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Methodology for Estimating Total Automotive Manufacturing Costs

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Final Report

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16. Abstract

A number of methodologies for estimating manufacturing costs have been developed. This report discusses the different approaches and shows that an approach to estimating manufacturing costs in the automobile industry based on surrogate plants is preferred. This method, which specifies the manufacturing processes and plant types required to make a component or a whole vehicle, provides reliable and traceable estimates of manufacturing cost. Examples are used to illustrate this preferred approach.

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PREFACE

This report reviews several manufacturing cost methodologies appropriate to estimating manufacturing cost of motor vehicle systems, components and material. It employs a manufacturing cost methodology which relies strongly on a surrogate plant methodology developed at TSC for estimating capital cost requirements and related cost factors. The surrogate plant methodology and supporting data are documented in a companion report, "Surrogate Plant Data Base," by George Byron, TSC August 1982.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

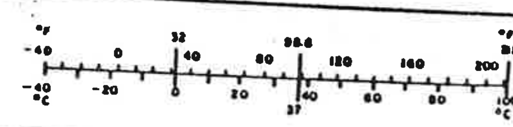


TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (CONTINUED)

1. INTRODUCTION

1.1 BACKGROUND

The National Traffic and Motor Vehicle Safety Act of 1966 (PL 89-563), as amended, authorized the National Highway Traffic Safety Administration (NHTSA) to promulgate motor vehicle safety standards and regulations, and consumer information requirements. Two additional legislative acts which provide the NHTSA with the authority to promulgate standards are the Motor Vehicle Information and Cost Savings Act of 1972 (PL 92-513) and the Energy Policy and Conservation Act of 1975 (PL 94-163).

The Motor Vehicle Information and Cost Savings Act of 1972 (PL 92-513) provides authority for the NHTSA to establish bumper standards (Title I) to reduce the damageability of motor vehicles; and to rate vehicles for resistance to damage, ease of diagnosis and maintenance, and crashworthiness performance (Title II).

The Energy Policy and Conservation Act of 1975 (PL 94-163) amends the Motor Vehicle Information and Cost Savings Act by adding a Title V, Improving Automotive Efficiency. It provides authority for the NHTSA to establish fuel economy standards for passenger cars and light trucks. The Auto Fuel Efficiency Act of 1980 further amended Title V to simplify the regulatory requirements.

In response to this legislation, the NHTSA has adopted and continues to adopt standards and regulations addressing these issues. The NHTSA also conducts periodic reviews of existing regulations to ensure that they are current, accurate and consistent with the present state-of-the-art. In each instance where the NHTSA is considering the adoption of a standard or regulation, it is necessary to conduct a regulatory evaluation or regulatory analysis to assess the impact of the standard or regulation. The cost impact of the standard or regulation is one of the assessments that must be performed. In conducting such an assessment, it is often necessary to identify the manufacturing costs associated with a particular vehicle modification. This need to provide an estimate of the cost impact and a method to develop reliable and traceable estimates, is the subject of this report.

1.2 PURPOSE AND SCOPE

This report presents the results of a study designed to provide the NHTSA with a methodology to perform detailed manufacturing cost analyses for vehicle systems, subsystems, components and materials. This methodology, based on the manufacturing process or processes, utilizes a surrogate (or representative) plant concept to provide insight into the total manufacturing cost structure. As such, the level of detail provided allows the user to evaluate a variety of factors which influence manufacturing cost.

The following chapters address the development of the manufacturing cost methodology, the development of the data base to support the methodology, and an application of the methodology. Also included is a review of presently available manufacturing cost methodologies and their required data inputs.

2. MANUFACTURING COST OVERVIEW

A variety of methodologies for estimating manufacturing costs have been developed. Each of these methodologies has been developed to respond to a particular need or address a specific set of objectives. As such, there is considerable variance in the degree of detail, accuracy, and complexity of each methodology. Over the years, several of these methodologies have been applied to the estimation of automotive manufacturing costs.

Figure 2-1 shows a summary breakdown of manufacturing costs typical of those that are generally followed in the automotive industry. All cost methodologies involve the concepts of variable cost and fixed cost, and of direct cost and indirect cost (which is generally called burden). The structure of Figure 2-1 will be followed and explained in greater detail throughout this report, the cost elements are defined and discussed in Section 2.2.

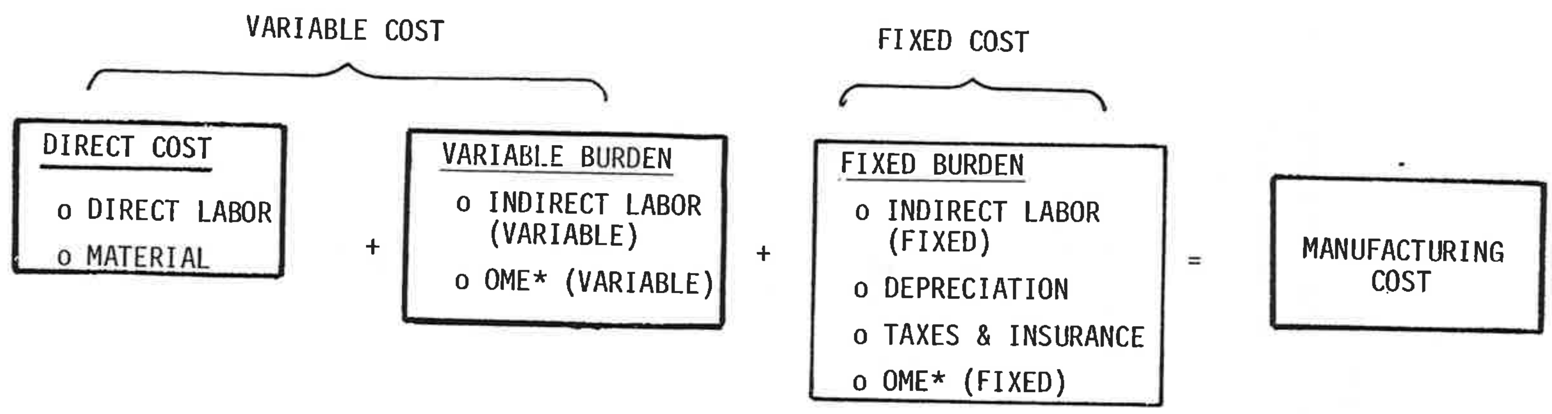
The following sections of this chapter provide an overview of the basis for development of the manufacturing cost methodology. Specifically addressed are the objectives of the methodology, the basic cost elements, the factors which influence cost, the available manufacturing cost methodologies, and the available data sources.

2.1 OBJECTIVES OF COST METHODOLOGY

The initial step in the selection or development of a methodology must be the identification or definition of the needs of the user. This definition of the user's needs establishes the objectives of the methodology. For the NHTSA, the basic need is to develop manufacturing costs to support rulemaking efforts.

This need may be further broken down into two parts:

1. a need to evaluate the manufacturing costs associated with various alternatives to permit selection of the



*Other manufacturing expenses.

FIGURE 2-1. SUMMARY BREAKDOWN OF MANUFACTURING COST most cost-effective alternative for further study or for rulemaking action, or

2. a need for a detailed, defensible cost breakdown for a particular vehicle modification being promulgated as a regulation.

From these two needs, we may establish the objectives of the cost methodology.

Table 2-1 presents nine cost methodology objectives identified to meet the NHTSA manufacturing cost analysis needs. A basic discussion on each of the nine objectives of the cost methodology is contained in the paragraphs following the table.

TABLE 2-1. AUTOMOTIVE MANUFACTURING COST METHODOLOGY OBJECTIVES

1.	Be Credible and Traceable
2.	Provide Detailed Cost Breakdown
3.	Provide Quick-Reaction Estimates
4.	Provide System, Subsystem, and Component Cost Estimates
5.	Provide Cost Estimates for New and Unique Designs
6.	Consider Major Factors Influencing Cost
7.	Be Flexible to Allow User Variations in Input Parameters
8.	Be Available and Consistent for All NHTSA users
9.	Have Low Application and Maintenance Cost

2.1.1 Be Credible and Traceable

The methodology must ensure that manufacturing cost estimates are credible and traceable. This is fundamental to the defensibility of the analyses when used in support of regulatory actions. Credibility and traceability are ensured by avoiding the application of unsubstantiated cost elements, and by providing detailed and auditable cost estimates on all basic cost elements. Sponsors, reviewers, and critics then must deal with actual costs rather than cost factors. A concise, realistic, and supportable methodology ensures credible and traceable manufacturing cost elements.

2.1.2 Provide Detailed Cost Breakdown

A detailed cost breakdown is essential in understanding the basis upon which the actual manufacturing cost is developed. Cost breakdown details are necessary to fully support and qualify assumptions such as production volume; level of technology; processes to be employed; the production schedule; design configuration; and other assumptions. The methodology and discussion on assumptions are discussed further in Section 3.

2.1.3 Provide Quick-Reaction Estimates

Quite often, when considering several alternatives, it is necessary to evaluate the cost estimates for each alternative to select the few to be studied. In this instance, it is necessary to provide an estimate of manufacturing cost in a reasonably short period of time.

2.1.4 Provide System, Subsystem and Component Cost Estimates

Vehicle modifications may require that costs be developed for a system, subsystem, or a component. As such, the cost methodology must be capable of addressing various levels of vehicle modification. The methodology must have the capability to consider all of the steps in the manufacture of an entire vehicle system or just one piece in a system. To accomplish this, it is necessary to consider the materials used; processes to manufacture the part; the assembly operations that may be necessary; and the parts or materials that may be purchased by the system or component manufacturer.

2.1.5 Provide Cost Estimates for New and Unique Designs

Many of the vehicle modifications deal with an existing vehicle system or component. As such, information and actual data are available and may be adapted and used in estimating the cost of the modifications. In some instances, a cost estimate is required for a new or unique system or component design. Where this is the case, the methodology must be capable of developing the cost from the basic cost elements and costing factors discussed in Sections 2.2 and 2.3.

2.1.6 Consider Major Factors Influencing Cost

The manufacturing cost is influenced by a variety of factors which have direct and indirect impacts on the cost. To obtain a credible manufacturing cost estimate, the methodology must consider as many of the influencing factors as possible. Several of these influencing factors are system, subsystem or component production volume, design, manufacturing and production plans, and material requirements.

2.1.7 Be Flexible to Allow User Variations in Input Parameters

The ability to vary the input parameters in the cost estimating methodology will provide a means to identify the sensitivity of the cost elements or influencing factors. This ability will, if used properly, identify the cost elements or influencing factors which control the manufacturing cost. Identification of these sensitive elements and factors will provide NHTSA with a clearer understanding of the constraints on the manufacturers.

2.1.8 Be Available and Consistent for All NHTSA Users

The availability of a consistent cost methodology which may be used by all organizations in NHTSA will be a benefit to the evaluation process for proposed vehicle modifications. It will also provide a better understanding of the factors influencing manufacturing costs associated with the system, subsystem or component.

2.1.9 Have Low Application and Maintenance Cost

The methodology should have a low application and maintenance cost. Future cost estimating tasks should contribute to the improvement of the data base which is used with the methodology.

In summary, a methodology which meets each of the above objectives will provide NHTSA with a powerful cost estimating tool for evaluating prospective rulemaking actions and for identifying the most suitable alternatives for further study or evaluation.

2.2 BASIC COST ELEMENTS

2.2.1 General

This section will identify and discuss the basic cost elements which comprise total manufacturing costs for a part, sub-assembly and/or a complete vehicle. It is assumed that a detailed manufacturing analysis is made during the cost estimating process. This detailed analysis method is similar to the methodology used by the automotive industry to determine manufacturing costs. This cost is usually called a Standard Product Cost by the automotive industry. Other estimating methods for preliminary or quick response estimates as well as the more detailed procedures are discussed in Section 2.4.

2.2.2 Manufacturing Costs

The manufacturing cost refers to that portion of the consumer cost which is directly associated with the manufacture of a part, component or sub-assembly. The major elements are the cost for manufacturing, labor, materials, and overhead or burden factors. There are several ways that these major cost elements can be categorized within the definition of manufacturing cost. A primary classification relates costs to product volume. These two categories of cost are called variable and fixed. Figure 2-1 shows the basic cost elements assembled under the variable and fixed cost categories. Labor (direct and indirect), material, and the other sub-categories of variable and fixed burden costs are placed under the appropriate headings.

2.2.3 Variable and Fixed Costs

The variable costs of production are those costs which are proportional to the production volume. These costs relate directly to what is being made, and the wages to the workers (directly and indirectly involved) for their time. This category also includes the cost of material from which the product is made as well as other production expenses to operate the manufacturing line or plant.

Fixed costs are independent of the production volume and exist in the complete absence of production. In general, these costs result from the ownership, general management and maintenance of the manufacturing plant and its equipment.

