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WORKING GROUP ON ECONOMIES OF SCALE IN
THE LATIN AMERICAN AUTOMOTIVE INDUSTRY

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COST-VOLUME RATIOS IN THE MOTOR-VEHICLE INDUSTRY- FINAL ASSEMBLY

prepared by

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Note: The meeting of this Working Group is one phase of the project "Prospects and possible forms of regional integration in the automotive industry in Latin America" that is being carried out by the Economic Commission for Latin America (ECLA) and the Inter-American Development Bank (IDB), with the collaboration of the United Nations Industrial Development Organization (UNIDO).

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/The question

The question of assembly costs is of special importance when a country, irrespective of the way it handles the manufacture of parts and components, has undertaken to establish one or several assembly plants. In the major industrialized countries, there are a large number of plants engaged in the final assembly of all the various parts and components produced by different plants.

There are many different types of assembly plants, each having a different approach and form of organization depending on the volume produced: they range from plants producing only a few vehicles per day (3 to 5 in some extreme cases) to highly automated plants with very large production runs (100,000 vehicles or more per year).

One reason why there are so many assembly plants in the world is that it is cheaper to transport CKD units than built-up units, the transport costs varying considerably depending on volume. Another reason is that, for developing countries, the establishment of an assembly plant is the first step along the road towards industrialization since it is in the assembly plant that locally manufactured parts or components are combined with imported parts or components to create the complete vehicle delivered to the consumer.

The present paper will begin by considering the operations involved in final assembly and the way in which installations are modified as production volumes become greater, and then go on to examine how investment varies in relation to production volumes and the effect of the cost-volume ratio on production.

21. Brief description of final assembly operations

Final assembly operations comprise the assembly of the parts and components making up a vehicle from a CKD set. It should be noted, however, that some components may already have been assembled during operations at an ealier stage. The aim of final assembly is to assemble a complete vehicle in running order ready for delivery.

/Diagram 1

Diagram 1 shows the interrelationship of all the different operations involved in final assembly, i.e. the logical sequence of operations leading up to the production of the complete vehicle. These operations can be broken down into the following categories:

Receipt of CKD sets - unpacking - storage
Assembly of body - welding line
Painting line
Upholstery line
Mechanical parts and finishing line
Finishing line - delivery

211. <u>Receipt of CKD sets - unpacking - storage</u>

Before assembly proper begins, parts and components have to be unpacked and checked for quantity and quality, whether imported or of local manufacture. The set of components, sub-components, parts and accessories comes in a number of containers holding the following:

Body parts and components
Mechanical parts and components
Upholstery parts and trim
Seat frames and supports
Other

After being unpacked, containers are sent to the assembly lines and placed where needed at the various assembly points.

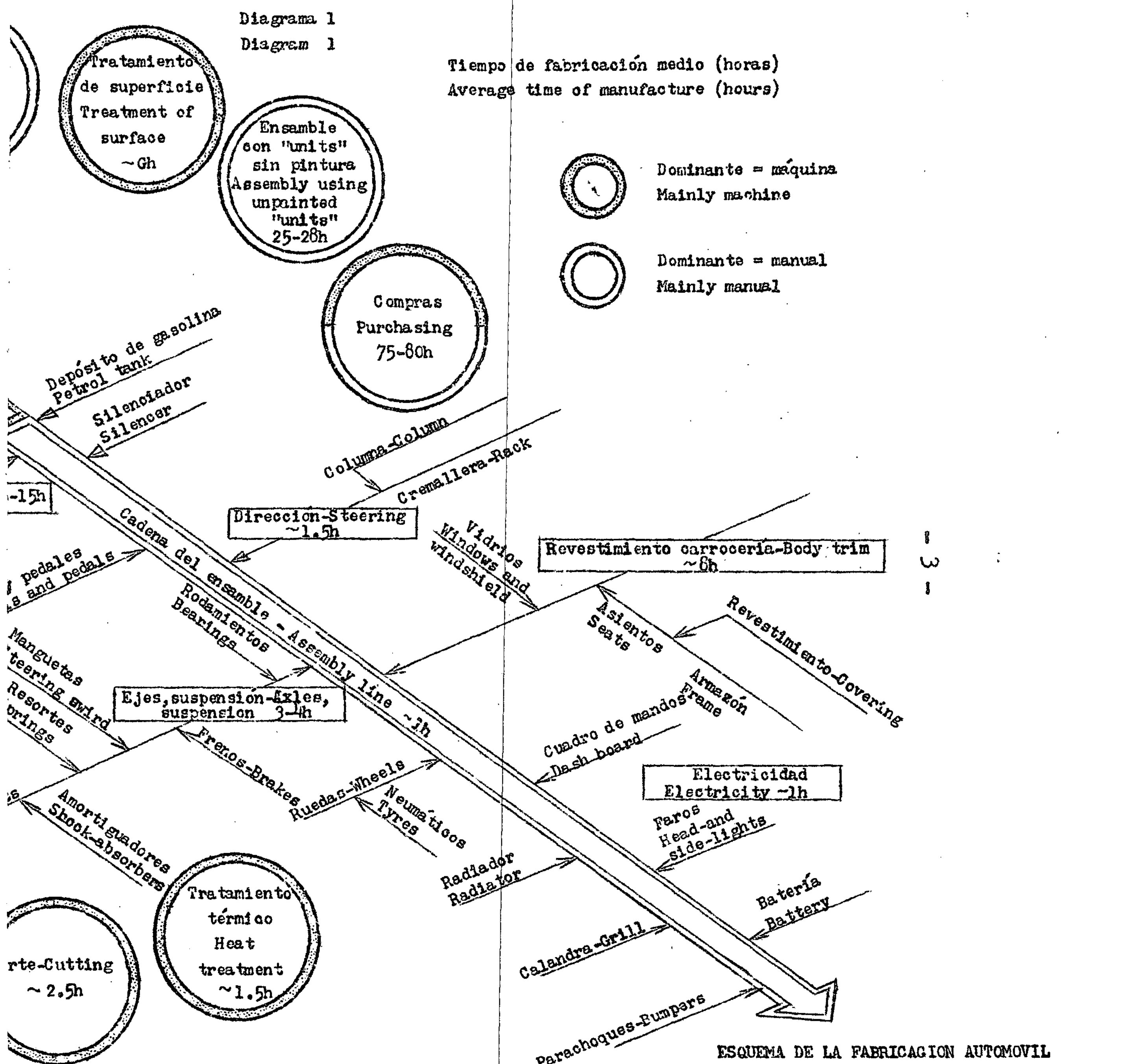
212. <u>Assembly of body - welding line</u>

Note that the term "unit" refers to a bodywork component made up of several pieces of sheet.

(a) The first section assembles certain units with which, for transport reasons, are sent incomplete or even completely unassembled.

(b) The second section carries out the basic assembly of the body using units placed on specific frames, either fixed or pivoting, known as assembly jigs. This section has resistance welding equipment (spot welders) which may be installed either on a travelling gantry or fixed to the overhead beams of the plant.

/Diagram 1



ESQUEMA DE LA FABRICACION AUTOMOVIL
THE MANUFACTURE OF A MOTOR VEHICLE

(c) Once the body carcase is assembled it is placed on a special cart and goes down the welding line where it receives:

Further welding for purposes of structural rigidity or sealing;

Removable units such as doors, bonnet, wings, etc.

213. <u>The painting line</u>

The unpainted body leaves the welding line and enters the painting shop where it is moved by conveyor system through the various sections in the following order:

Degreasing, phosphating, rinsing
Oven drying
Anti-corrosion under-sealing
Two coats of undercoating
Baking of undercoating
Top coats of enamel
Baking of enamel
Retouching

214. <u>The upholstery line</u>

(a) The upholstery line proper is mentioned here simply pro memoria since body accessories, including seats, often arrive completely made up from local plants. It involves cutting and sewing the interior trim and, in the case of plastic trim, high frequency welding.

(b) The body accessories and wiring line: the vehicle is provided with inside equipment and accessories, windows, windshield, electrical wiring, steering column, door and roof trim, sealing strips, dashboard, headlights, external trim, etc.

215. <u>Mechanical parts and finishing line</u>

In addition to assembly proper, a number of preparatory operations are necessary and are carried in parallel sections, for example:

Assembly of motor and gear box
Installation of chassis equipment and suspension,
Braking and steering system.

/In the

In the mechanical parts and finishing line, the body is placed over the mechanical components mentioned above. The components are installed and regulated along the production line, with a final check being made at the pit at the end of the line, after which point the vehicle in running order is handed over to the controllers and testers.

216. Finishing-delivery line

After being test-driven, the vehicle is checked and mechanically regulated and the paintwork is touched up in a special room. It is then tested for leaks and passed on for cleaning and polishing.

22. Investment requirements for final assembly plant

To give an idea of the weight of a final assembly plant in a complete manufacturing plant, the investment required for final assembly accounts for roughly 10 to 15 per cent of the total investment needed for a plant producing 100,000 vehicles per year with a local content of 95 per cent.

221. Categories of investment

Investment requirements fall into four categories:

Land, services and roads
Buildings
Equipment, machines, tools
General facilities and ancillary services

Generally speaking, these categories account for the following proportions of the total:

Land, services, roads	5%
Buildings	35 to 40%
Equipment, machines, tools	45 to 35%
General facilities	15%
Total investment	100%

/(a) It

(a) It should be noted that the surface area of land and covered buildings is much larger than for a machining or pressing plant. However, the amount of investment required for equipment and tools is much less.

(b) The volume of investment in buildings is also dependent on the climate of the country concerned, the cost per covered square metre increasing threefold between a tropical zone country and a country near the arctic circle, as shown below:

Country	Venezuela	France	Finland
Cost per covered square metre (French francs)	200	450 to 500	650

(c) If the assembly and painting lines are highly mechanized and automated, the amount of investment required for equipment may increase substantially. In this respect, the painting line poses a particular problem for it alone may account for more than 20 per cent of the total investment required in a highly mechanized assembly plant. It should be noted that a great deal of thought must be given to the capacity of the painting line since in most cases it constitutes a bottleneck in the assembly line. Increasing the capacity of the painting line requires a sizeable amount of investment and it should therefore be designed on a large scale when installed so that it will be able to cope with any future increase in total assembly capacity.

222. Ratio between total investment and annual output

Figure 1 shows the results of studies of the amount of investment needed at different levels of production, with annual output on the abscissa and average total investment required on the ordinate.

Note: The cost of land was not taken into account. The investment levels indicated therefore cover investment in buildings and roads; equipment, machines and tools; and general facilities and ancillary services.

