of about 60 to 70 million francs. Therefore, second-hand tools could be bought from a firm which for marketing reasons has decided to change its model and thus has available tools that are still good enough to produce about 300,000 vehicles. However, this has a strong disadvantage: that of producing a vehicle whose line would already be "old fashioned though the mechanical design would be still very modern.

- renting of tools and moulds

The purchase of the tools and moulds specific to a model may represent as much as 50% of the value of the machines.

In order to avoid depreciating over a small number of vehicles this high and specific investment, the rental of tools and moulds could be considered in order to produce in a very short period the vehicles usually manufactured in one year.

However, each case should be treated individually and be thoroughly examined.

- Use of pressing tools suitable for small series

This refers mainly to plastic tools and all the benefits derived therefrom.

- Compensation or cooperation agreements with the neighboring countries

This is a new possibility that should interest the countries in the same geographical area, or belonging to a free trade area, for example.

This would enable each country to attain the critical mass for the manufacturing technique used and favor the exportation of manufactured products that would have a guaranteed market.

Such agreements are naturally difficult to reach, but they would permit the industry of each one of the interested countries to compete with the big international firms, since a clear reduction in manufacturing overprices would be achieved.

9.4 Effect of the number of models on production costs

The unfavorable effects of the number of models has been stressed repeatedly in the preceding chapters, both from the point of view of the investment required and the cost price of production. These effects are more pronounced for low outputs.

For each given model, specific tools and equipment has to be purchased and it should be recalled that depreciatio charges are very high in the case of low output. A world manufacturer produces a minimum of 300,000 cars of a given model and many times he will manufacture 1'000,000 cars of the same model. Organization and setting up expenses as well as machine and tool depreciation are thus well distributed over very large productions.

In the case of industrializing countries whose national markets are often small, if cost prices similar or close to those of the main constructors are desired, it would be necessary to give the models a longer life than in Europe and, a fortiori, than in the USA.

. Considering the size of national markets it would be necessary to:

- produce only one model;
- "freeze" the model chosen for a period of 12 to 15 years, i.e. the life span expected by European manufacturers for their most popular models.

Chart No. 5, showing the cost-volume phenomenon in the automobile industry, indicates clearly that for the same integration rate, 60% for example, the overprices in a country with a market of only 25,000 vehicles would be as follows:

- manufacture of a single model: overprice of about 60%;
- manufacture of two models: overprice of about 70 to 80%.

For higher local integration rates, the distorsion of the results would be even greater. The cost price could be multiplied by 1.5 if two models instead of one are built. By model is meant an entirely different vehicle with practically no common units.

Thus if a country wishes to produce at the lowest possible cost, it should choose to manufacture a single model. This model should be chosen in a way to satisfy most of the needs of the public, and should have a very long life span, at least 12 years, if possible 15 years. It is desirable to choose a modern model so that it will not become obsolete too rapidly.

This model should also make it possible to built a small derived industrial vehicle in order to cater for an important group of customers looking for a "commercial vehicle" (delivery van, small station wagon). This "variation" should differ as little as possible from the basic model in order to reduce the price to a minimum.