2.2.4 Direct and Indirect Costs

There are two other general sub-categories that can be placed under the variable and fixed cost headings. These are direct and indirect costs. A direct cost is clearly traceable to a part or unit of output of the manufacturing line such as direct labor or direct material. The indirect costs alternatively are the costs not clearly attributed to the actual manufacture or production of a part or unit of output. Between these two distinct areas lies a gray region where a cost may not be clearly identifiable as direct or indirect. Some companies and/or industries may have definite cost accounting procedures which suitably subdivide cost elements into each category. Relatively small costs may be classified as indirect simply because it is not worthwhile to break the costs out to a specific product. All fixed costs are indirect.

2.2.5 Basic Cost Elements

This subsection will discuss in detail the cost elements normally encountered when making a manufacturing cost estimate for typical automotive parts. Figure 2-2 shows the major elements that make up this cost and the general categories. An overview

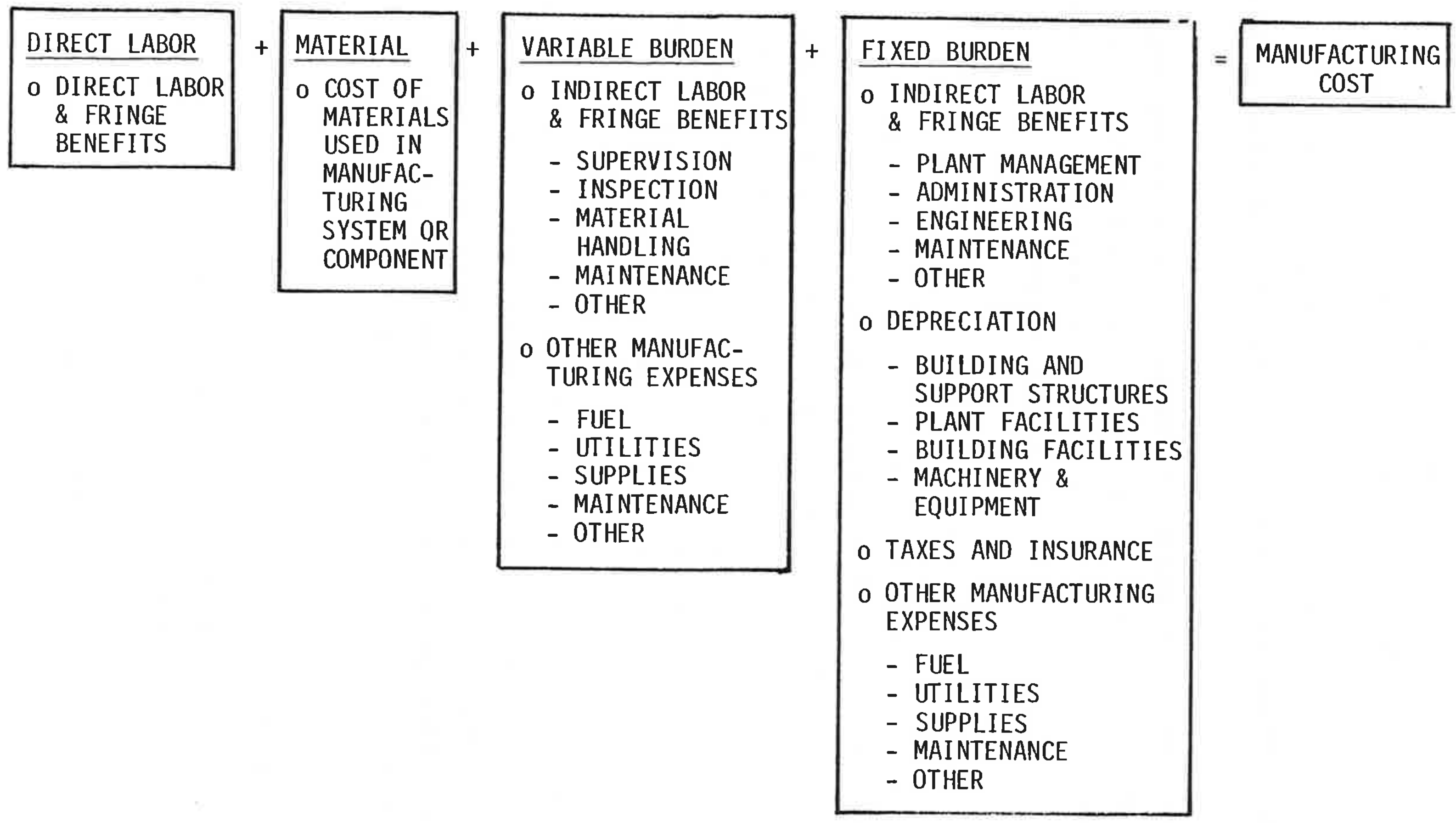


FIGURE 2-2. STRUCTURE AND ELEMENTS OF MANUFACTURING COST

of all costs normally associated with a traditional cost and profit structure is shown in Figure 2-3. This figure shows that the cost of goods sold is equal to the sum of manufacturing cost and selling, distribution, and administrative costs. The selling price minus the cost of the good is the profit.

a. Direct Labor

Direct labor costs are those associated with the actual production of a part or assembly of a unit of output in the manufacturing line or assembly plant. It is for wages (including fringe benefits) for a machine operator, assembler, welder, painter, in-process inspector, or other production workers. The workers actually perform some task on a part which results in a change in the shape, form or composition of the material that makes up the part. Labor costs are determined by the engineering time evaluation of each operation in the fabrication process. It generally includes the following: the time allowed for the work content; the time required to make production system repairs; lost time because of unavoidable time imbalance; and relief time. To calculate the direct labor cost, the estimator multiplies the time required for processing or fabricating the part by the basic hourly wage rate plus the fringe benefits. The average hourly rate (base pay and fringe benefits) for the U.S. automotive industry is shown in Table 2-2.

b. Direct Material

The direct material costs are those associated with the purchase of the material required for the finished product. This cost includes not only the material in the finished part, but also that portion of the material that may be scrapped or lost due to metal removal or incorrectly worked parts that are not salvageable.

The cost should also include the shipping charges and any pre-processing and/or cutting charges that may be done by the supplier prior to delivery. The unit cost for the material

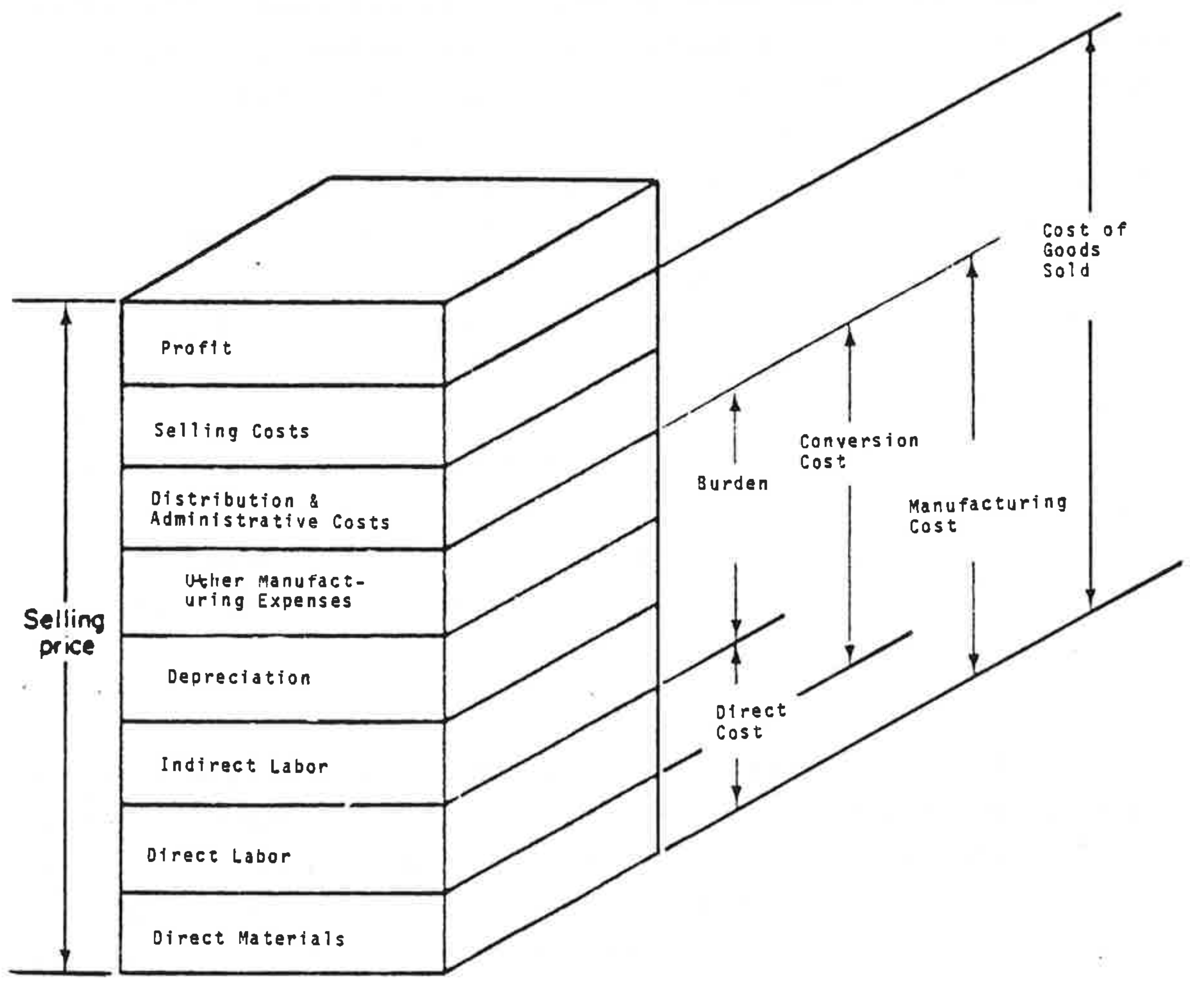


FIGURE 2-3. TRADITIONAL COST AND PRICE STRUCTURE

TABLE 2-2. U.S. AUTOMOTIVE AVERAGE HOURLY LABOR RATES (1980 DOLLARS)

ELEMENTS	HOURLY DIRECT LABOR	HOURLY INDIRECT LABOR	SALARY
o AVERAGE BASE PAY PER HOUR	$ 9.84	$11.20	$15.75
o FRINGE BENEFITS PER HOUR			
- OVERTIME & SHIFT PREMIUM	$ .57	.58	$ .60
- COST OF LIVING	1.85	1.85	1.74 *
- VACATION	1.10	1.17	- **
- HOLIDAY	1.06	1.20	- **
- PENSION	1.67	1.80	2.00
- GROUP INSURANCE	.64	.64	.60
- HEALTH INSURANCE	1.46	1.66	1.50
- F.I.C.A.	.64	.70	.98
o UNEMPLOYMENT			
- FEDERAL/STATE	.34	.34	.33
- SUPPLEMENTAL***	.33	.36	-
TOTAL FRINGES	9.66	10.30	7.75
RATIO FRINGE TO BASE	(98%)	(91%)	(49%)
TOTAL BASE PAY & FRINGES	$19.50	$21.50	$23.50

* DEC. 15, 1981 RATE IS $2.04

** Vacation and Holiday Pay Included with Base Pay

*** Supplemental unemployment benefit (SVB) applies only to hourly employees under union negotiated agreement.

SOURCE: HARBOUR AND ASSOCIATES, INC.

portion of the part cost is calculated by dividing the total material cost (including allowances for scrappage, etc.) by the number of units produced.

c. Direct Cost

The sum of the direct labor and direct material costs can be defined as the direct cost. This cost is the major component of the variable cost since it reflects the design, size and complexity of the part as well as the manufacturing processes needed to produce the end item. In making a preliminary estimate of a similar part or assembly, it is sometimes quicker to adjust or alter the direct costs accordingly, and then estimate the resultant increases (or decreases) in the variable and fixed burden.

d. Indirect Labor, Variable

The indirect labor cost is due to the efforts needed to supplement the manufacturing process, but resulting costs are not traceable directly to one specific product. Variable indirect labor costs are incurred as a result of the actual production and are not those related strictly to the fixed costs of the factory, equipment, and machinery. The indirect labor includes such production related functions as inspection (in-process), material handling, some of the supervision on the production line, and others such as the maintenance, set-up, and cleaning of the production equipment, manning the tool room, and inventory control.

e. Other Manufacturing Expenses, Variable

These include certain utility and supply costs. Utility costs are for the necessary power to run the production equipment during the manufacturing cycle. They also include those needed to heat, cool, ventilate and illuminate the various work areas of the plant. These latter costs are over and above those needed just for normal maintenance of the buildings. Supply costs in this category include costs for perishable production tools (hand tools, drills, reamers, grinding wheels, welding tips and/or rods). Other costs may be for maintenance materials used up during the production such as lubricants, cutting oils, machine oils and replacement parts for the equipment.

f. Indirect Labor, Fixed

Fixed costs are independent of the production volume and exist in the complete absence of production. In general, these costs result from the ownership, management, engineering design of the product, and maintenance of the buildings, equipment, and property. Specific examples of fixed indirect labor costs are for wages (including fringe benefits) for those involved not only in the management, administration, maintenance, and protection of the plant but also for all engineering, and for quality control. Other examples of indirect labor that are considered as fixed costs may include product development, tool design, and production control tasks.

g. Depreciation

Another important element of the fixed costs is the depreciation of the building and of the capital equipment. In the automotive industry, buildings have been depreciated based on a 30 year life. The average lifetime used for capital equipment is 12 years. Depreciation applies to building and support structures, including manufacturing building, power house, waste treatment facility and tank farm; plant facilities, including tool room, automatic storage system, material handling equipment, and washers; building facilities, including central coolant system, electrical, heating and ventilation, underground services and other building utilities; and production machinery and equipment, including machine tools (for cutting, boring); pressed metal machinery (for stamping, forming); forging equipment; foundry equipment; automatic transfer machinery; and many other kinds of production, support and test equipment.

h. Taxes and Insurance

Tax and insurance costs are based primarily on the property, building and equipment that is in the production plant. These are considered as fixed costs since they have no relationship to the production volume.

i. Other Manufacturing Expenses, Fixed

Other fixed manufacturing expenses include the costs for maintenance items and supplies, utilities, rentals, outside services, and miscellaneous other items not directly related to the production volume.