/Figure 1

Figure 1

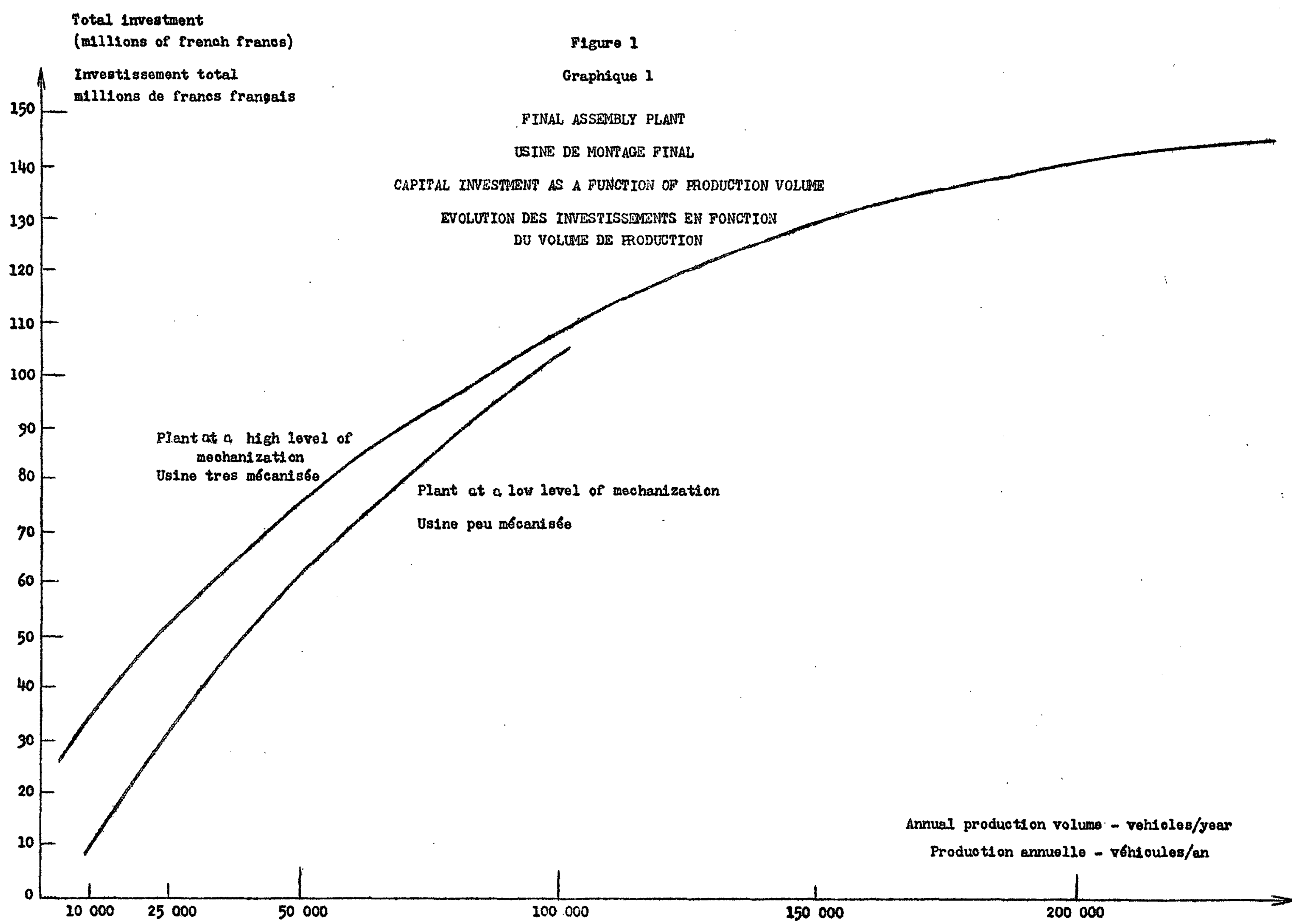
Graphique 1

FINAL ASSEMBLY PLANT

USINE DE MONTAGE FINAL

CAPITAL INVESTMENT AS A FUNCTION OF PRODUCTION VOLUME

EVOLUTION DES INVESTISSEMENTS EN FONCTION
DU VOLUME DE PRODUCTION



At low production volumes, it was found useful to consider plants with the same capacity but different degrees of mechanization. The figure therefore contains two curves: an upper curve, corresponding to a highly mechanized plant; and a lower curve, corresponding to a plant with a low level of mechanization.

At production volumes above 100,000 vehicles per year, the curves tend to follow the same path since at such levels assembly plants are always highly mechanized. The figures given apply to plants in temperate-zone countries.

A. The effect of economies of scale

There are three areas on the total investment curve:

(i) From 0 to 25,000 vehicles per year. In this case the scale-up factor is about 0.7. This would mean that to increase capacity fivefold, from 5,000 to 25,000 vehicles per year, investment has to increase threefold. Moreover, in plants at a low level of mechanization, investment has to increase slightly more than proportional to capacity, while in a highly mechanized plant the increase is less than proportional because, logically enough, the highly mechanized plant has had mass production equipment from the outset.

(ii) From 25,000 to 100,000 vehicles per year. In this case the scale-up factor is about 0.6. Investment would have to increase from 45 million francs to slightly over 100 million francs in order to raise production capacity fourfold.

(iii) At levels of production above 100,000 vehicles per year the curve has a clearly downward trend and the scale-up factor is only 0.4, i.e. investment needs to increase much less than proportionally to capacity. To raise output from 100,000 to 200,000 vehicles per year, investment has to increase roughly 1.3 times, which is to be expected since at this level plants are always highly mechanized.

B. Influence of mechanization on the level of investment

Figure 1 shows that the influence of mechanization on investment is particularly strong at low levels of output. As mechanization increases and production capacity rises, this problem becomes less and less apparent.

/Since the

Since the level of investment in a highly mechanized plant may double at volumes of production less than 25,000 vehicles per year, it may be useful to consider in which sections of the assembly plant mechanization may be involved.

(i) While it is admissible to use a fixed assembly line for very low levels of production, say 15 vehicles per day (3,750 vehicles per year), it is essential to automate the line once output rises to about 6,000 vehicles per year. Above a rate of around 3 vehicles per hour, the assembly line should be mechanized, and this entails a high level of investment in floor-mounted and elevated conveyors.

(ii) The paint shop is also very much affected by the volume of production. At very low outputs, less than 2 vehicles per hour (4,000 vehicles per year), it is admissible for painting to be done in an enclosed space using spray-guns. Once output moves above 2-3 vehicles per hour, it is necessary to mechanize the line. However, the amount of investment may be less if painting is done by means of spot dipping. At high levels of production, above 4 vehicles per hour, it becomes preferable to replace spot dipping with automated dipping. At this level of output, painting is generally done by means of electrophoresis, which involves a very high level of investment.

(iii) The above explains why the level of investment increases rapidly at low levels of output. It should be noted, however, that a deliberate decision may be taken to set up a highly mechanized assembly plant, even if not justified by the level of output, if output is expected to increase some time in the future or if it is wished to limit the amount of labour used because labour costs are high.

C. Influence of the number of models on the level of investment

(i) Assembly line

(a) Increasing the number of models involves only a fairly small increase in investment, mainly for assembly patterns or jigs specifically designed for each model and for control equipment. In particular, a control jig will be required for each model. The additional investment required for the introduction of a new model is roughly as follows:

Main assembly jig

Average cost for a small vehicle	100,000 FF
Approximate cost for a medium-size vehicle	300,000 FF

Control jig: this is simply an unpainted carcase strongly braced to make it very rigid:

Approximate cost for a small vehicle	10,000 FF

Secondary assembly jigs:

Floor jig
Side jig
Door jig, etc.

These are often made in the plant and are therefore less costly.

(b) Additional investment in spot-welding equipment may be required, depending on the degree of mechanization of the welding line. If the line is not very mechanized, a travelling welder with simple equipment is used. This can be used for different models and therefore no additional investment is required. If the line is comparatively more mechanized, multiple spot-welders are used which are generally designed specifically for a particular model. If an additional model is introduced, it is also necessary to take account of investment in resistance welding equipment, which would range between 150,000 FF and 500,000 FF for a medium-size vehicle. It should be noted that, if the body shell is to be assembled, investment in welding equipment may rise as high as 1,000,000 FF.

(ii) <u>Painting line</u>

Irrespective of the level of mechanization, introducing a new model will not entail additional investment in the painting line.

/(iii) The

(iii) The upholstery line

Here, too, a new model does not require additional investment. But the shop assembling body accessories will require a slight amount of additional investment if a new model is introduced.

(iv) Storage of CKD sets

Introducing a new model obviously entails an increase in the storage area to provide enough space between the different containers holding the sets for each model. This will involve investment in warehouses or covered storage areas, or in land if the climate permits storage in the open air.

D. Level of investment at different production volumes

Table 1 gives a breakdown of investment by the major categories at different production volumes. For low production volumes, the table distinguishes between a highly mechanized plant in a temperate-zone country and a plant with a low level of mechanization in a tropical-zone country.

The figures are only rough orders of magnitude and are averages, the uncertainty spread being 20 per cent at low production volumes and 10 per cent at high volumes.

The table is basically designed to give a clearer idea of the relative size of investment in each category and of the influence of economies of scale. The figures, it must be stressed, are relative only, absolute values not being of any great importance in the context of the present study.

/Table 1

Table 1

BREAKDOWN OF INVESTMENT FOR AN ASSEMBLY PLANT BY VOLUME OF PRODUCTION a/

	Production volume vehicles per year	Land		Buildings		Investment: equipment and tools				Facilities and ancillary services	Total investment excluding land
		Area m2	Invest. FF	Area m2	Invest. FF	Bodywork assembly	Painting	Upholstery	Mechanical parts and finishing		
HIGHLY MECHANIZED PLANT TEMPERATE-ZONE COUNTRY	10 000	60 000	Pro memoria	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		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
PLANT WITH LOW LEVEL OF MECHANIZATION TROPICAL-ZONE COUNTRY	10 000	60 000	Pro memoria	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

a/ Approximate figures giving a reasonable order of magnitude for investment.

/23. Study of

23. Study of assembly costs

This section, which deals with motor-vehicle assembly costs, describes the various parametres and examines each in terms of the intended assembly rate. In this way, it should be possible to indicate the cost penalty for the entire assembly operation at successive stages of production.

The influence on the assembly cost of the degree of mechanization and the variety of models being manufactured on the same production line will also be examined.

231. Motor-vehicle assembly cost parametres

Generally speaking, the assembly cost of a vehicle can be broken down into four main elements:

- direct labour costs
- manufacturing costs
- overheads
- depreciation

in which the assembly cost corresponds to the value added by the assembly plant.

A. Direct labour

It is not always easy to distinguish direct labour from the over-all labour factor in a plant.

It shall here be taken as meaning the workers directly involved in assembly operations, those responsible for unpacking and sorting CKD kits and the handling staff.

For the most part, these workers are relatively unqualified (OS1-OS2) and paid by the hour.

In addition to direct wages, labour costs include social security payments, holiday bonuses, productivity bonuses and other special benefits (sickness, transport, etc.).

B. Manufacturing costs

Manufacturing costs relate to expenditure necessarily involved in assembly operations which is directly affected by the level of production.

These are usually grouped as follows:

(a) variable manufacturing costs, which grow in proportion with the rate of assembly; namely:

/-supplies

- supplies (paint, oil, rags, etc.)
- small tools
- power and industrial fluids (electricity, gas, compressed air, water)

(b) semi-fixed manufacturing costs, which do not vary in proportion with production but increase in successive stages, above all:

- indirect labour (cadres, plant officials)
- maintenance

C. <u>Overheads</u>

Overheads are costs that are not connected with production but come about by the mere existence of the factory. They are frequently referred to as administration costs, or structure costs.

The most important items under this heading are:

- remuneration of managerial and administrative staff
- travel expenditure
- technical training costs
- miscellaneous overheads (office supplies, administration)
- financial costs

<u>Note</u>. The level of overheads in a plant of a given capacity can be taken as a measure of its general efficiency and standard of management.

D. <u>Depreciation</u>

This covers the cost of depreciation of the fixed assets required for the plant's production capacity.

Fixed assets are normally listed under three headings according to their rate of depreciation:

- buildings
- equipment and machines
- tools

The corresponding maximum annual allowance for depreciation is determined by law in each country.