2.2.6 Burden Rate Development

In estimating manufacturing costs, a major part is the computation and development of the variable and fixed burdens. These two categories of overhead costs are added to the direct labor and direct material costs to produce the total manufacturing cost. In many estimating systems, the burden is applied as a rate or percentage of the labor costs. The advantage of this method is the simplicity, and it probably is sufficiently accurate for a small shop or portion of a larger factory, or for making preliminary estimates.

A major factor in the calculation of the variable portion of manufacturing costs is variable burden. Variable burden costs attempt to account for expenditures directly related to the production process, and vary in proportion to the production level.

The principal components of variable burden, as mentioned previously are:

- o Indirect Labor
  - inspection
  - material handlers
  - machine maintenance
  - supervision
  - set-up
- o Utilities
  - electricity

- heat
- light

o Perishable tools

o Supplies

o Inbound freight (optional)

After all of the variable expenses of maintaining a facility are gathered and totalled, they are distributed among several distinct work areas or cost centers that comprise the total facility. [Cost centers are productive departments engaged in producing a common product or type of product to which a single burden rate can be applied. A cost center can be considered as a grouping of similar processes and support activities (grinding, milling, turning)]. For example, a stamping plant (automotive) is usually divided into four distinct cost centers: large press, small press, repair, and assembly. An engine plant, with more dedicated or product-specific equipment, may have many more cost centers: block line, head line, head assembly, valve line, crank line, etc. The breakdown is somewhat arbitrary, and it will vary from facility to facility of the same type.

The apportionment, or allocation, of variable cost to cost centers is made on a logical basis, and costs are assigned to proportion to the cost center's use of those variable services. The most popular methods of allocating variable costs are based on the square footage occupied by the cost center, or the amount of direct labor in that cost center. When the variable costs associated with a single machine, or machine system, are significant and easily identifiable, all of those costs are attributed to the cost center in which that equipment is located. In fact, large and expensive equipment (machining centers, block lines) is often considered to be a separate cost center.

<u>Variable burden rate</u> is a concept of distributing the variable costs of a cost center among the output, or production, of that cost center. Several methods are in use. The most popular method, the method used by the auto industry, apportions the cost

on the basis of direct labor hours planned for the cost center. Another frequently used method of determining burden rate is to apportion the costs on the basis of machine occupancy hours. This yields a burden rate which is expressed in dollars per hour of machine time. Other methods apportion the cost on the basis of material used, number of parts produced, direct labor time, cost center value, and services rendered.

Fixed costs, fixed burdens, and fixed burden rates are determined and allocated in the same manner. All of the same criteria apply. The principal elements of fixed costs as discussed previously, are:

- Indirect labor
  - all engineering
  - quality assurance
  - management
  - clerical
  - administration
  - maintenance
- Depreciation
  - equipment
  - building
- Taxes
- Insurance
- Supplies
- Utilities
  - electricity
  - heat
  - light

- o Rentals
- o Outside services

Some estimators combine the fixed and variable cost to establish a single burden rate called manufacturing burden. Another approach defines four categories of total burden: indirect labor (fixed and variable combined), depreciation, taxes and insurance, and other manufacturing expenses (fixed and variable combined). This approach is illustrated in Chapter 4.

The data used to develop burden rates comes from a facility's historical records and budget projections. Radical departures from this input data may require periodic recalculation and adjustment of burden costs and rates.

Table 2-3 summarizes the major constituents of variable and fixed burden, showing which are variable, which are fixed, and which can be both.

TABLE 2-3. ELEMENTS OF BURDEN (Partial)

VARIABLE BURDEN	ELEMENT	FIXED BURDEN
	LABOR	
x	Supervision	
x	Inspection	
	Engineering	x
x	Clerical	x
x	Material Handlers	x
	Property Maintenance	x
	Equipment Maintenance	x
	Custodial	x
	MATERIAL	
x	Fuel and Utilities	x
x	Perishable Tools	
	Office Supplies	x
x	Factory Supplies	
x	Support Materials	x
x	Rework and Scrap	
	OTHER	
	Communications	x
	Purchased Services	x
	Insurance	x
	Taxes	x
	Depreciation	x

2.3 FACTORS WHICH INFLUENCE COSTS

2.3.1 Design

During the design phase, a part is engineered so that it meets the functional and operational requirements. The design engineer also must consider and comply with specifications regarding weight limits, type of finish, corrosion resistance, durability, serviceability, maintainability, and other attributes. These requirements plus the part's shape, size, and material have a direct relationship to the manufacturing process which, in turn, impacts the cost.

Manufacturing engineers usually interface with the design engineer prior to the final release of the drawings and part specifications in order to make sure that the part and/or assembly can be easily and economically manufactured and/or assembled before any investment is made. At the same time, standardization of material, fasteners, tolerance, and surface finish can be made. This preproduction analysis is necessary to eliminate the cost of engineering changes, and the cost of re-working or scrapping of the tooling. During this time, before the drawings are released, the design engineer is more receptive to design changes. The resulting analysis should address the following:

a. Consider the end-use of the part and complete assembly.

b. Examine the need for surface finishes, tolerances and machined areas shown on the drawing.

c. Analyze the limitations imposed by the shape and material characteristics.

d. Consider potential interchangeability and service problems.

e. Consider fabrication and/or fastening device.

f. Investigate possible adaption of lugs, slots, etc. necessary for manufacture, handling, inspection and packaging.

g. Analyze probable limitations for future product changes.

2.3.2 Volume or Quantity of Parts to be Manufactured

Another important factor directly influencing the cost is the volume of parts that are to be manufactured. Major volume-related factors are the type and cost of the tooling, material, and other variable burden costs. Because of escalating costs in tools, tooling for some processes is one of the main items in a cost estimate. In many industries, the tool costs are treated as a separate component of the estimate, rather than being added under the heading of fixed burden. In the case of an automotive assembly plant, the tooling cost to convert to a new car model is approximately 70 million dollars, and for a typical stamping plant, the tooling cost is approximately 140 million dollars.* Since tooling costs are prorated over the number of units made, it can be seen that the unit cost (for tooling) is strongly tied to the volume of parts manufactured.

2.3.3 Manufacturing Plan

To obtain an estimate of sufficient accuracy, each part must have a processing plan. There must be some conception of the tooling and equipment to provide the part. In a small shop, or if only a small quantity is required, the manufacturing plan may only be a mental review of the processes. As the plant and/or the quantity increases, a more detailed plan is needed to document each process and its associated direct labor, equipment, tooling, and machine time to produce one unit. Special material handling test and inspection equipment, if needed, also must be identified and factored-in if it normally is not available or existing in the plant. The level of technology of the process also must be stated in order to clearly identify the type of equipment to be

*G. Byron, Surrogate Plant Data Base Vol. 1, TSC report August 1982, page B-8.

used and/or purchased. Several alternative plans can be examined to determine which plan is better suited for manufacturing the part in the most economical manner while meeting the production schedule.

2.3.4 Production Plan

Production planning includes the investigation, evaluation, and coordination of the manufacturing capabilities to assure timely production through efficient use of facilities, manpower, and materials. During the investigation, the production steps required, as well as where and when to perform them, have to be determined. Also included is the calculation of material or purchased part requirements, and development of detailed production schedules. The production plan is a further refinement of the manufacturing plan and fits the production of a specific part or assembly into the overall plan of the department or factory. Under the production control activity, the whole process is monitored and evaluated. The evaluation consists of reviewing production materials, methods, tooling, operating time, etc., so that the planned manufacturing results are realized in terms of quantity, quality, time, location, and cost.

2.3.5 Material Requirements

The material that is used in making a part is a direct factor in influencing the cost. The design engineer normally selects the material in order to satisfy the strength, weight, appearance and end use requirements. During the pre-production planning phase, the part configuration and material type is reviewed and evaluated as to its relative cost and manufacturability. The manufacturing engineer attempts to find less expensive, more easily handled material that would be a satisfactory substitution for the originally selected material. The recommended material change, however, should not compromise the strength, weight or other features of the part. The form in which the material is supplied also influences the process and cost. For instance, in the case of stamped parts, the use of steel in the coil form would allow for automatic feed into a punch press. This more automatic process would be less costly than a manual feed process and would probably result in more consistent parts.

Other cost related impacts due to material are the current and future projected material costs, inventory costs, quantity discounts, handling, transportation, and lead time. Trade-off studies are sometimes needed to evaluate the optimum material acquisition plan, balancing all of the cost related impacts.

2.4 REVIEW OF AVAILABLE MANUFACTURING COST METHODOLOGIES

A review of the existing cost estimating methodologies is the initial step in the selection or development of an automotive cost estimating methodology. This review is directed at ascertaining whether the existing methods adequately address the methodology objectives presented in Section 2.1. There are many manufacturing cost methodologies in existence, and they are utilized for a variety of applications. All of these methodologies may be grouped into three basic approaches.

1. Parametric Method of Cost Estimating
2. Analogy Method of Cost Estimating
3. Industrial Engineering (Detailed) Method of Cost Estimating

Within each of these three basic approaches, there are additional cost estimating methodologies which are modifications of the basic approach. The following paragraphs provide a brief discussion of each of the three approaches.

2.4.1 Parametric Cost Estimating

In parametric cost estimating, the total cost (manufacturing cost) of a particular alternative is determined by using physical or performance parameters for which the cost has been determined by some other means. In other words, a functional relationship must be established between the total cost of an alternative and the various characteristics or parameters of the alternative. This approach has, in past years, been used by the NHTSA in estimating the manufacturing costs associated with rulemaking actions. A specific example has been in the cost estimating of components such as bumpers. In evaluating bumper system alternatives, the manufacturing cost estimates were developed using the parameter of weight in pounds. Some of the early cost estimates were based on a factor of one-dollar per pound of weight of the bumper system. Hence, a bumper system weighing 132 pounds was estimated to cost $132. At other times, the weight per pound was less than or more than one-dollar.

The parametric approach is not too realistic, accurate or defensible. It therefore does not address some of the objectives of the methodology (Table 2-1) and is open to easy criticism from opponents of the rulemaking action.

2.4.2 Analogy Method of Cost Estimating

The analogy method is a specialized method by which judgment may be used to estimate manufacturing costs by making direct comparisons with historical information on similar existing alternatives or their components. It is probably the most widely used method of cost analysis to date. The major problem of the analogy method is that it is basically a judgment process and, as a consequence, requires a considerable amount of experience and expertise if it is to be done successfully. Moreover, judgment should always be recognized for what it is, namely a guess, albeit an educated guess.

Since all the factors seldom will be considered in the development of a manufacturing cost estimate, this reliance on judgment or historical data limits the usefulness of this method. Also, the method will not even provide an order of magnitude estimate for the manufacturing costs associated with new or unique designs. Furthermore, without historical data, this method is basically unuseable. As such, this method will not be credible, traceable or definable and, therefore, fails to satisfy some of the desired methodology objectives.

2.4.3 Industrial Engineering Method of Cost Estimating

Within this approach, there are several methods of cost estimating available. The method chosen is often dictated by the accuracy required, the time available to do this job, and the resources in the form of skilled personnel and cost data that are available. The most accurate method for estimating the manufacturing costs is to conduct a detailed manufacturing analysis of each step or process involved in the production of the system, subsystem and component. In this method, each of the basic cost elements, direct labor, burden, and material must be estimated. How each of these elements is estimated then determines the adequacy of the methodology in achieving the objectives set forth in Section 2.1. A further complication in the cost estimating process is the dependence of each of the cost elements on the data sources available.