Depreciation figures are a reflection of this unavoidable drop in value and generally appear in a special account. They should be fixed at such a level as to permit the restoration of the initial manufacturing capacity when the corresponding fixed assets are completely depreciated.

Depreciation is therefore directly related to the volume of investment for a given production capacity.

232. Analysis of variations in the components of assembly costs

The variations in each parametre of the unit cost of assembly defined above will be examined in the light of three main factors:

- volume of production
- degree of mechanization of the assembly plant
- number of models

A. Direct labour costs per vehicle

On the basis of the definition of direct labour adopted above, the cost of labour increases in proportion with output. This can be expressed more accurately as follows:

cost of direct labour = hourly rate X assembly time per vehicle

in which the hourly rate is constant in relation to the volume of production. It will therefore suffice to examine the variations in assembly time in relation to production volume.

Although it is obvious that the unit assembly time decreases as the volume of production increases, the real reason for the phenomenon resides in the fact that the assembly line becomes more and more mechanized as the production rate goes up. In other words, the organization of the assembly plant is modified as output rises.

(a) Effect of mechanization

When the rate of assembly exceeds 3 vehicles per hour, the assembly line becomes mobile: the vehicles are moved by ground-level and overhead conveyors from one assembly unit to the next, with each worker only carrying

/out a

out a limited number of simple operations (say, from 2 to 4). Thus, as the assembly rate goes up, instead of several workers carrying out a wide range of operations (more than ten) around a stationary vehicle, each worker becomes increasingly specialized, thereby improving his efficiency and reducing the time required for the few operations he carries out. This also helps cut down the number of assembly mistakes or omissions.

Naturally, on the other hand, more assembly points are needed. The organization of an assembly line is fairly complex and considerable experience is needed to be able to find the right economic compromise between increasing the assembly staff and lengthening the time required for assembly.

The effect of these considerations on the organization of an assembly line is shown more clearly in figure 2.

The axis of abscissae indicates the annual production volume and the axis of ordinates the corresponding assembly time.

Note: This figure relates to a medium-sized vehicle with a cubic capacity of about 1,000 c.c.

"Zero" overtime corresponds to the assembly time in a major European plant producing 300,000 vehicles per year.

It can be seen that, with a fairly small output of around 10,000 vehicles per year, assembly overtime drops very sharply as the production rate rises. As output increases further, the decrease in overtime becomes less marked but remains noticeably constant. Beyond 150,000 vehicles per year, assembly overtime is almost negligible.

Since, by hypothesis, the hourly rate for labour is constant, the direct labour cost curve must follow exactly the same pattern as the assembly time curve given an appropriate change of scale.

Apart from affecting the organization of the assembly line itself, mechanization also bring changes to the assembly and welding line and the painting line, as pointed out in the section of investment.

This technical reorganization makes further cuts in assembly time possible, thereby reducing direct labour costs.

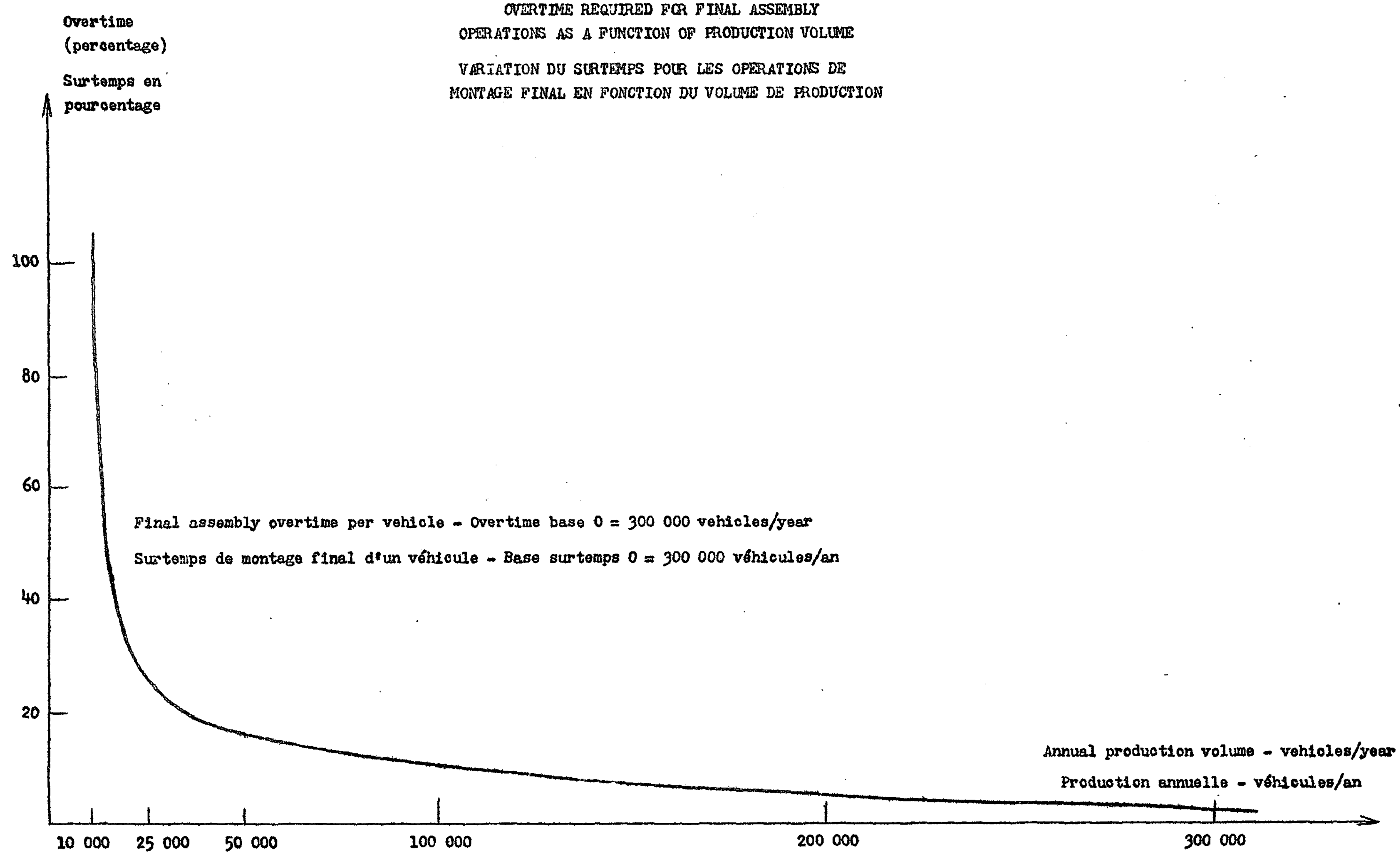
/Figure 2

Figure 2

Graphique 2

OVERTIME REQUIRED FOR FINAL ASSEMBLY
OPERATIONS AS A FUNCTION OF PRODUCTION VOLUME

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



(b) Effect of the number of models

It shall now be seen what effect the number of models of motor vehicles being assembled has on the three main sets of operation:

- the welding line (assembly and welding)
- the painting line
- principal assembly line

(i) The welding line

A distinction must be made between cases where the welding line is relatively unmechanized and those where the body-assembly process is highly mechanized.

- In the first case, the welding tools are not specific (simple welders) and can therefore be used regardless of the model involved. On the other hand, since he will no longer be guided by an assembly process specifically designed for the model, the worker will probably be more hesitant, therefore increasing the possibility of error and, generally speaking, the length of time required for assembling and welding.

- In cases where the welding line is more mechanized, the tools and assembly equipment are specifically designed for a particular model. Thus, carefully guided by the welding pattern, the operator can use multiple spot welders and work rapidly, in which case the assembly time is not affected by the number of models.

It can therefore be concluded that an increase in the number of models entails a corresponding increase in welding-assembly time which is all the greater when mechanization is minimal. In other words, an increase in the number of models means that the lower the assembly rate the greater the increase in assembly time will be, since it has already been pointed out that a more rapid assembly rate usually went hand in hand with greater mechanization.

(ii) The painting line

Generally speaking, increasing the number of models does not involve any overtime as far as the painting line is concerned since painting equipment is not specific to a particular model whatever the degree of mechanization.

/(iii) The

(iii) The assembly line

A large number of models may be a disadvantage at the assembly level, especially if the models are very different, e.g. small capacity popular car and American-style car, or passenger car and industrial vehicle.

Here a distinction must be made between high and low rates of assembly.

- High rate of assembly

In the case of a high rate of assembly it is advisable to alternate the models on the same assembly line.

The worker, who has few operations to carry out on each vehicle, can then switch from one type of vehicle to another without any difficulty and there is no loss of time owing to hesitation. The number of different parts for each vehicle is low and the assembly points can therefore easily be organized.

- Low rate of assembly

In the case of a low rate of assembly, the work can be carried out either by taking identical vehicles in batches or by alternating from one model to another. Both methods depend on specific conditions involving, above all, the degree of mechanization. Lack of mechanization obliges the worker to carry out a large number of operations on each vehicle and it may not always be advisable to alternate the models; moreover, because of the large number of parts that have to be stocked around the assembly line, it is more difficult to organize the assembly points.

(iv) Thus, a large number of models entails assembly overtime which is all the more marked when output is low. When the production level is high, on the other hand, the number of models has hardly any bearing on the assembly time since mechanization will have reached such a point that the maximum use is made of specific equipment, which means that the various assembly operations can be carried out in the shortest possible time. Moreover, the assembly line itself will be so organized that each worker only performs very few operations and there is therefore hardly any unnecessary waste of time.

/(c) Conclusions

(c) Conclusions to be drawn from the section on direct labour costs

Direct labour costs decrease as the volume of production rises. This is due to the increasing degree of mechanization that is introduced as the assembly rate is stepped up.

A large number of models may cause the assembly time, and therefore the cost of assembly, to rise; this however only applies to assembly rates below 10,000 units per year when there is normally very little mechanization.

Moreover, this general fall in assembly costs as output goes up is inevitably accompanied by a rise in investment which is all the greater if there is a wide variety of models and which is reflected in assembly costs through depreciation.

B. Manufacturing costs

An examination of total manufacturing costs for the entire assembly plant will make it possible to calculate the corresponding cost per vehicle and the extent to which it varies with the volume of production.

(a) Total manufacturing costs

As has already been pointed out, there are two kinds of manufacturing costs:

(i) variable costs, which grow in proportion with output (paint, oil, power consumption, etc.)

(ii) semi-fixed costs, which increase in successive stages as the production level rises; the main reasons for this are as follows:

Cadres

As mentioned above, mechanization is minimal when the assembly rate is low (around 3,000 vehicles per year). The vehicles are assembled entirely on one spot and each worker is expected to carry out a number of operations. Consequently, it is often necessary to have a large staff of cadres because of the added risk of mistakes and omissions in assembly.

As the assembly rate and mechanization increase, the number of cadres diminishes proportionally.

Total manufacturing costs will therefore increase in proportion with the assembly rate when that rate is low.

/Maintenance costs

Maintenance costs

Maintenance costs are low when mechanization is minimal, as is generally the case with low assembly rates. When mechanization is introduced, they rise rapidly at first and then relatively slowly once production reaches a high level.

By and large, therefore, total manufacturing costs tend to grow in diminishing proportion to the production volume.

This phenomenon is illustrated in figure 3.

(b) Unit manufacturing cost

Turning now to the share of manufacturing costs in the unit cost of assembling a vehicle, it will be seen that, with a low output, it falls rapidly as the assembly rate rises and then more slowly once the production rate is high.

This can be clearly seen from figure 4 showing the unit manufacturing cost for various rates of production.

Note: An increase in the number of models always entails a rise in unit manufacturing costs, especially when output is low.

(c) Effect of the number of models

As a general rule, an increase in the number of models is reflected in the number of cadres and plant officials, since invoicing and marketing operations become more complex once there is a large number of different models. Moreover, expenditure on tools is higher, the classification and stocking of the different parts, accessories and units take on far greater proportions, control costs rise, and maintenance costs for specific equipment also increase.

It can therefore be assumed that an increase in the number of models automatically adds to total manufacturing costs.

C. Overheads

Overheads are those costs which, in a plant of a given capacity, are not affected by variations in the production volume.

However, in a large-capacity plant with a sizable production staff, the managerial and administrative personnel will obviously have to be increased in order to ensure the smooth running of the plant.

/Figure 3

Figure 3

Graphique 3

MANUFACTURING COST AS A FUNCTION OF PRODUCTION VOLUME

EVOLUTION DES FRAIS DE FABRICATION EN FONCTION DES VOLUMES DE PRODUCTION

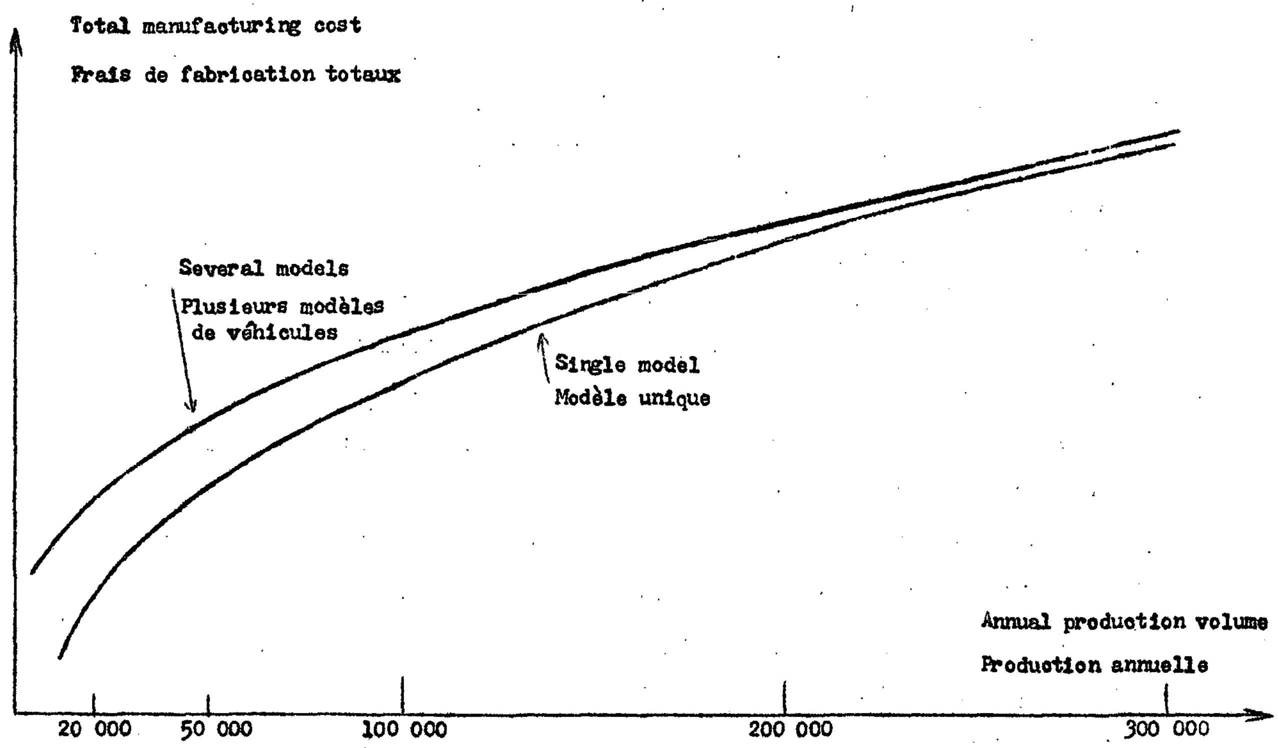
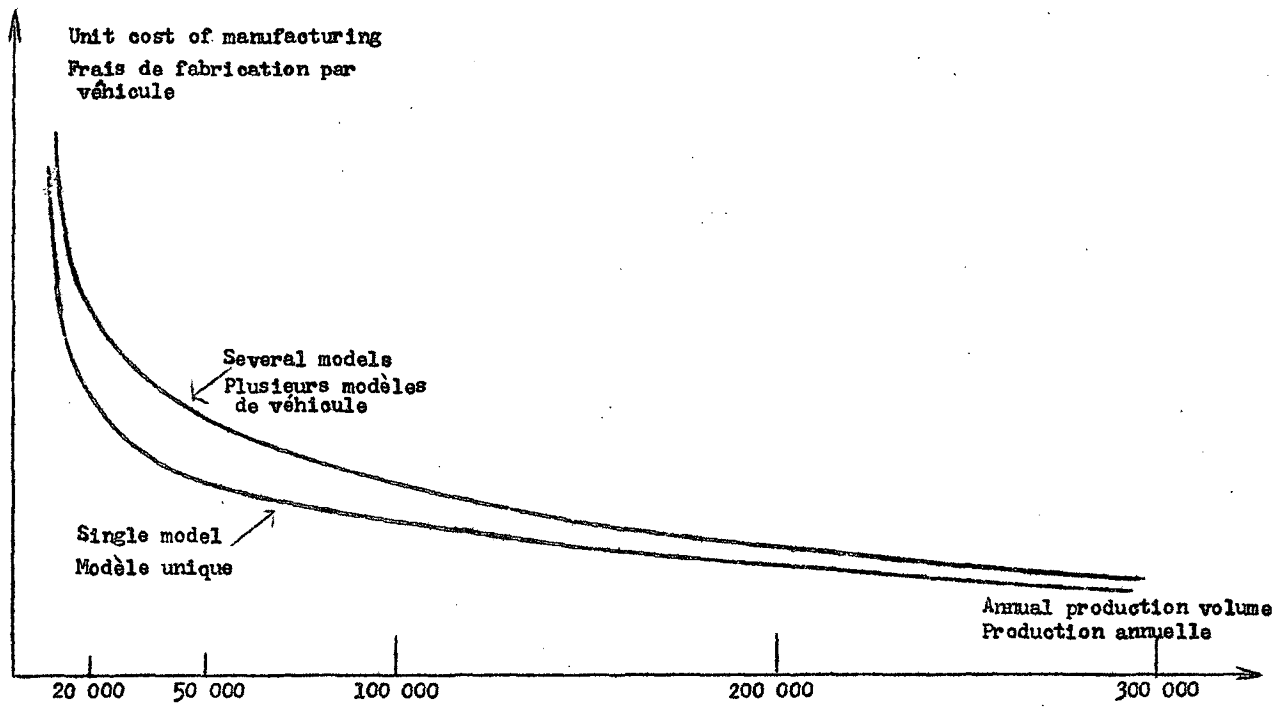


Figure 4

Graphique 4

UNIT COST OF MANUFACTURE AS A FUNCTION OF PRODUCTION VOLUME

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



Furthermore, certain items of social expenditure (canteen, technical training course) become more and more necessary as the volume of production rises. This in turn is accompanied by a rise in related costs (transport, office supplies, postage, etc.).

Finally, financial costs also increase with a larger assembly capacity.

In conclusion, then, it can be said that total overheads tend to increase with the output of the assembly plant, though this increase will be less than proportional to the rise in rate of assembly.

(a) Effect of the number of models

The fact that a plant assembles a range of very different models entails a major increase in the administrative staff. More personnel is needed to control the supply of parts etc., and the greater the number of models the more complicated it is to organize the reception and despatch of CKD kits. The problem of controlling production costs becomes more difficult, too.

For a given assembly capacity, therefore, any increase in the number of models is bound to be accompanied by higher overheads.

(b) Share of overheads in the unit assembly cost

As has been seen, total overheads are not constant but rather increase gradually as the production volume goes up.

This is illustrated in figure 5.

Whereas this upward movement of total overheads is fairly rapid in the case of low rates of assembly, it slows down noticeably when the rate of assembly is high. In this it differs from manufacturing costs.

As regards the share of overheads in the assembly cost per vehicle, this declines as the production level rises.

For very low assembly rates, the share of overheads in the unit cost is high; as the assembly capacity increases, on the other hand, it declines fairly rapidly. For higher annual production levels, the share of overheads in the unit cost decreases very slowly and tends to become constant.

/Figure 5

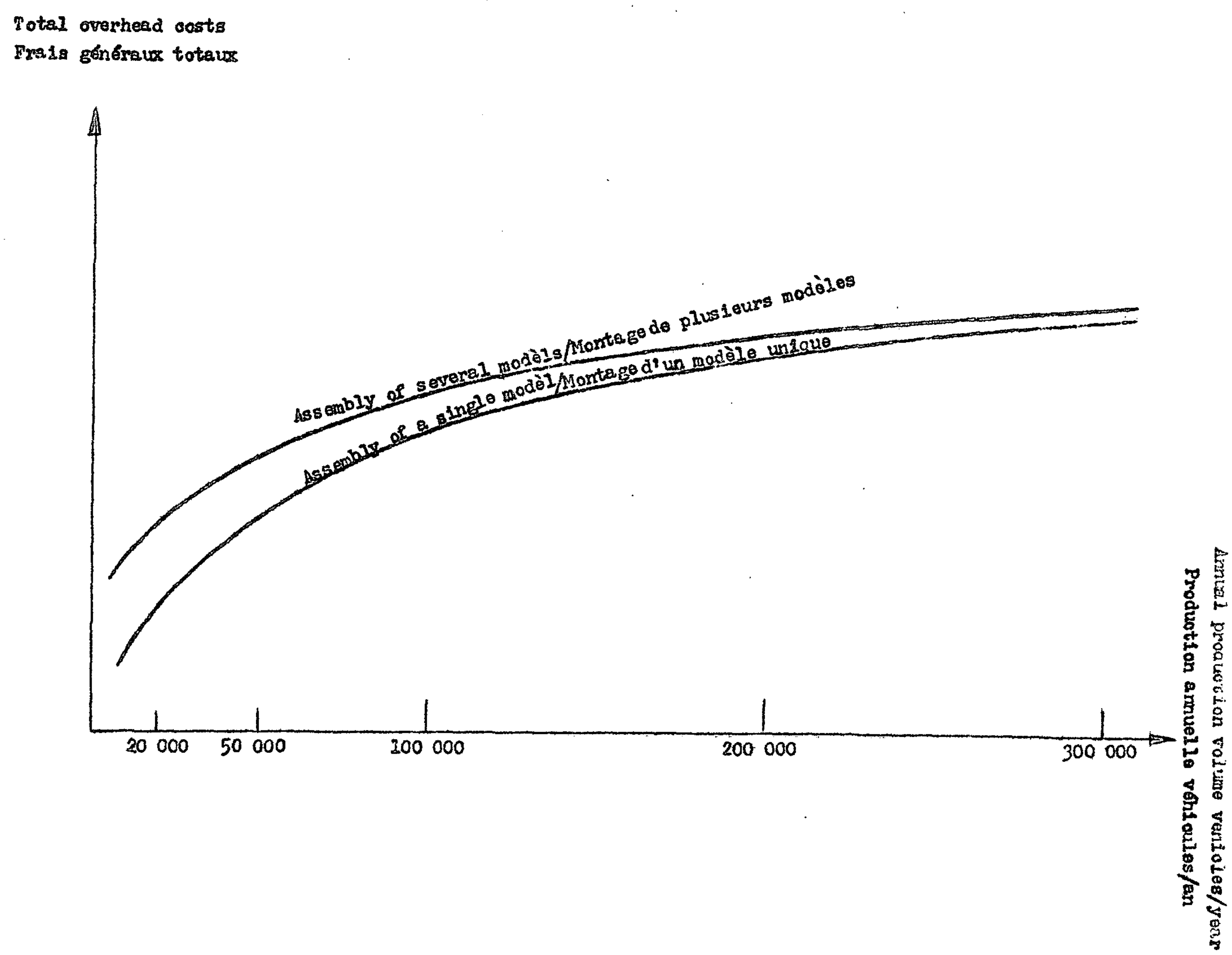
Figure 5
Graphique 5

FINAL ASSEMBLY PLANT

VARIATION OF TOTAL OVERHEAD COSTS

USINE DE MONTAGE FINAL

VARIATION DE LA MASSE DES FRAIS GENERAUX



This trend is reflected in figure 6 which shows the variation of the share of overheads in the unit assembly cost in terms of the capacity of the assembly plant.