The most difficult cost element to quantify is the burden. Several methods of estimating the burden are in use. The most popular method, the method used by the auto industry, apportions the cost on the basis of direct labor hours planned for that cost center. This yields a burden rate which is a multiplier of direct labor cost. Another frequently used method of determining burden rate is to apportion the costs on the basis of machine occupancy hours. This yields a burden rate which is expressed in dollars per hour of machine time. Other methods apportion the cost on the basis of material used, number of parts produced, direct labor time, cost center value, and services rendered (asset center approach). The methods which utilize a burden rate multiplier of direct labor cost or machine occupancy time are difficult to use, and, often, the results are not very traceable or defensible. The major difficulty with these two methods is their reliance on historical data which, in some instances, is proprietary and may also be out of date or based on similar, but not identical, components or processes. Furthermore, in instances where there is no specific direct labor (automatic machine operations), there can be no burden multiplier used, hence, no burden calculation. Other problems with those methods arise in estimating costs of new or unique designs where no previous information is available, in the ability of these methods to estimate costs at different levels such as system, subsystem, or component, and the availability of a data base for use by all concerned in NHTSA.

Another cost estimating methodology that may be used to complement this method or to independently estimate manufacturing costs has recently been developed for the NHTSA. This method, which is similar to the asset center approach, is explained, in detail, in Chapter 3 and is demonstrated in Chapter 4. The method utilizes an available data base, and enables the user to examine all parts of the manufacturing cost estimate. The approach is one that is presently used by the automotive manufacturers, and it serves to clarify the determination of burden rates for manufacturing operations.

2.5 REVIEW OF AVAILABLE DATA SOURCES

To develop a manufacturing cost estimate, using one of the available methodologies, requires that the user provide data to be inputed into the methodology. This section examines the data inputs necessary. The data sources selected for review here are those that are relevant or utilized in the methodologies discussed in Section 2.4.

2.5.1 Historical Data Files

Primarily, historical data is obtained from previous estimating efforts or is developed during or after manufacture of the particular system, subsystem or component. The most accurate historical data is in the possession of the automobile manufacturer not with a rulemaker like NHTSA. Organizations which are users and procure equipment, such as the Department of Defense, also have historical data from their last procurement. The historical data serves as the basis for the Parametric Method of Cost Estimating and the Analogy Method of Cost Estimating. Even with the application of fairly recent historical data, the cost estimates developed will be questionable. For the NHTSA, the historical data available is from estimates which have been developed in-house or with consulting firms, and there is no accurate mechanism by which the data can be validated. Considerable historical cost information is available from the numerous teardown studies that the NHTSA has funded over the years. This information is documented in several reports.

2.5.2 Data Sources for Burden Rates

One of the primary cost estimating methods presently employed by NHTSA and their contractors utilizes the burden rate multiplier concept. This method requires that the estimator have available a schedule of burden rates which are current and applicable to the specific process or machine operation. Ideally, these burden rate schedules are obtained from the actual manufacturing costs recorded in the accounting department. As such, they are neither readily available nor can they be substantiated. The burden rates will also vary among companies. As noted in a recent study funded by the NHTSA, several different contractors used different burden rates for the same process or operation. Furthermore, where none of the burden rates were traceable, the manufacturing cost estimates cannot be considered credible or tracrable.

2.5.3 Data on Capital Costs and Plant Budgets

Capital cost and plant operating data can be used to develop a detailed manufacturing cost estimate in which all of the cost elements are identified and presented. Sources of this data are available from the "surrogate plant" data base developed for NHTSA studies of the automobile industry's capital investment program.

The surrogate plant data base consists of data on various standard or "typical" automotive plants. It has been developed with the hypothesis that the inherent economics of U.S. auto manufacturing have resulted, over time, in standard manufacturing plant design. The "surrogate" automotive plants are typical of automotive manufacturing plants in terms of:

- o Size
- o Production rate
- o Manufacturing process
- o Technological sophistication
- o Flexibility

Thus, a surrogate automobile engine plant, while not representing any particular manufacturer's plant, does provide information that when appropriately aggregated or scaled will yield accurate industry statistics. Table 2-4 presents a listing of the plants covered, to date, in the surrogate plant data base.*

For each plant shown in Table 2-4, the following information has been developed:

- o Manufacturing processes. A description of the key manufacturing processes in the plant.
- o Capital cost. A detailed description of capital costs associated with the plant site, building and manufacturing facilities, and machine tools and equipment. The capital costs are presented at four levels of detail:
  - total facility
  - plant and equipment
  - major department
  - major equipment

*A detailed discussion of surrogate plants is presented in G. Byron, Surrogate Plant Data Base, Vols 1-4, TSC report, August 1982.

TABLE 2-4. PLANTS CONTAINED IN THE SURROGATE PLANT DATA BASE

Final Assembly Plants

- Passenger Car
- Light Truck and Van

Body Manufacturing Plants

- Stamping
- Hardware
- Electronic Components
- Plastics Molding
- Instrumentation
- Trim
- Foam Pad and Supports
- Seat Frame and Spring
- Glass
- Heater and Air Conditioning
- Seat Belt
- Air Bag
- Fiberglass Products

Chassis Manufacturing Plants

- Forge
- Grey Iron Foundry
- Nodular Iron Foundry
- Alunimum Fountry
- Die Cast
- Wheel
- Steel Bumper
- Plastic Bumper
- Electric Motor
- Engine: 4-Cylinder Gas
- Engine: 4-Cylinder Diesel
- Engine: V-6 Cylinder Gas
- Engine: V-8 Cylinder Gas
- Manual Transmission
- Manual Transaxle
- Automatic Transmission
- Automatic Transaxle
- Axle
- C-V Joints and Half Shafts
- Suspension
- Brake
- Radiator and Coil
- Steering
- Frame

- Layout. A layout is provided for each plant showing a typical floor plan and typical area requirements (See Figure 2-4).
- Manpower. Detailed manpower requirements are provided for each plant by department. Department manning requirements to the level of each job position are also provided for some plants. (See Tables 2-5 and 2-6.)

In addition, for selected automotive manufacturing plants which are typical of groups of plants, the following information has been developed:

- Operating expenses. Manufacturing budgets for various plants showing expenses for labor, maintenance, utilities, and taxes and insurance. (See Table 2-7.)
- Manufacturing cost. Operating and capital costs are allocated on a per unit basis to provide the total manufacturing cost of plant products, not including materials. The output of one plant becomes the material input into another.
- Pre-production timing. Timing charts are provided showing the planning requirements for the plant prior to product launch.
- Launch rates. Typical start-up employment and plant volume are shown for a new product launch (actual start of production).
- Pre-production and launch expenses. Capital, manpower and other manufacturing expenses are detailed for the preproduction and launch period.

With this data base, which is readily available in NHTSA, it is possible to develop detailed manufacturing costs for systems, subsystems, and components. The following sections will present, in detail, the methodology and its application to the modifications of a vehicle structure and the assembly of the total vehicle.

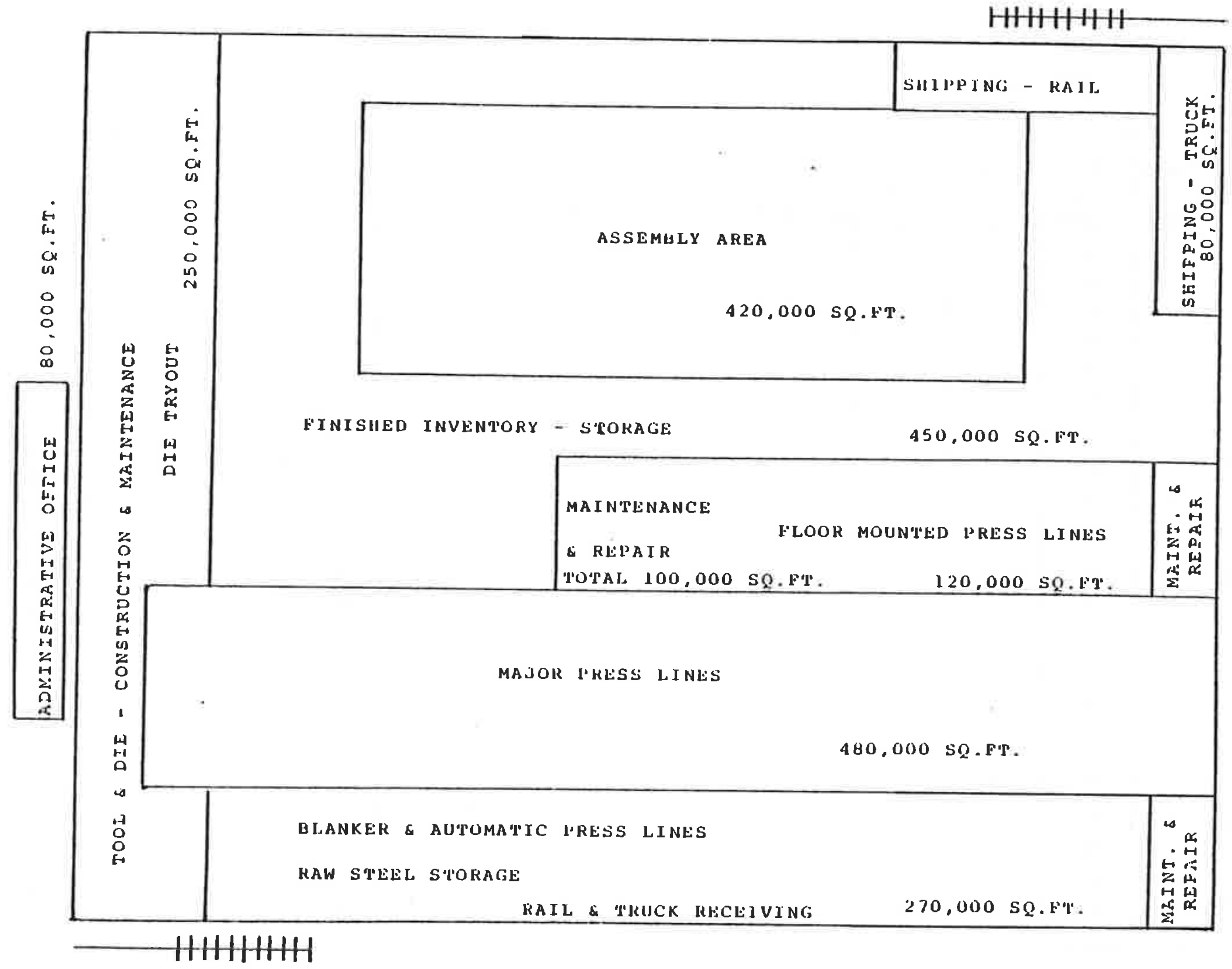


FIGURE 2.4. NEW STAMPING PLANT LAYOUT

TABLE 2-5. DETAIL ANALYSIS OF MANPOWER BY PLANT AND ORGANIZATION

DEPARTMENT	PLANT MANPOWER									
	CAR ASSEMBLY	BODY STAMPING	4 CYLINDER ENGINE	F.W.D. A/T	F.W.D. M/T	BRAKE PLANT	STEERING PLANT	C.V.JOINT PLANT	SUSPENSION PLANT	IRON FOUNDRY
PLANT MANAGER	10	5	6	10	8	4	3	4	5	8
PLANT PROTECTION	34	32	24	32	24	10	10	10	12	24
MEDICAL	5	5	4	4	4	3	3	3	3	4
CONTROLLER	56	40	30	42	32	10	9	10	10	34
INDUSTRIAL ENGINEER	14	10	10	14	10	5	4	5	5	10
QUALITY CONTROL - SALARY	42	33	24	40	31	9	8	10	12	36
- I/L HOURLY	307	80	30	130	75	25	20	43	55	125
PRODUCTION CONTROL - SALARY	91	90	38	40	34	10	8	11	15	40
- I/L HOURLY	232	420	73	116	85	22	16	55	55	155
MANUFACTURING ENGINEERING -SALARY	50	135	70	105	80	18	14	16	26	88
- I/L HOURLY	376	740	320	390	317	91	78	97	144	502
PERSONNEL - SALARY	19	20	19	20	19	6	6	6	8	20
PRODUCT ENGINEERING - SALARY	15	5	10	23	18	3	3	3	4	16
- I/L HOURLY	26		4	10	8					8
PRODUCTION - SALARY	167	125	50	90	70	22	12	22	25	80
- I/L HOURLY	162	90	5	20	10	8	4	10	10	20
- D/L HOURLY	2,788	1,500	670	1,048	860	260	185	244	445	880
UNION - I/L HOURLY	27	20	8	16	10	4	2	5	6	10
TOTAL - SALARY	503	500	285	420	330	100	80	100	125	360
- I/L HOURLY	1,130	1,350	440	682	505	150	120	210	270	820
- D/L HOURLY	2,788	1,500	670	1,048	860	260	185	244	445	880
GRAND TOTAL	4,421	3,350	1,395	2,150	1,695	510	385	554	840	2,060
CARS/CARSETS/UNITS PER DAY	1,200	3,673	1,632	2,040	2,040	2,040	2,040	2,040	2,040	11,666
TOTAL HOURS PER UNIT	29.5	8.1	6.8	8.4	6.6	2.0	1.5	2.2	3.3	1.4

Trucks 5.7

TABLE 2-6. DETAIL ANALYSIS OF MANPOWER BY PLANT AND ORGANIZATION, BY DEPARTMENT

	PLANT MANPOWER									
	CAR ASSEMBLY	BODY STAMPING	4-CYLINDER ENGINE	F.W.D. A/T	F.W.D. M/T	BRAKE PLANT	STEERING PLANT	C.V.JOINT PLANT	SUSPENSION PLANT	IRON FOUNDRY
PLANT MANAGER										
PLANT MANAGER	1	1	1	1	1	1	1	1	1	1
SECRETARY	1	1	1	1	1	1	1	1	1	1
MANUFACTURING MANAGER	1		1	1	1	1				1
PRODUCTION MANAGER	1	1		1						
SUPERINTENDENT	4	2	2	4	4	1	1	2	2	4
CLERK	2		1	2	1				1	1
TOTAL PLANT MANAGER SALARY	10	5	6	10	8	4	3	4	5	8
PLANT PROTECTION										
CHIEF	1	1	1	1	1	1	1	1	1	1
FIRE CHIEF & CAPTAIN	1	2	2	2	2	1	1	1	1	1
SARGEANTS	4	3	2	1	2	1	1	1	1	2
PATROLMEN	24	21	16	21	16	6	6	6	8	16
FIRE MARSHALLS	4	5	3	5	3	1	1	1	1	3
TOTAL PLT.PROTECTION SALARY	34	32	24	32	24	10	10	10	12	24
MEDICAL										
DOCTOR	1	1	1	1	1	1	1	1	1	1
NURSES	4	4	3	3	3	2	2	2	2	4
TOTAL MEDICAL SALARY	5	5	4	4	4	3	3	3	3	4

TABLE 2-7. MANUFACTURING BUDGET, BODY STAMPING PLANT

ANNUAL VOLUME 900,000 CAR SETS

($000)

	FIXED AND NON-VARIABLE	VARIABLE	TOTAL
DIRECT LABOR	—	$ 28,100	$ 28,100
FRINGE BENEFITS	—	26,100	26,100
TOTAL		54,200	54,200
INDIRECT LABOR			
SALARY	$ 10,300	5,200	15,500
FRINGE BENEFITS	4,100	2,000	6,100
HOURLY	9,700	18,700	28,400
FRINGE BENEFITS	8,000	15,000	23,000
TOTAL	32,100	40,900	73,000
OTHER MANUFACTURING EXPENSES			
MAINTENANCE	3,100	2,600	5,700
PERISHABLE TOOLS	80	600	680
SPOILAGE		6,400	6,400
UTILITIES	6,000	800	6,800
SUPPLIES AND OTHER	4,800	3,100	7,900
TOTAL	13,980	13,500	27,480
FIXED EXPENSES			
TAXES AND INSURANCE	4,400	—	4,400
DEPRECIATION	29,500	—	29,500
TOTAL	33,900	—	33,900
TOTAL MANUFACTURING BUDGET	$ 79,980	$ 108,600	$ 188,580

3. DEVELOPMENT OF MANUFACTURING COST METHODOLOGY

This chapter will identify and explain each of the steps in the methodology. An example of a vehicle modification cost estimate is demonstrated in Section 4.1.

3.1 DEFINITION OF PART OR VEHICLE MODIFICATION TO BE COSTED

This section will focus on the identification of the part or vehicle modification to be made. In general, the definition is obtained by asking the following:

- o What must be manufactured?
- o When or if assembly work is needed?
- o What kind of material is involved?
- o What volume is needed?

Depending on the type of estimate required (preliminary or final), the part or modification may be described by a written description, specifications, sketch, layout detail and/or assembly drawings. The purpose of the estimate may be the following:

- o Establish a bid price for a quotation or contract
- o Verify a vendor's quotation
- o Determine whether a product can be manufactured profitably
- o Provide data for a make-or-buy decision
- o Help determine most economical method, process of material
- o Provide a temporary standard for production efficiency and/or cost goal
- o Help in evaluating different design proposals

The description and/or drawing, should provide the answer to what must be manufactured by indicating the form, shape, and size of the part or product. Whether or not assembly is needed or when it is needed will depend on the part's function. For instance, is the part used alone or as part of another subassembly? If it is not a stand-alone part, how is it attached or fastened to the next sub-assembly?

The type or grade material used is important since it will have a direct bearing on the cost and, most likely, will influence the handling and manufacturing process required. Some part or product material specifications allow latitude in the choice of material which can be used to make the end product. This flexibility gives the cost estimator a range of choices in material and processes to obtain the material/process combination with the lowest cost.

The volume of parts needed has a similar relationship to costs as the material, since the total quantity and rate of production will directly influence the process required and other cost related items such as machinery, equipment and tooling.

3.2 MANUFACTURING ASSUMPTIONS

Now that the part, product or vehicle modification is defined according to Section 3.1, the next question is how is this item actually made. The following steps will identify the manufacturing and production assumptions required:

- Identification of the Manufacturing/Assembly Processes to be used
- Selection of Level of Technology needed
- Development of Process/Plant Operating Schedule
- Identification of Other Pertinent Assumptions

As previously mentioned, the process selected is dependent on the size, shape, form of the piece, material required, and quantity needed. The optimum process is one that results in the most economical solution and one that fits within the area of interest and expertise of the manufacturing facility. Otherwise, if this were not true, an earlier decision should have been made to purchase rather than make the part. There are exceptions, however, where, for some reason (high quality requirements, lack of qualified vendors, need to maintain optimum shop loading, available tooling, etc.), some part would be kept in-house even though lower cost parts may be available from vendors.

The identification of the process also leads to the type of facility and equipment requirements. A stamping process would require punch presses and dies to shape and form the part. If the material was supplied in a coil or rolled form, then handling equipment to decoil, straighten and feed the material into the first stage of the press line would be required. A sand casting, on the other hand, would need a foundry facility with the specialized handling equipment, and foundry tooling such as the core and pattern making equipment. A machinery line to finish the casting would result in specifying milling, turning and/or boring machine tools or a dedicated transfer line in the case of an engine block or head.

Along with the process selection, the level of technology is picked based on economic considerations. A more automated process would require fewer workers, but would have higher capital equipment and depreciation costs. A study of several technological levels ranging from fully manual to fully automatic could be made to determine the best solution if a long term facility or process were being planned. If only a short term process requirement was being planned, it may be that the currently available equipment and technology would be used. Many variations between these two extremes could be investigated for an optimal solution.

After the process is fully identified and defined, a schedule has to be set up to provide the parts in the proper quantity and at the required time. The volume requirements per year will determine the number of lines and the support and material handling equipment required. The example in Section 4.1 will better illustrate how the output of the proposed process is checked and allowances made for downtime.

3.3 PRODUCTION PLAN

This portion of the methodology consists of the detailed specification of the production process such as:

- o Overall layout of the line
- o Equipment type
  - Size
  - Number
  - Floor Space
  - Production Rate
  - Tooling
- o Tooling
- o Material Handling Equipment
- o Special Supplier
- o Manpower Required

With all of the above defined, the methodology can proceed to the next step.

3.4 ESTIMATING COST ELEMENTS AND TOTAL COST

The following cost structure is followed:

- o Direct labor, including fringe benefits
- o Materials
- o Burden
  - Indirect labor, including fringe benefits
  - Depreciation
  - Taxes and Insurance
  - Other manufacturing expenses

These costs are estimated in each plant that is involved in the production of the part or assembly under consideration. The structure of surrogate plants provides a baseline for estimating factors, such as the ratio of indirect to direct labor, the depreciation cost per 1,000 square feet allocated to a production process, and the ratio of taxes and insurance to total labor cost. A description of the estimating process is best understood by following the example of Section 4.1.

The estimation procedure depends on the objective of the analysis. For example, if it is desired to estimate the cost difference of a safety requirement from today's production, and additional parts are required to meet a safety standard, the simplest way of doing this is to cost only the incremental steps required to accommodate these added parts. Such an example is carried out in Section 4.1. If the difference is more substantial, for example, a requirement for a wholly redesigned front door, cost analysis would probably have to be performed for the entire fabrication and assembly of both the re-designed and the standard door for a particular car line. The difference of the two costs would be calculated.

If, on the other hand, the objective is to perform a sensitivity analysis for impact of changes in manufacturing technology, labor requirements, labor rates, or plant size on car cost, the use of the entire surrogate plant cost structure is necessary. This is illustrated in Section 4.2.

4. DEMONSTRATION OF COST METHODOLOGY

This Chapter contains an actual demonstration of how the previously discussed methodology is used. Two examples will be used: a) modification of Volkswagen Rabbit "A" post costs; and b) calculation of cost to assemble a passenger vehicle. Both of the above are based on surrogate plant and other related information.

4.1 MODIFICATION OF VOLKSWAGEN RABBIT "A" POST

The purpose of this modification to a VW Rabbit was to improve the crashworthiness of the vehicle. Other portions of the vehicle were also strengthened, but only the "A" post estimate is discussed. The "A" post is shown in Figure 4-1 without the modification. Figure 4-2 shows the "A" post with the modification. Four pieces (part no. 146, 147, 254 and 255) are needed for each side of the car, and the cost to fabricate these parts as well as to assemble them will be determined.

The production process for these parts is a basic stamping line and an addition to the assembly line to add four parts to each side. Figure 4-3 described these basic processes.

Prior to selecting the actual machining and equipment, it is important to know that the total quantity required is enough for 1,000,000 cars per year, 8 parts per car (4 left hand and 4 right hand parts) or 8,000,000 parts per year.

Three typical stamping lines are shown in Figure 4-4. This range of press lines covers the currently available technology for this process. Each of the three types (fully automatic, partially automated, and manual) has the same decoiler/cut off line using only one worker. The rest of the workers are needed to transfer the stamped parts between each press (for the semi-automated and manual lines) and to unload the piece at the end of the line. Currently, the most predominant stamping operation in use is the