As shown in the graph, the unit cost rises as the number of models increases.

D. Depreciation

Depreciation is clearly related to investment: therefore, the total cost of depreciation increases with the growing capacity of the plant. This is particularly marked in the case of a highly mechanized plant.

The total cost of depreciation can be represented by a curve which rises very fast at first and then rather more slowly, as can be seen from figure 7.

(a) Trend of depreciation costs

When the assembly rate is low, the cost of depreciation per vehicle drops sharply as output goes up, levelling off progressively as the assembly rate grows. This is illustrated in figure 8.

(b) Influence of the model life: advantage of "freezing" models

For a given investment, depreciation will be affected by two factors:

- the type of investment
- the legal depreciation period.

(i) Minimum legal depreciation period

In each country, a minimum depreciation period for different types of investment is fixed by law.

Generally speaking, depreciation periods in the motor-vehicle industry are as follows:

Buildings	20 to 25 years
Equipment	
bodywork	7 years
painting	10 to 15 years
body accessories	7 years
mechanical	7 years
facilities and ancillary services	7 years

/Figure 6

Figure 6

Graphique 6

FINAL ASSEMBLY PLANT

VARIATION OF OVERHEAD COSTS PER UNIT

USINE DE MONTAGE FINAL

VARIATION DES FRAIS GENERAUX UNITAIRES

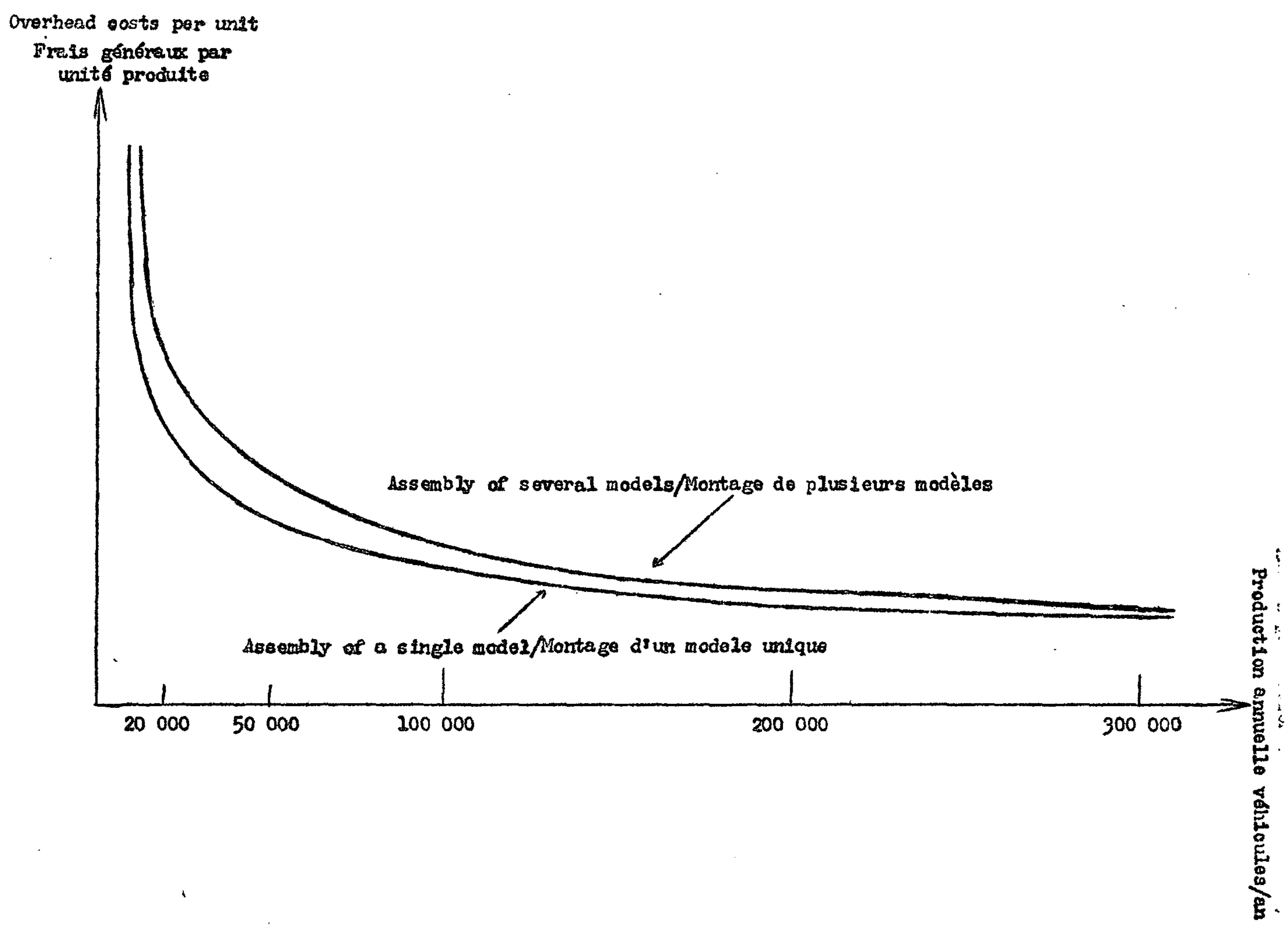


Figure 7

Graphique 7

TOTAL DEPRECIATION FOR AN ASSEMBLY PLANT AS A FUNCTION OF PRODUCTION VOLUME

EVOLUTION DE LA CHARGE TOTALE D'AMORTISSEMENT POUR UNE USINE DE MONTAGE EN FONCTION DU VOLUME

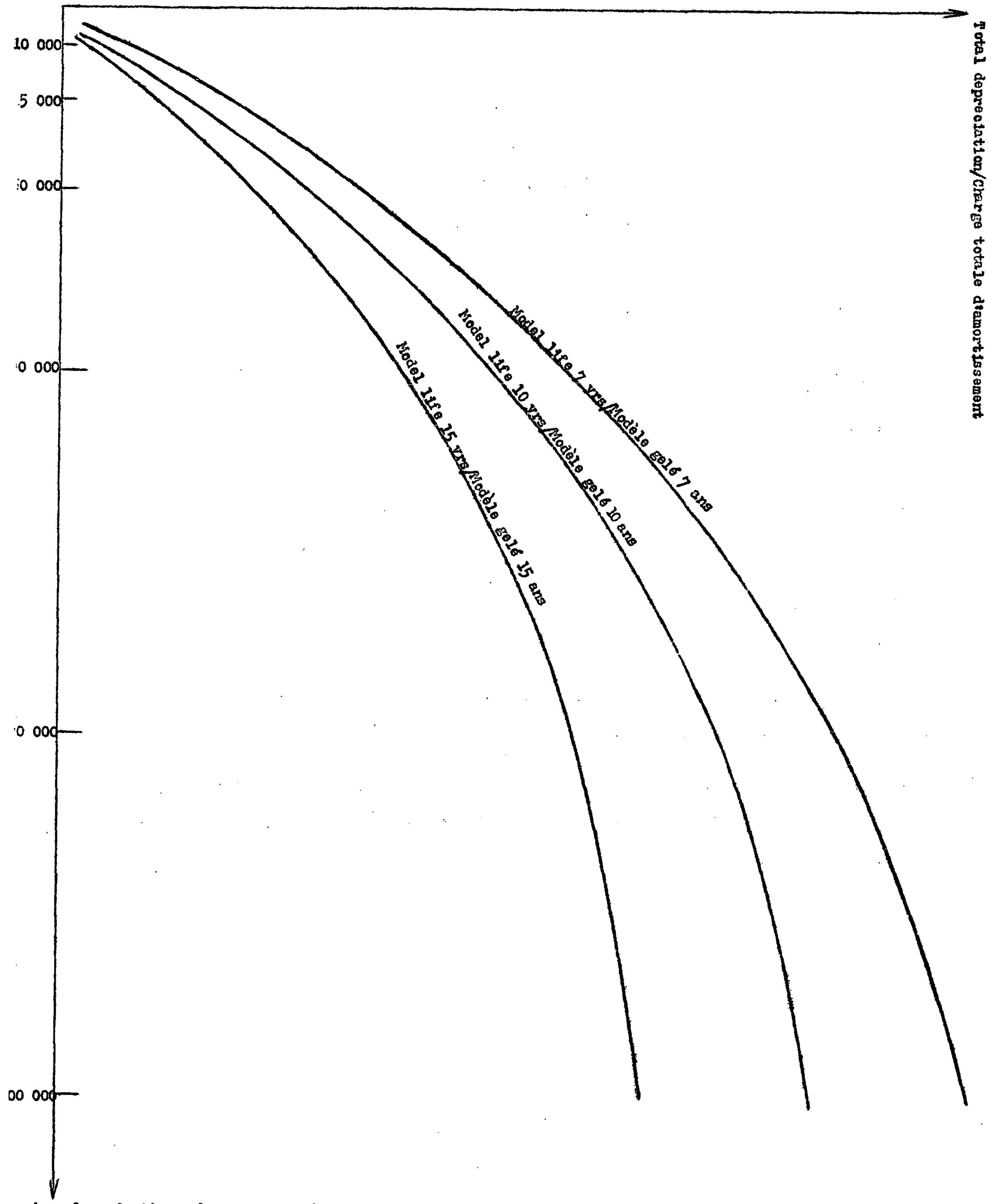
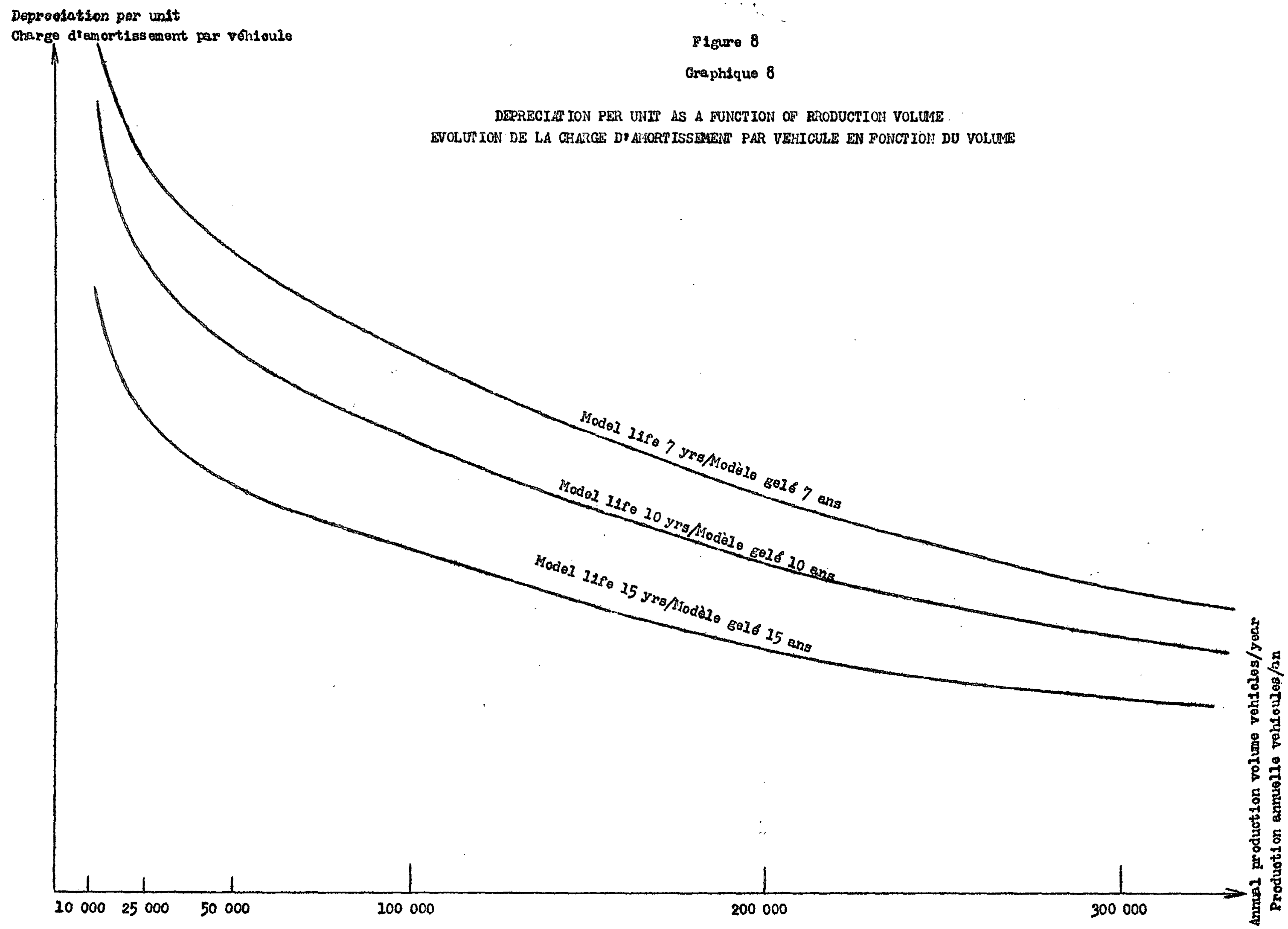


Figure 8

Graphique 8

DEPRECIATION PER UNIT AS A FUNCTION OF PRODUCTION VOLUME
EVOLUTION DE LA CHARGE D'AMORTISSEMENT PAR VEHICULE EN FONCTION DU VOLUME



handling	6 to 10 years
Specific tools	3 years
Non-specific tools	5 years

Specific tools are taken to mean those that can only be used on a single model (assembly jigs, control jigs, multiple spot welders, etc.).

Because of the fierce competition between manufacturers in industrialized countries, they are obliged to bring out more and more new models of vehicles (every three years in many cases). Since their output is usually over 150,000 vehicles per year for a mass production model, they are allowed to write off these specific tools over three years (giving an output of 450,000 units of the same model during that period). Depreciation per vehicle only enters to a small extent in the unit assembly cost and, as shown above, hardly drops at all beyond a production level of 150,000 vehicles per year. There is therefore little point for a major manufacturer to spread the depreciation of specific tools over a longer period. On the other hand, a rapid depreciation allowance protects the manufacturer from the risk of poor sales owing to unfavourable economic conditions and, above all, from the danger of his models going out of date if his competitors put new models on the market that sell better.

(ii) Advantage of "freezing" models

It should be noted that the depreciation periods mentioned above refer to the legal minimum for accounting purposes. In actual fact, production of a model goes on much longer (about ten years) with sales dropping off towards the end of the model life.

If it were possible to guarantee a manufacturer a certain rate of sales for a period of ten years, for example, and protection from competition, then depreciation of equipment, buildings and tools could, at the outset, be spread over the whole period so that, from the very start, the cost of depreciation per vehicle sold would be lower and the unit assembly cost could thus be reduced.

/This would

This would be the case if the authorities of a country decided to "freeze" a model, on the necessary understanding, of course, that no other competitive model would be allowed to appear on the market during the ten-year period. Naturally, such a decision is never popular and for this reason has to be taken at the very highest level in a political and economic context.

Note: Such solution might be in the interests of developing countries. An attempt to estimate the possible advantage has been made in section 242.

24. Over-all analysis of motor-vehicle assembly costs

241. Variation of assembly cost in relation to production volume

Subsection 232 dealt with the variation of each component of assembly cost per vehicle in relation to production volume.

All those observations can now be brought together to indicate the trend of assembly cost per vehicle in relation to annual production volume. This variation is shown in figure 9, in which the ordinates indicate the assembly cost penalty in relation to production volume.

For each volume, the cost penalty is estimated in relation to the assembly cost of the same model produced in an industrialized country at the rate of 300,000 units per year. In this case, a medium-sized low-cost vehicle with a cubic capacity of 1,000 c.c. has been selected. Therefore cost penalty 0 corresponds to an annual production of 300,000 units.

This curve indicates that the assembly cost penalty is very high where the volume of production is small and that it falls rapidly as the volume increases. From 90 to 140 per cent for an output of 10,000 vehicles per year, the cost penalty drops to 70 to 100 per cent for 25,000 vehicles annually, and is only 15 to 30 per cent once the volume rises to 100,000 vehicles per year.

The upper curve in this figure represents a plant with a low level of mechanization which assembles several models, and the lower curve represents a highly mechanized plant assembling a single model. It is a striking fact that, for a given capacity, where the level of mechanization is low and many models are assembled, the cost penalty is high. The assembly cost penalty rises all the more steeply as annual production drops.

/Figure 9

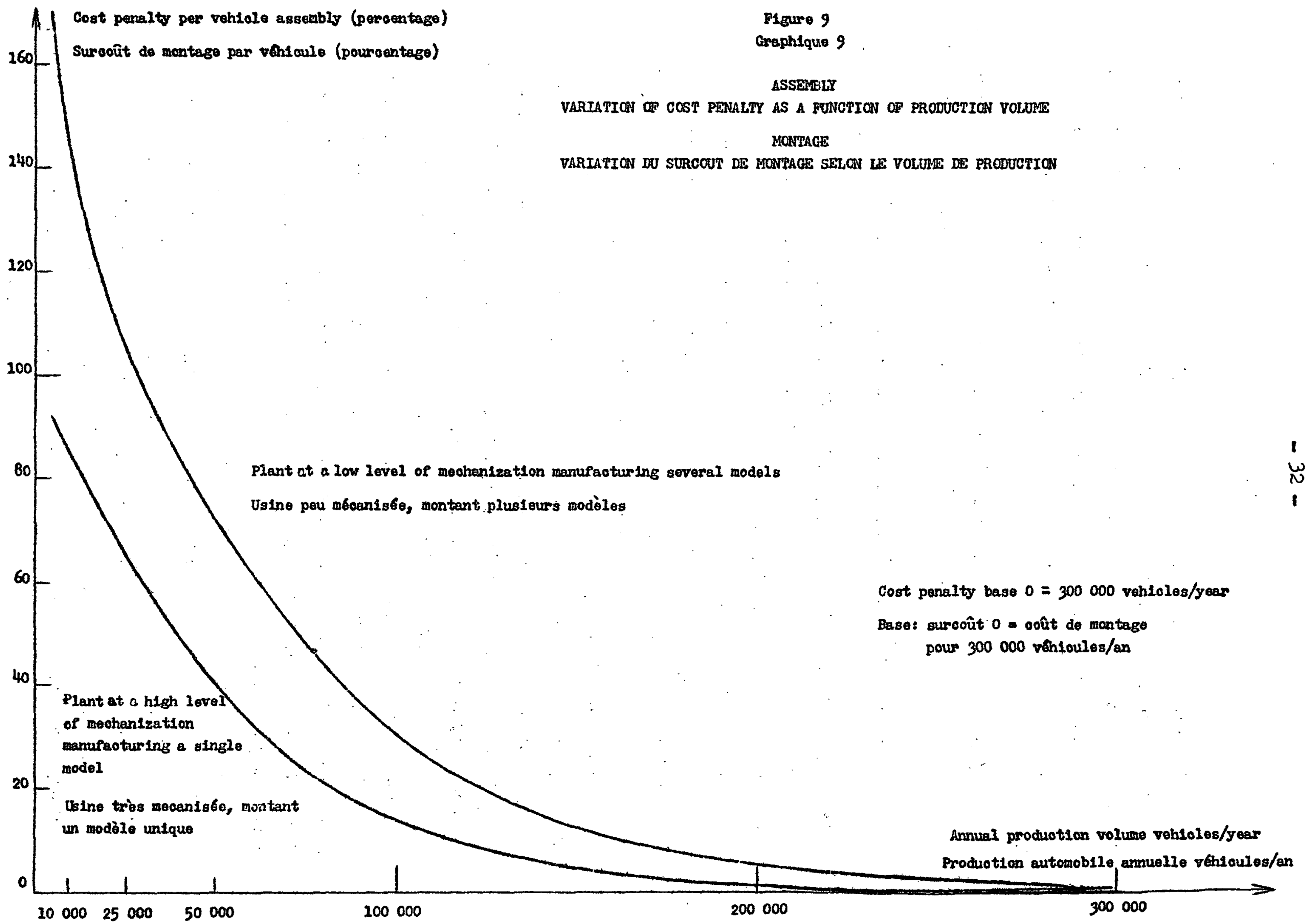


Figure 9
Graphique 9

ASSEMBLY
VARIATION OF COST PENALTY AS A FUNCTION OF PRODUCTION VOLUME

MONTAGE
VARIATION DU SURCOUT DE MONTAGE SELON LE VOLUME DE PRODUCTION

242. Study of a specific example

In order to express the above observations in more specific terms, the variations in assembly costs are given for a particular vehicle.

A. Calculation hypotheses

A medium-sized low-cost vehicle is assembled in a fairly industrialized temperate country. The plant is highly mechanized, even when the rate of production is low. Lastly, this hypothetical plant assembles a single model.

For outputs of 10,000, 25,000, 100,000 and 300,000 vehicles a year, the assembly cost is considered to be based on the four main factors indicated above.

Labour is fixed at 12 francs an hour.

The following are the minimum depreciation periods considered:

Buildings	20 years
Equipment (excluding painting equipment)	7 years
Painting equipment	10 years
Annexes and service areas	7 years

Specific or other tools, which account for a small share of total investment, are not listed separately in this example, but are included under the head of equipment and the period of depreciation is therefore seven years.

Note: Land does not depreciate in value.

Figure 1 shows the total investment for the different levels of production. The following distribution of the various components of total investment has been selected:

/Buildings

	Percentages a/
Buildings	40
Equipment (excluding painting equipment, but including tools)	20
Painting equipment	15
Annexes and service areas	15
Land	5

a/. Subject to revision.

The assembly cost of models frozen for three different periods of 7, 10 and 15 years is estimated for the various levels of production.