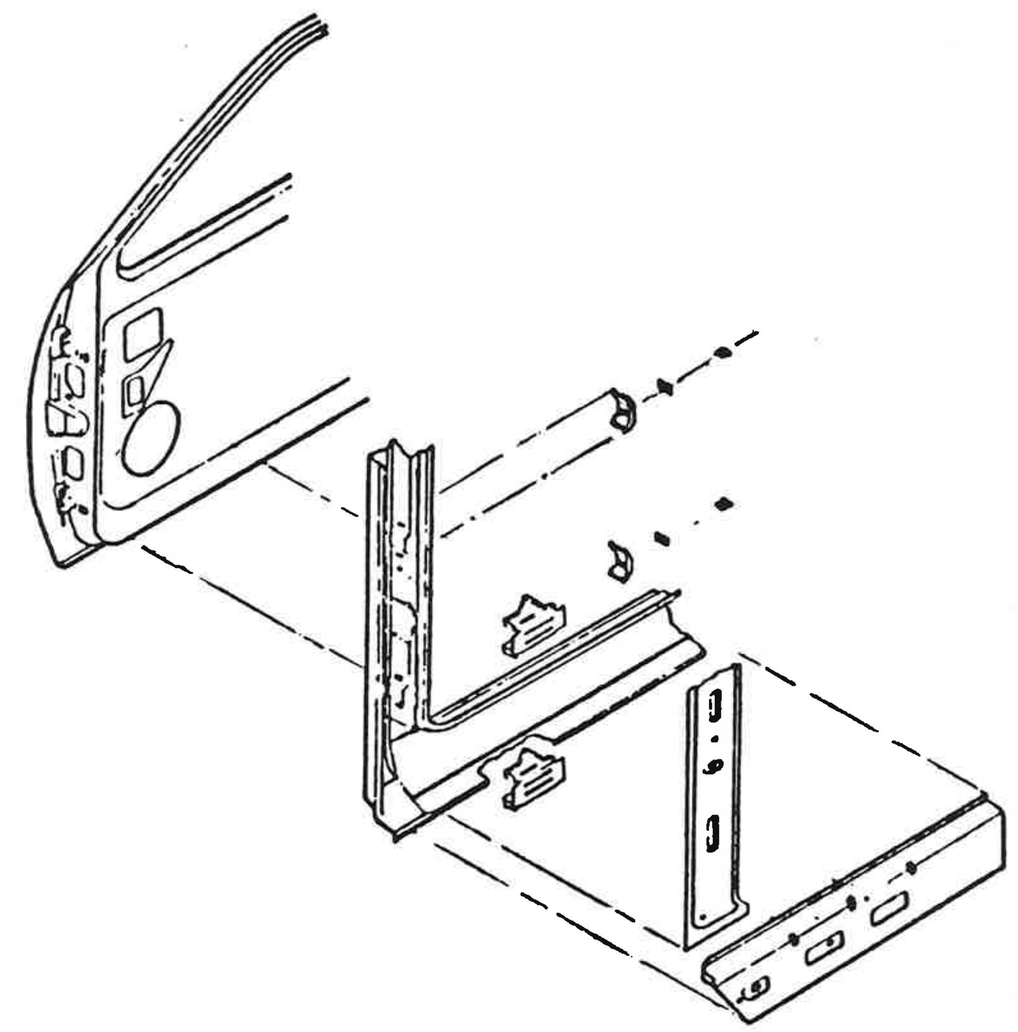


FIGURE 4-1. VEHICLE BEFORE "A" POST MODIFICATION

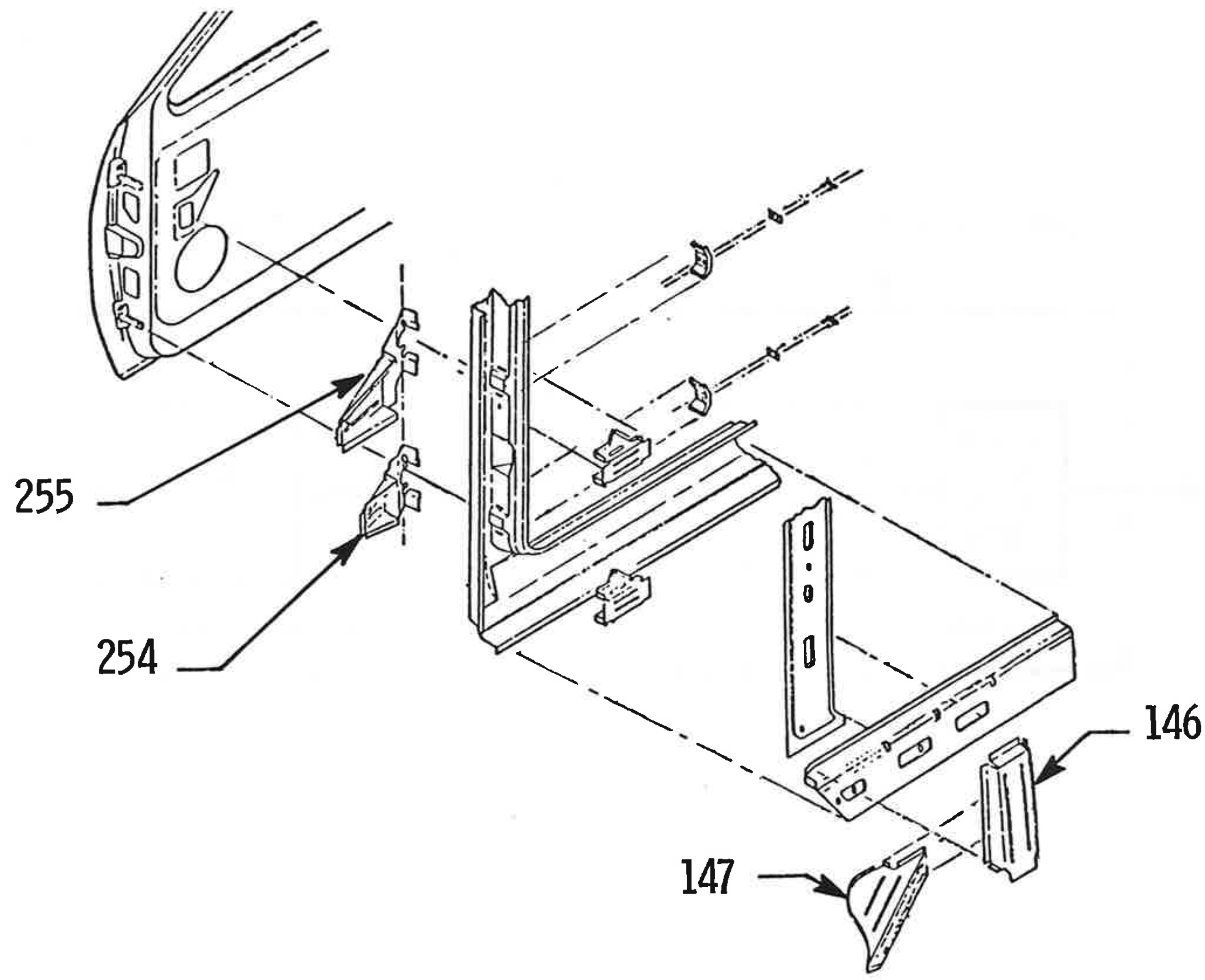


FIGURE 4-2. "A" POST MODIFICATIONS

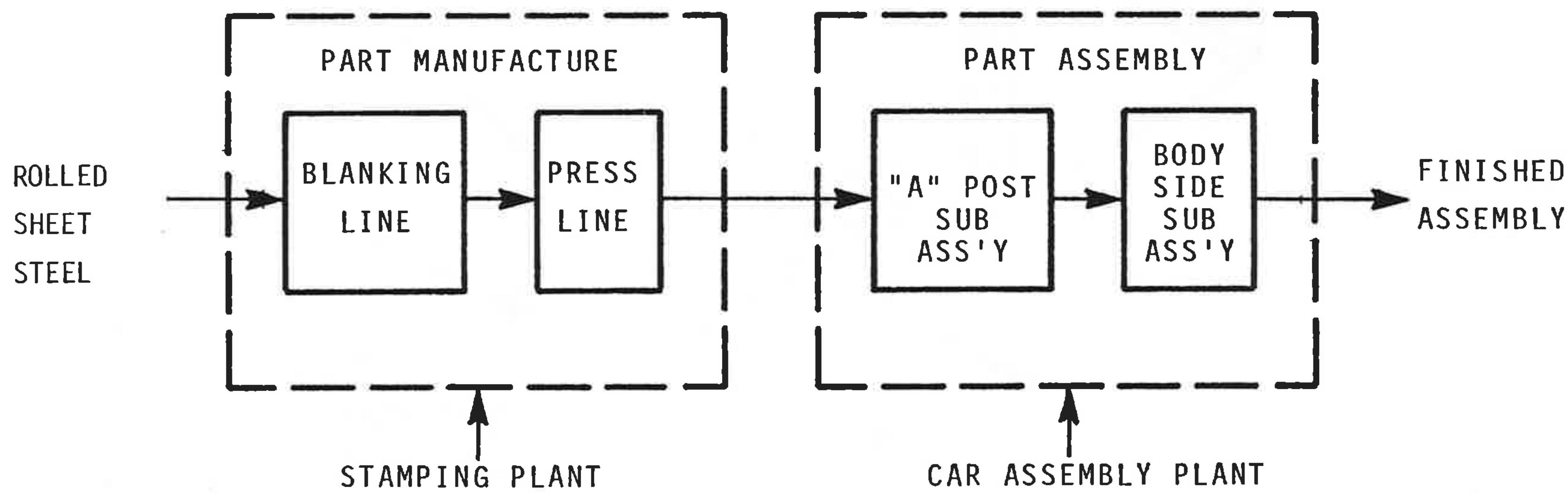


FIGURE 4-3. "A" POST PRODUCTION PROCESS

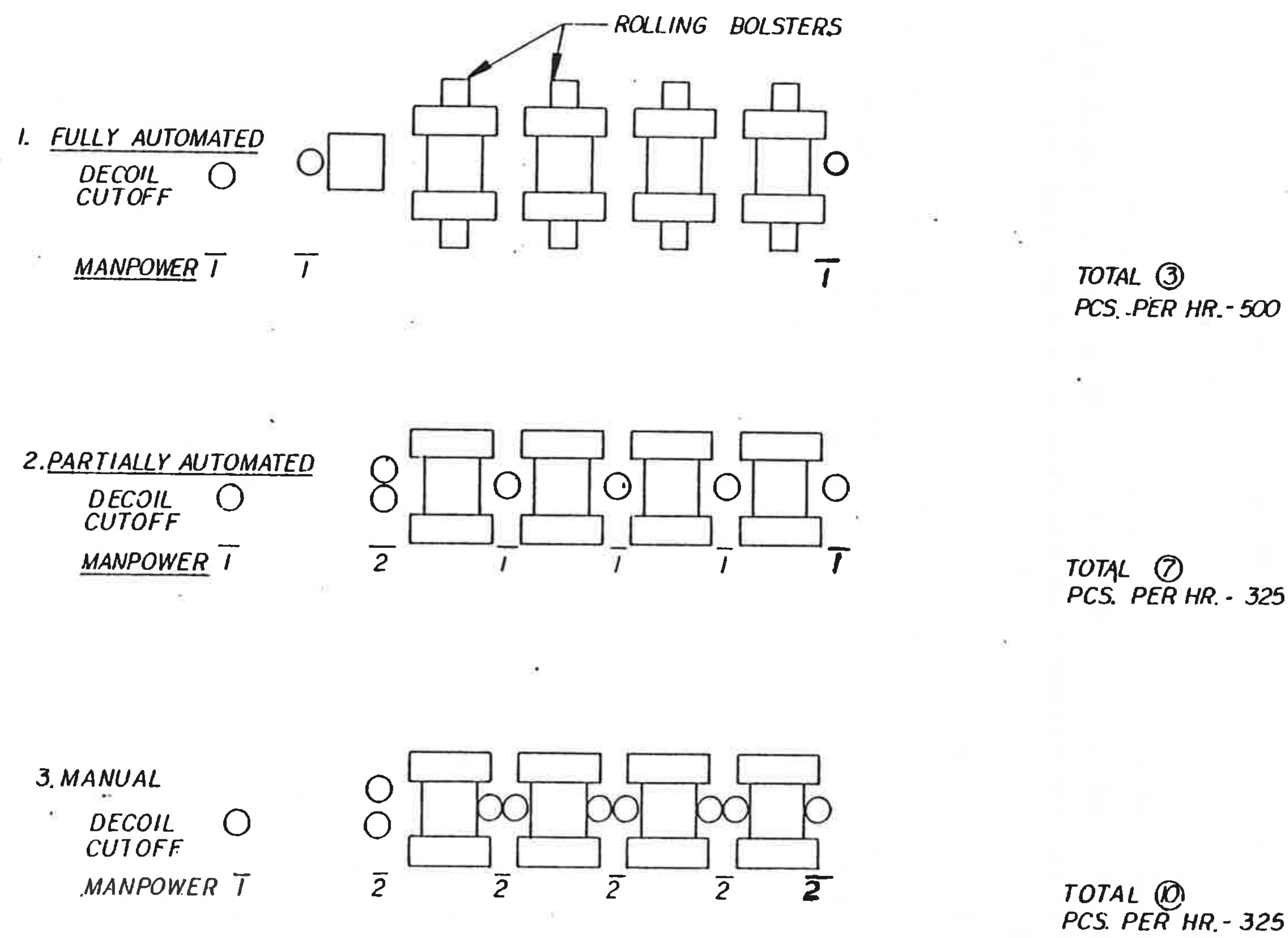


FIGURE 4-4. THREE DIFFERENT APPROACHES TO A TYPICAL STAMPING OPERATION

semi-automated version. This is the type assumed to be used in this example.

Knowing the level of technology needed, the material to be used and the quantities, a specific stamping press line can be selected. These general assumptions are shown in Table 4-1. Additional information is obtained by computing the material weight for each part in Table 4-2. The weight is computed by calculating the volume from the drawing and multiplying the volume by the material density.

The first step in specifying the process is to select a blanking line containing the decoiler, straightener, feeder and blanking press, Figure 4-5. The decoiler and straightener is used since the material will be supplied in coil form. The capacity of such a line is 2500 parts per hour and requires one operator; the hourly rate is multiplied by the number of hours per year worked in a typical stamping plant. This results in 9,800,000 parts per year which is adequate for the 8,000,000 parts plus allowances for downtime for repairs and die changes. This calculation is shown in Table 4-3.

The press line is shown in Figure 4-6 and has a capacity of 650 parts per hour. All the parts except for part no. 147 will require only 4 presses. Part no 147, being more complex, requires a fifth press to form it. Note that a worker is needed for each press. The press line capacity requirements are adequate for the desired output as shown in Table 4-4. A separate press line is needed for each part.

The basic assumptions for assembling these parts into 1,000,000 cars per year are shown in Table 4-5. The "A" post part sub-assembly line is shown in Figure 4-7, and the body side subassembly lines are shown in Figure 4-8. These two lines, operating at 64 assemblies per hour, will provide the nominal 250,000 units per year for each of the 4 plants.

The next step is the actual cost estimating now that the processes and the direct labor requirements are defined. Figure

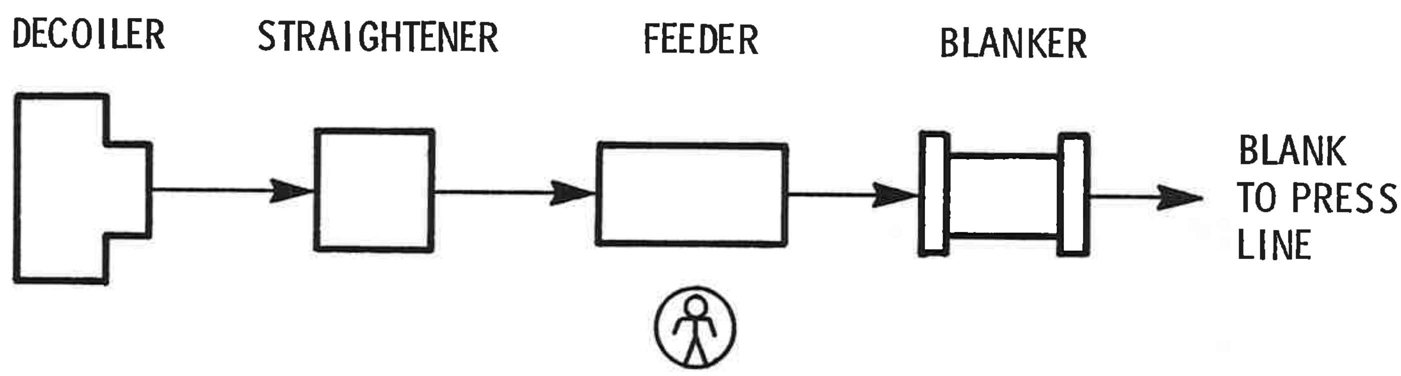
TABLE 4-1. ASSUMPTIONS FOR PART MANUFACTURING

- PRODUCTION
  - FACILITIES WILL PRODUCE DETAIL PART REQUIREMENTS FOR ANNUAL VOLUME OF 1,000,000 VEHICLES
  - HOURLY PRODUCTION RATES
    - BLANK LINE 2,500 PIECES PER HOUR
    - PRESS LINE 650 PIECES PER HOUR
- OPERATING PATTERN
  - NORMAL OPERATING PATTERN OF 245 DAYS PER YEAR
  - TWO EIGHT HOUR SHIFTS PER DAY
- GENERAL
  - ALL RIGHT AND LEFT HAND PARTS ARE PROCESSED AS INDIVIDUAL PARTS
  - FACILITY COSTS BASED ON SURROGATE PLANTS AND FACILITIES BUDGETS

TABLE 4-2. TOTAL OF 8 PARTS REQUIRED TO MODIFY ONE VW "A" POST

FOR 1,000,000 CARS/YEAR
8 PARTS/CAR (4 LEFT HAND & 4 RIGHT HAND PARTS)
OR 8,000,000 PARTS/YEAR

PART NO.	PART NAME	QUANTITY	BLANK WEIGHT-LB (EACH)
0409-254	LOWER HINGE REINFORCEMENT	1RH, 1LH	0.85
0409-255	UPPER HINGE REINFORCEMENT	1RH, 1LH	1.40
0409-146	INNER POST REINFORCEMENT	1RH, 1LH	0.70
0409-147	INNER POST STIFFENING RIB	1RH, 1LH	0.90



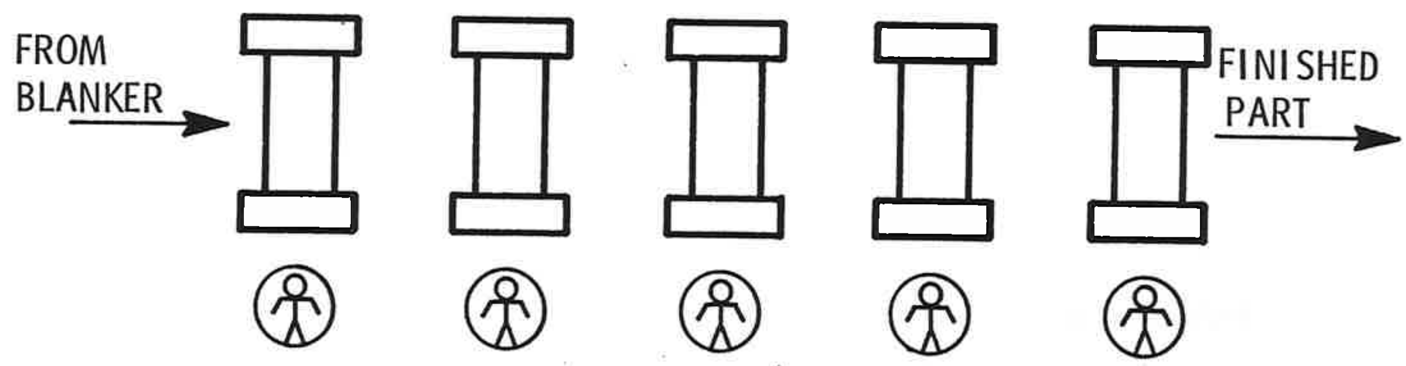
BLANKING CAPACITY IS 2500 PARTS/HR, 1 MAN REQUIRED

FIGURE 4-5. BLANKING LINE

TABLE 4-3. BLANKING LINE CAPACITY REQUIREMENTS

• TOTAL CAPACITY = 2500 PARTS/HR x 16 HRS/DAY x 245 DAYS/YR	= 9,800,000 PARTS/YR.
DOWNTIME LOSSES FOR REPAIRS & DIE CHANGE	= 1,600,000 " "
NET PRACTICAL CAPACITY	= 8,200,000 PARTS/YR.

• TOTAL PARTS NEEDED = 8,000,000 HENCE ONLY ONE BLANKING LINE NEEDED



PRODUCTION RATE 650 PARTS PER HOUR

NOTE: ONLY PART 147 WILL REQUIRE FIFTH PRESS AND EMPLOYEE

FIGURE 4-6. CONVENTIONAL PRESS (PARTIALLY-AUTOMATED)

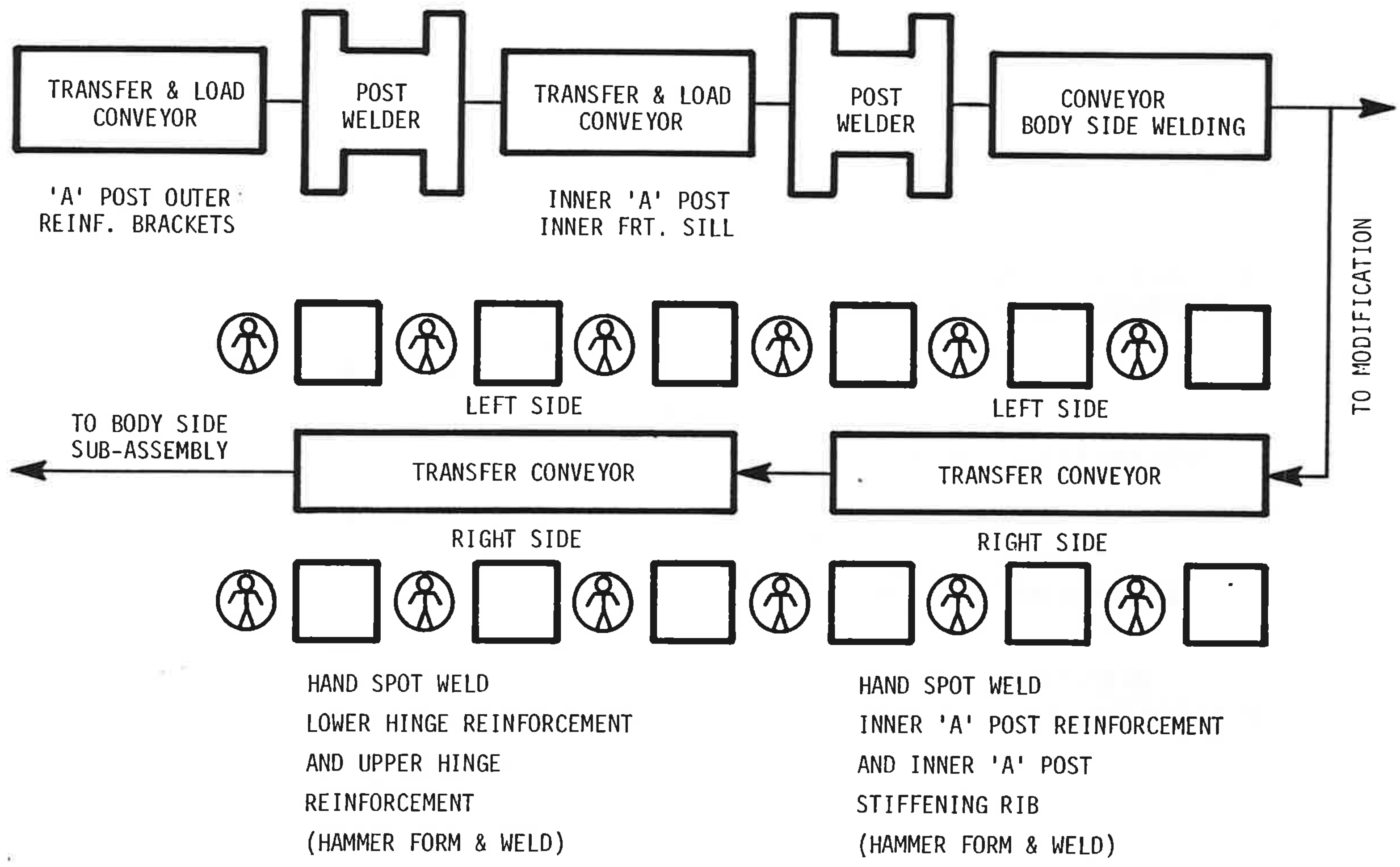
TABLE 4-4. PRESS LINE CAPACITY REQUIREMENTS

• TOTAL CAPACITY = 650 PARTS/HR x 16 HRS/DAY x 245 DAYS/YR	=	2,548,000 PARTS/YR
• FOUR PRESS LINES WILL BE NEEDED AND PRODUCE	=	10,192,000 PARTS/YR
DOWN TIME LOSSES FOR REPAIRS AND DIE CHANGE	=	1,600,000 PARTS/YR
NET PRACTICAL CAPACITY	=	8,592,000 PARTS/YR

TABLE 4-5. ASSUMPTIONS FOR PART ASSEMBLY

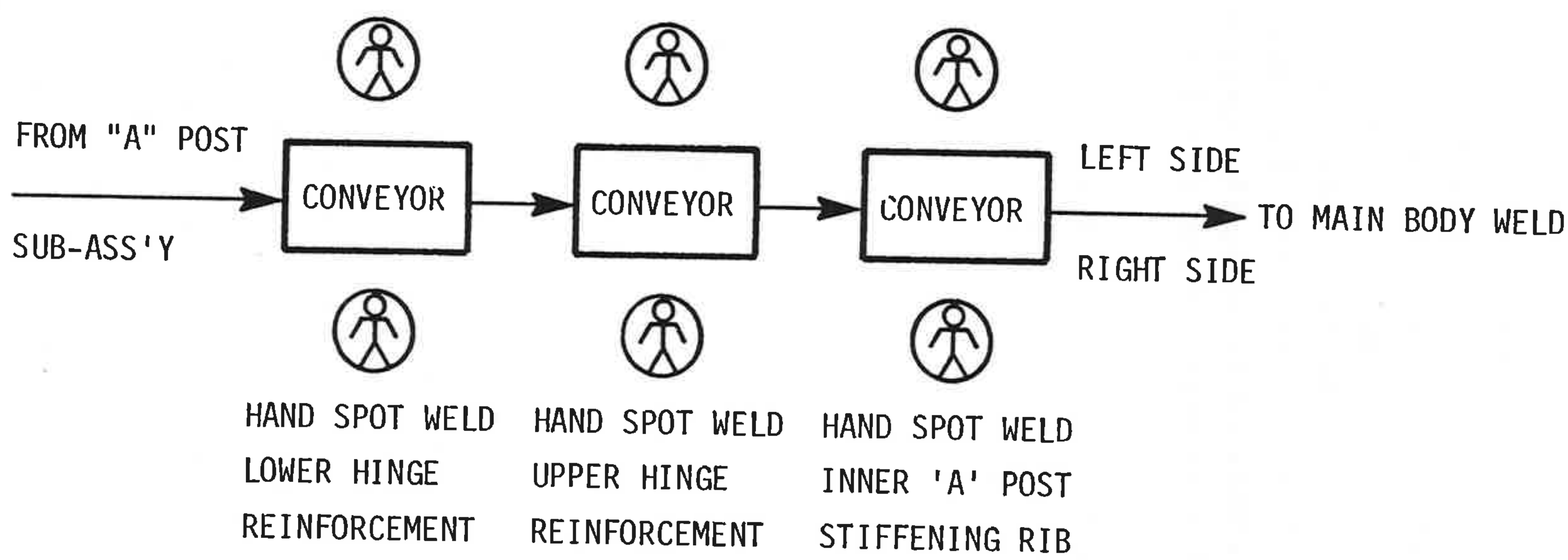
- PRODUCTION
  - FACILITIES WILL ASSEMBLE THE FOUR ADDITIONAL PARTS ON EACH SIDE INTO RIGHT AND LEFT HAND "A" POSTS AT A RATE OF 250,000/YEAR
  - FOUR CAR ASSEMBLY PLANTS (CAPACITY 250,000/YEAR) ARE REQUIRED FOR 1,000,000 CAR ASSEMBLIES A YEAR
- OPERATING
  - NORMAL OPERATING PATTERN IS BASED ON 240 DAYS PER YEAR
  - TWO (8) HOUR SHIFTS PER DAY
- GENERAL

  THE FOUR ADDITIONAL REINFORCEMENT PARTS ARE ASSEMBLED IN THE RIGHT HAND AND LEFT HAND 'A' PILLARS ON A SUB-ASSEMBLY LINE



- "A" POST SUB-ASSEMBLY LINE CAPACITY IS 64 ASSEMBLY/HR, 12 MEN REQUIRED

FIGURE 4-7. "A" POST SUB-ASSEMBLY LINE



BODY SIDE SUB-ASSEMBLY LINE CAPACITY IS 64 ASSEMBLY/HR, 6 MEN REQUIRED

FIGURE 4-8. BODY SIDE SUB-ASSEMBLY OPERATIONS

4-9 summarizes and defines the cost elements to be calculated. Note that this is a condensation of Figure 2-2 which combines variable and fixed burden. The direct labor costs to make the parts in the blanking and stamping operation are shown on Table 4-6. This procedure is simply the calculation of the man-minutes per part multiplied by the labor rate (wage and fringe benefits) that equals the direct labor cost. The indirect labor portion of the burden is calculated by using the ratio of direct to indirect labor based on the surrogate plant data for stamping operations. See Table 4-7.