B. Breadkown of assembly cost per vehicle

The assembly cost for the various levels of production is broken down into its four components in table 2, which relates to a model life of 10 years. It was not considered necessary to give percentages for a model life of 7 years or 15 years because the figures are practically identical.

It should be noted that this is the assembly cost structure in an industrialized country where labour is expensive. This explains why expenditure on labour is as high as 30 per cent of the total cost of assembly at a level of 10,000 vehicles per year, and over 50 per cent at the admittedly somewhat theoretical level of 300,000 vehicles per year.

/Table 2

Table 2

BREAKDOWN OF UNIT ASSEMBLY COST IN AN INDUSTRIALIZED COUNTRY

(Percentage value added)

	Production volume: vehicles per year			
	10,000	25,000	100,000	300,000
Direct labour costs	34	37	43	51
Manufacturing cost	29	28	27	25
Overheads	24	23	19	16
Depreciation	13	12	11	8
Total unit assembly cost	100	100	100	100

This table is illustrated in figure 10.

C. Analysis of results

Table 3 shows the assembly cost per vehicle for different production volumes and for different periods during which the model concerned has been frozen.

The figures are given in the form of an index, with 100 representing the *minimum* assembly cost for an output of 300,000 vehicles per year, and the model being frozen for 15 years.

By way of illustrating the results, figure 11 shows the trend of the assembly cost per vehicle in relation to production volume. Three similar curves represent the three periods during which the model is frozen.

The freezing of vehicle models will be seen to result in a greater reduction in assembly costs the longer the life of the model. In addition, this gain is all the more noticeable where the level of production is lower.

/Figure 10

Figure 10

Graphique 10

BREAKDOWN OF UNIT ASSEMBLY COST

DECOMPOSITION DU COUT UNITAIRE DE MONTAGE

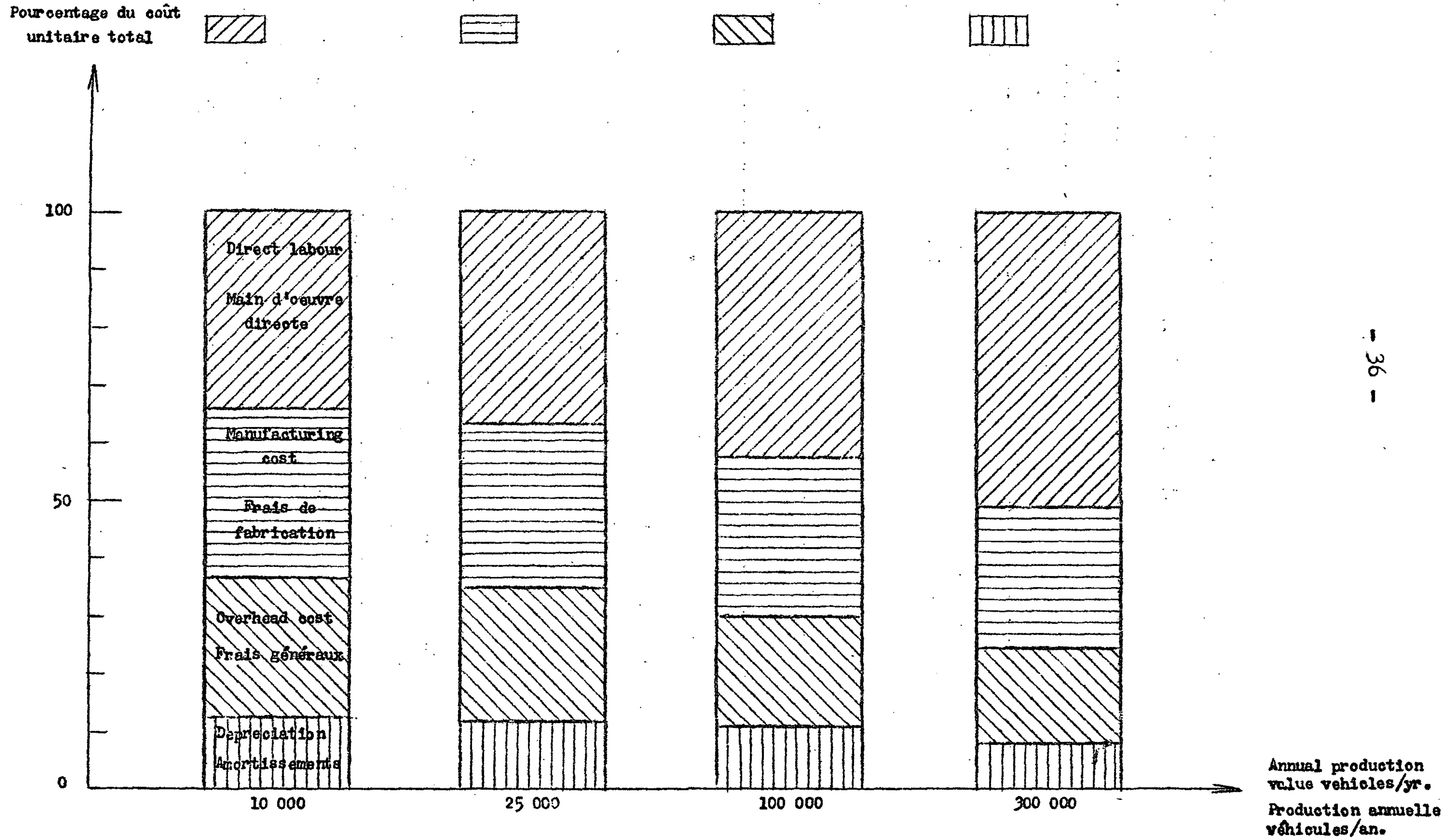


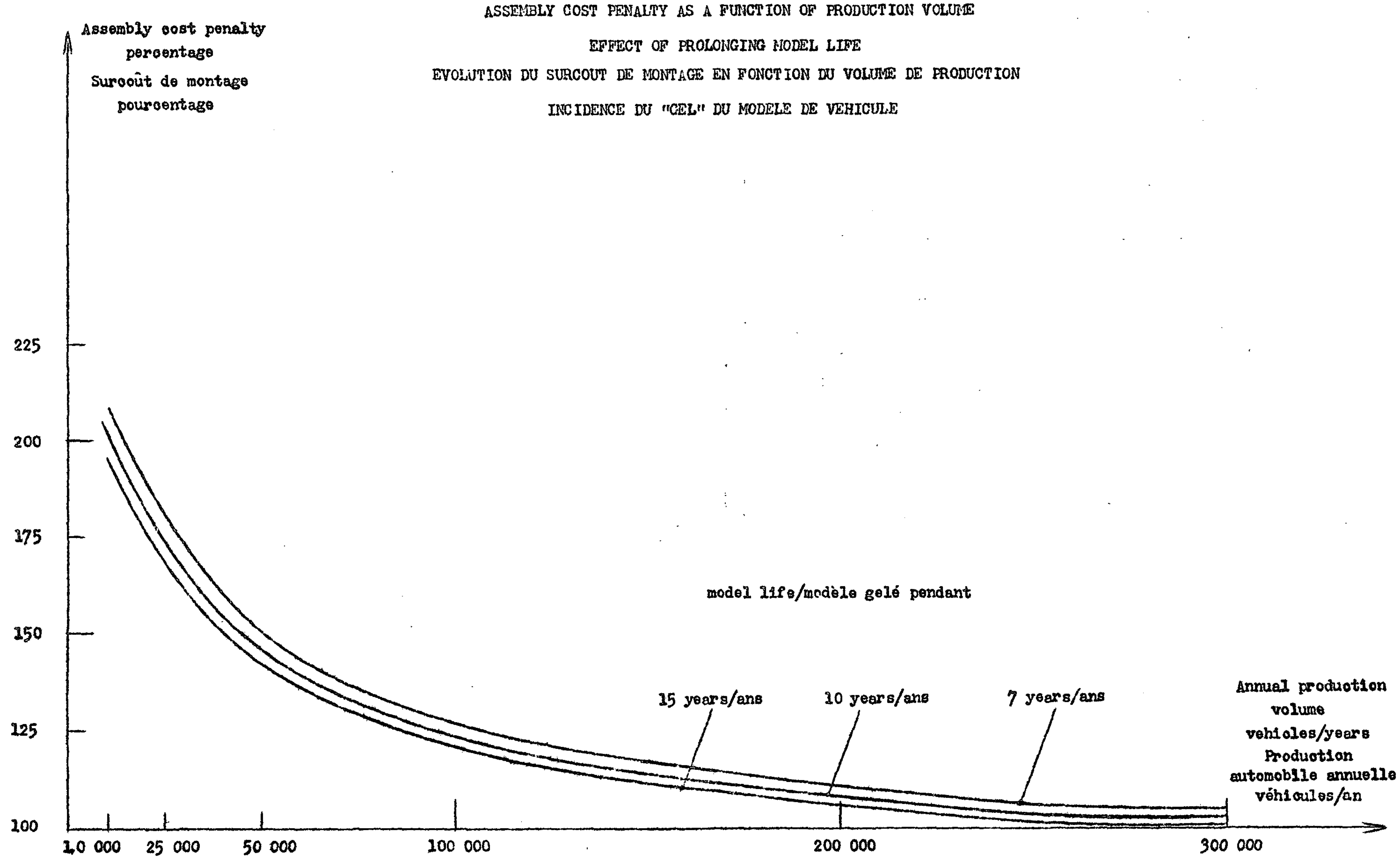
Figure 11
Graphique 11

ASSEMBLY COST PENALTY AS A FUNCTION OF PRODUCTION VOLUME

EFFECT OF PROLONGING MODEL LIFE

EVOLUTION DU SURCOUT DE MONTAGE EN FONCTION DU VOLUME DE PRODUCTION

INCIDENCE DU "CEL" DU MODELE DE VEHICULE



It should be noted, however, that the freezing of vehicle models results in only a small reduction of assembly costs, because equipment for an assembly plant entails much less investment than that required for a machining or stamping plant. Only investment in buildings is high, but since the legal minimum period of depreciation is twenty years, this has no effect on assembly costs because the life of a model is never as long as that.

Table 3

TREND OF VEHICLE ASSEMBLY COSTS IN RELATION TO PRODUCTION VOLUME IN AN INDUSTRIALIZED COUNTRY, EXPRESSED AS AN INDEX

		Production volume:	vehicles per year		
		10,000	25,000	100,000	300,000
	Model life (years)				
Unit	7	203	176	128	105
Assembly	10	201	172	124	103
Cost	15	197	168	121	100

In figure 11, the sharp reduction in assembly costs as the rate of production rises, at the level of 10,000 vehicles per year, is due to the fact that these estimates are based on a high rate per hour for direct labour. As the volume increases, and since the plant selected is highly mechanized, the time taken to assemble a vehicle is sharply reduced and the effect on direct labour costs is all the greater as the hourly rate rises.

For 100,000 vehicles per year the assembly cost penalty is not more than 25 per cent, and it is reduced to negligible proportions for an annual output of 200,000 vehicles.

/D. Conclusion

D. Conclusion

This example confirms the observations set forth in the preceding section and shows the importance of freezing models.

Generally speaking, the cost-volume relationship is quite clear in the case of an assembly plant. The assembly cost penalty which is very high for production levels below 25,000 vehicles per year, falls sharply at a level of 100,000 vehicles per year, but becomes negligible only when more than 200,000 vehicles are produced.

Mechanization of an assembly plant brings down the assembly cost penalty. Moreover, a wide range of models pushes up the assembly cost, particularly if output is low.

For the reasons explained above, however, the freezing of models has relatively little effect on assembly costs (a 3 per cent variaton in assembly cost for a production of 10,000 vehicles per year between a model frozen for 7 years and a model frozen for 15. Since assembly represents about 10 per cent of the cost price of a vehicle, the final effect on the price ex-plant would be only 0.3 per cent).

25. The case of developing countries

251. Effect of the hourly rate for labour and of labour productivity

In the preceding example, a high rate per hour was considered for labour, equal to that payable in an industrialized country.

It must be remembered that this rate may be considerably lower in other countries, particularly those in process of development. It may be inferred that the cost of direct labour, and therefore the total assembly cost, will be much lower in an assembly plant operating in a less industrialized country.

It should nevertheless be noted that labour productivity is often lower in the less industrialized countries, particularly those with fairly hot climates. This is a distinct drawback which makes it impossible to take full advantage of the low hourly rate.

/A. Calculation

A. Calculation hypotheses

In order to express these observations in more specific terms, the same example as that used for the previous calculation has been taken here, the hypotheses being 6 francs per hour for labour and a productivity equal to two-thirds of the productivity in an industrialized country.

The rest of the hypotheses are the same as those used in the example in section 241, particular that of a highly mechanized plant assembling a single model. Total investment in a plant with a given output and the cost of depreciation are therefore the same. Moreover, the same overheads are applicable to the different levels of production.

Under these conditions, it is easy to determine the effect of the hourly rate for direct labour on the assembly cost.

B. Results of the calculations

The results of these calculations are embodied in table 4, which shows the assembly cost as an index, the cost basis being the same as that used in the previous example: 100 thus corresponds to assembly costs in a large-scale European plant assembling 300,000 vehicles of a single model per year, the hourly rate for labour being 12 francs and productivity 100, which corresponds to a productivity of 66 in a less industrialized country.

Table 4

TREND OF ASSEMBLY COST IN RELATION TO PRODUCTION VOLUME
IN A DEVELOPING COUNTRY

		Production volume: vehicles per year		
		10,000	25,000	100,000
	Model life (years)			
Unit	7	185	157	110
Assembly	10	182	154	108
Cost	15	176	150	106

/C. Criticism

C. Criticism of results

It should be noted, however, that the saving in assembly cost might be substantially less in a plant with a lower level of mechanization, since the longer time taken by the assembly process would cancel out the saving in direct labour costs.

Moreover, it is interesting to note that the level of overheads used for these calculations could be reduced in the case of a developing country; this would result in a not insignificant decrease in assembly costs which may be estimated at about 15 per cent.

D. Breakdown of assembly costs in a developing country

The preceding example is illustrated in table 5, which shows a breakdown of assembly costs for different rates of production in developing countries.

This table presents the actual cost structure.

An analysis of the table shows that labour costs represent a small proportion of the total assembly cost, since labour is fairly cheap in the countries considered.

Table 5

BREAKDOWN OF ASSEMBLY COSTS IN DEVELOPING COUNTRIES

(Percentages)

	Production volume: vehicles per year		
	3,500	4,500	12,000
Direct labour costs	15	19	23
Manufacturing cost	52	48	45
Overheads	18	18.5	17
Depreciation	15	14.5	13
Total unit assembly cost	100	100	100

/It should

It should also be noted that the level of overheads is lower than in the first example (see table 2).

Lastly, it will be seen that manufacturing costs are high. This is attributable in particular to the cost of indirect labour; for a plant located in a developing country it is often necessary to bring in European staff. Thus the cost of travel, accommodation and salaries is high, which goes to swell the share of manufacturing costs in the total cost of assembly, in relation to plants in an industrialized country.

252. Effect of assembly costs on vehicle prices

It is important to assess the effect of assembly costs on the sales price of vehicles, first to the distributor, and secondly to the public.

A. Price to the distributor

For a better understanding of the problem of assembly costs as such, it is assumed here that no domestic parts are incorporated in the countries where the vehicles are assembled.

Thus the following comparison may be made with a built-up vehicle imported directly from a particular foreign country (see table 6).

In this table, the value of the CKD kit is assumed to be 100. Thus:

The value of the corresponding built-up vehicle produced by a major world manufacturer would be 110.

Allowing for the cost of collecting and conditioning the parts, and of the necessary packaging, the sales value of the CKD kit is 112, or 2 points more than that of the built-up vehicle. This may at first glance appear somewhat paradoxical, but in fact it is perfectly true. The explanation is that collecting and packaging are fairly important items, and that the cases in which the CKD kits are packed must be of very good quality in order to prevent damage to the parts (this packaging is almost never re-utilized).

The advantage of the CKD kit is apparent in the cost of transport. It is naturally difficult to give over-all figures, because maritime freight rates are known to vary considerably, not so much according to distance but rather according to the flow of traffic between the two countries concerned. This example is based on reliable figures for freight rates between Europe and a major Latin American country

/Table 6

Table 6

BREAKDOWN OF PRICE TO THE DISTRIBUTOR

	Locally assembled vehicles			Imported built-up vehicle
	Production volume			
	10,000	25,000	100,000	
Cost of CKD kit	100	100	100	
Cost of built-up vehicle				110
Conditioning of CKD kit	12	12	12	
Transport, insurance, commission, shipping, maritime freight rate	8	8	8	11
Customs duties		pro memoria		pro memoria
Cost of local assembly	20	17	12	
Price to the distributor (cost price)	140	137	132	121
Cost penalty as a percentage of the cost of the imported built-up vehicle (percentages)	15	13	9	-

(Mexico, for example). Transport of CKD cases is undoutedly cheaper than that of the bulkier buit-up unit; however, this relative advantage is not so great as might have been expected, since it amounts to only about 3 points; thus the final price of a built-up vehicle at port of destination is generally much the same as that of a CKD kit. Vehicles delivered in the form of CKD kits will have been assembled locally, however, at a cost which, as has been shown in this section, will be all the higher in assembly plants operating at low levels of production.

The following assembly rates are considered in the above table:

Table 6 envisages assembly rates of 10,000, 25,000 and 100,000 vehicles per year. At these rates, the assembly costs may be considered to be 100 per cent, 70 per cent and 20 per cent higher, respectively, than those of a major world manufacturer. Thus, the differences in relation to a built-up vehicle are approximately:

/15 per cent

15 per cent at a rate of 10,000 vehicles per year
13 per cent at a rate of 25,000 vehicles per year
9 per cent at a rate of 100,000 vehicles per year

Of course, these are merely average figures which may have to be modified in many cases for such different reasons as particularly advantageous conditions of sales to a developing country (dumping by a world manufacturer) or relative advantages in terms of transport costs for CKD kits compared with those payable for larger built-up vehicles than the ones considered here. It will be noted, therefore, that a vehicle assembled in a developing country - which, as is nearly always the case, has a limited market - will be delivered to the distributor at a price 15 to 20 per cent higher than that of an imported vehicle; the cost penalty is substantially higher than in the case of a vehicle placed factory in the country of origin, since in a plant assembling 10,000 vehicles per year an index of 140 must be compared with an index of 110, which represents a difference of about 27 or 28 per cent.

Moreover, assembly plants in developing countries often operate at a level of less than 10,000 vehicles per year.

Figure 11 suggests that for rates below 10,000 vehicles a year assembly costs tend to soar; therefore, it is easy to reach differences of as much as 80 per cent between prices in assembly plants operating at low levels of production and those obtained in highly developed countries.

B. Consumer prices

The dealer's margin of profit, which fluctuates between 12 to 15 per cent and 30 per cent according to the country, slightly modifies the effect of assembly costs on the price to the consumer.

Assuming that the distributor's margin of profit is 25 per cent, the following figures obtain:

/Table 7

Table 7

BREAKDOWN OF THE PRICE TO THE PUBLIC

	Locally assembled vehicles			Imported built-up vehicle
	Production volume			
	10,000	25,000	100,000	
Price to the distributor	140	137	132	121
Distributor's margin of profit	46	45	43	40
Price to the public	186	182	175	161
Cost penalty as a percentage of the cost of the imported built-up vehicle	16	13	8	-

26. <u>Conclusion regarding the cost-volume relationship in an assembly plant</u>

The following conclusions may be drawn from the observations set forth in the preceding sections:

261. Investment required

The amount of investment required in an assembly plant increases with the volume of production. Its growth is more rapid at the lower levels of output (scale factor 0.70), but it slows up at the higher rates of assembly of about 100,000 vehicles per year (scale factor 0.4).

Investment can be higher or lower according to the level of mechanization selected for the plant; this effect is felt only at the lower rates of assembly, since a plant with a large volume of production is necessarily highly mechanized.

Moreover, if a large number of models is assembled, the increase in investment will be all the greater if the plant is highly mechanized, since it must then use expensive equipment specifically designed for each model.

/262. Vehicle

262. Vehicle assembly costs

As regards vehicle assembly costs, the above observations can be summed up as follows:

Unit assembly cost is highly sensitive to the volume of production and decreases when the rate of assembly rises (see table 8). It falls sharply at low rates of production up to 50,000 vehicles per year. Above that rate the saving in assembly costs levels out and is insignificant at rates of 200,000 vehicles per year. At a given low volume of production, intensive mechanization enables assembly costs to be sharply reduced. This saving could be about 30 per cent for a volume of 10,000 vehicles per year. Since a plant producing more than 50,000 vehicles per year must in any case be highly mechanized, the difference in assembly costs between a plant with a relatively low level of mechanization and a fully mechanized plant at that level is insignificant. Under those conditions the assembly cost penalty becomes negligible when production reaches the level of 150,000 vehicles per year.

If several models are assembled at a given level of production, assembly costs will rise fairly sharply, and the cost penalty due to the large number of models is particularly heavy at low or average rates of production of 25,000 to 50,000 vehicles per year. The freezing of models, which enables the depreciation of specific equipment to be spread over long periods, does not result in a significant reduction in the cost of assembly operations, owing to the relationship between labour and depreciation in the cost structure.

Lastly, in developing countries where labour is usually cheaper than in industrialized countries, the saving in labour costs makes it possible to reduce assembly costs fairly substantially. It is estimated that at a level of production of 10,000 vehicles per year the assembly costs would normally be twice as high as in a mass production plant. In a developing country, while recognizing that the level of labour productivity is far lower than in the highly developed countries, the effect on costs could be reduced to 85 per cent instead of the normal 100 per cent.

/Table 8

Table 8

AVERAGE VARIATION IN UNIT ASSEMBLY COST PENALTY ACCORDING TO VOLUME OF PRODUCTION

(Basis: Cost penalty 0 for 300,000 vehicles per year)

Volume of production: vehicles per year	3 500	5 000	10 000	25 000	50 000	100 000	200 000
Cost penalty in relation to the basis of 300 000 vehicles per year (percentages)	200 extra-polation	145 (115 to 175)	115 (90 to 140)	85 (70 to 105)	55 (40 to 70)	22 (15 to 30)	3

Be that as it may, assembly costs represent not more than 10 to 12 per cent of the cost price of a vehicle; therefore, the fact that assembly costs are twice as high should not raise the sales price of vehicles by more than about 10 per cent. In spite of the small difference in price between a completely assembled CKD kit and a built-up vehicle, except in the particular case where the saving in CKD transport costs may be considerable, the difference in price between a vehicle assembled in a developing country and the same vehicle imported as a built-up unit can hardly be less than 15 per cent.

From a developing country's standpoint, however, this difference in price is generally justified:

First, because of the social worth of such projects, which contribute a significant value added to the country;

Secondly, because of the indirect effects achieved, since assembly is a necessary step towards future industrialization.