The calculation of the stamping plant depreciation costs (burden) is made by first determining the depreciation cost per square foot as shown in Table 4-8. This, again, is based on the four major building, plant, and machinery costs of the total stamping plant. In Table 4-9, based on the square foot requirements for the blanker and press lines, the depreciation costs per part are shown.

The other two burden costs of Taxes and Insurance (T&I) and Other Manufacturing Costs (OME) are calculated based on a percentage of the total (direct and indirect) labor costs in Table 4-10. These percentages are typical U.S. industry figures for a stamping plant. All of the burden costs for the stampings are now summarized in Table 4-11. Adding the latter to the direct labor and material costs provides the total manufacturer's cost for each part (as shown in Table 4-12).

The assembly costs start with the direct labor calculation shown in Table 4-13 followed by the indirect labor costs in Table 4-14. The depreciation costs, taxes/insurance, other manufacturing expenses, and totals are calculated, in a manner similar to that for stampings, in Tables 4-15 through 4-18. The total overall manufacturing costs for fabricating and assembling the parts for the "A" post modification are finally shown in Table 4-19.

This concludes the part cost estimate examples for a typical stamped part, and illustrates the four steps outlined in Chapter 3.

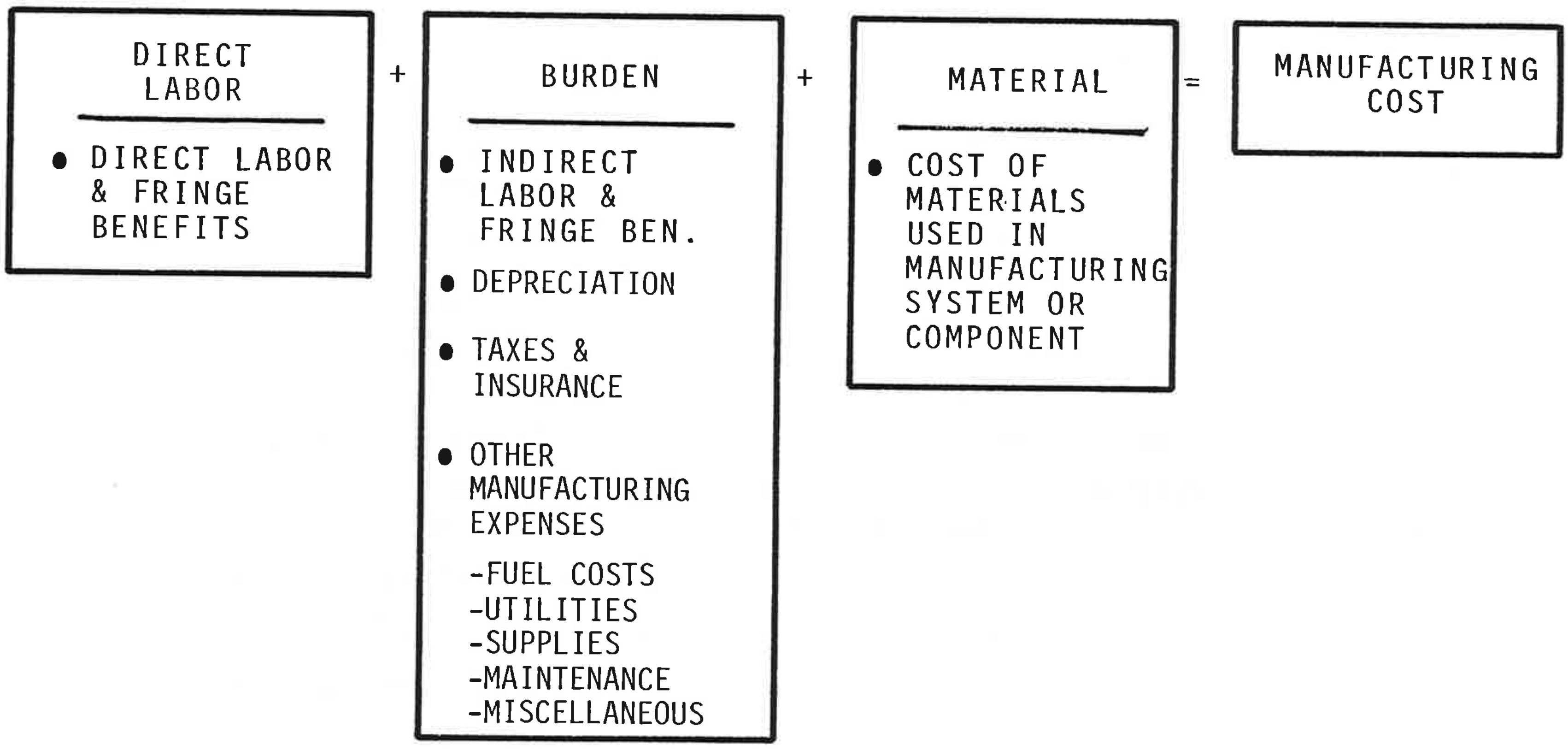


FIGURE 4-9. DEFINITION OF COST ELEMENTS

TABLE 4-6. CALCULATION OF DIRECT LABOR FOR STAMPING (DL)

- DIRECT LABOR IN BLANKING OPERATION
  - 1 MAN ÷ 2500 PARTS/HR = 0.024 MAN-MINUTES/PART
- DIRECT LABOR IN PRESS LINE OPERATION
  - 4 MAN ÷ 650 PARTS/HR = 0.369 MAN-MINUTES/PART
  - FOR PART 147, 5 MAN ÷ 650 PARTS/HR = 0.462 MAN-MINUTES/PART
- TOTAL DL DOLLAR COST = TOTAL TIME x WAGE & FRINGE BENEFITS ($19.50)

PART NO.	TOTAL TIME (MIN.)	DIRECT LABOR COST ($)
254	0.393	0.1277
255	0.393	0.1277
146	0.393	0.1277
147	0.486	0.1580

TABLE 4-7. CALCULATION OF BURDEN FOR STAMPING, INDIRECT LABOR

	PART NUMBER			
	254	255	146	147
o INDIRECT LABOR & FRINGE BENEFITS				
INDIRECT LABOR * - MINUTES				
- HOURLY 90% OF DIRECT LABOR	.354	.354	.354	.437
- SALARY 33% OF DIRECT LABOR	.130	.130	.130	.160
o WAGE & FRINGE BENEFITS				
INDIRECT LABOR				
- HOURLY ($21.50/HOUR)	.1268	.1268	.1268	.1566
- SALARY ($23.50/HOUR)	.0509	.0509	.0509	.0627
TOTAL WAGE & FRINGE BENEFITS	.1777	.1777	.1777	.2193

*CALCULATED FROM SURROGATE PLANT DATA

NOTE: ALL LABOR RATES ARE AVERAGE UAW 1981 RATES

TABLE 4-8. CALCULATION OF BURDEN FOR STAMPING, DEPRECIATION PER SQUARE FOOT

- DEPRECIATION COSTS FOR STAMPING PLANT

	CAPITAL COST*	USEFUL LIFE	DEPRECIATION PER YEAR
BUILDING & EQUIPMENT	$257,500,000	30 YEARS	$ 8,583,333
PLANT FACILITIES	20,200,000	12 YEARS	1,683,333
BUILDING FACILITIES	35,000,000	30 YEARS	1,166,666
MACHINERY & EQUIPMENT	213,306,000	12 YEARS	17,775,500
			$29,208,832
TOTAL SQUARE FOOTAGE IN MANUFACTURING			1,300,000
DEPRECIATION PER SQUARE FOOT			$22.47

*DERIVED FROM SURROGATE PLANT DATA

TABLE 4-9. CALCULATION OF BURDEN FOR STAMPING, DEPRECIATION PER PART

• DEPRECIATION COSTS FOR STAMPING PLANT

	PART NUMBER			
SQUARE FOOTAGE TO MANUFACTURE FOUR "A" PILLAR PARTS	254	255	146	147
BLANK LINE	500	500	500	500
PRESS LINE	6,000	6,000	6,000	6,000
	6,500	6,500	6,500	6,500
DEPRECIATION COST	$146,055	$146,055	$146,055	$146,055
DEPRECIATION COST PER PART	$.073	$.073	$.073	$.073

TABLE 4-10. CALCULATION OF BURDEN FOR STAMPING, TAXES AND INSURANCE AND OTHER

TAXES AND INSURANCE (T&I)

T&I = 3.5% OF TOTAL WAGE AND FRINGE COSTS**

OTHER MANUFACTURING EXPENSES (OME)

OME = 21.6%* OF TOTAL WAGE AND FRINGE COSTS

*CALCULATED FROM FACILITIES PLANNING DATA MANUFACTURING BUDGETS

**TOTAL WAGE AND FRINGE COST (TOTAL DIRECT & INDIRECT LABOR COSTS)

TABLE 4-11. SUMMARY: TOTAL BURDEN COSTS (STAMPING)

BURDEN ELEMENT	PART NUMBER - COST ($)			
	254	255	146	147
INDIRECT LABOR & FRINGE BENEFITS	0.1777	0.1777	0.1777	0.2193
DEPRECIATION	0.073	0.073	0.073	0.073
TAXES AND INSURANCE	0.011	0.011	0.011	0.013
OTHER MANUFACTURING EXPENSES	0.066	0.066	0.066	0.081
TOTAL BURDEN COST ($)	0.3277	0.3277	0.3277	0.3863

TABLE 4-12. SUMMARY: TOTAL MANUFACTURING COST (STAMPING)

	PART NUMBER - COST ($)			
COST ELEMENT	254	255	146	147
• DIRECT LABOR COST	$.1277	$.1277	$.1277	$.1580
• BURDEN	.3277	.3277	.3277	.3863
• MATERIAL $0.25 A LB.	.2125	.3500	.1750	.2250
TOTAL MFGR. COST PER PIECE	.6679	.8054	.6304	.7693
TOTAL COST PER CAR (2 PIECES)	$1.3358	$1.6108	$1.2608	$1.5386

TABLE 4-13. CALCULATION OF DIRECT LABOR FOR ASSEMBLY

	DIRECT LABOR MINUTES
• DIRECT LABOR IN "A" POST SUB-ASSEMBLY	
– HAMMER FORM AND HAND SPOT WELD INNER 'A' POST REINFORCEMENT AND INNER 'A' POST STIFFENING RIB	
SIX MEN FOR 64 PIECES PER HOUR	5.625
– HAMMER FORM AND HAND SPOT WELD UPPER & LOWER HINGE REINFORCEMENT	
SIX MEN FOR 64 PIECES PER HOUR	5.625
TOTAL	11.250
• DIRECT LABOR IN BODY SIDE SUB-ASSEMBLY	
– BODY SIDE SUB-ASSEMBLY	
SIX MEN FOR 64 JOBS PER HOUR	5.625
TOTAL ADDED D/L MINUTES PER CAR	16.875
• DIRECT LABOR COST ($19.50/HOUR)	$ 5.484

TABLE 4-14. CALCULATION OF BURDEN FOR ASSEMBLY, INDIRECT LABOR

INDIRECT LABOR	
– HOURLY 40.5%* OF DIRECT LABOR	6.834 MIN.
– SALARY 18.0%* OF DIRECT LABOR	3.038 MIN.
– WAGE & FRINGE BENEFITS	
INDIRECT LABOR	
– HOURLY ($21.50/HOUR)	$2.449
– SALARY ($23.50/HOUR)	1.190
TOTAL INDIRECT LABOR COST	$3.639

*CALCULATED FROM SURROGATE PLANT DATA

TABLE 4-15. CALCULATION OF BURDEN FOR ASSEMBLY, DEPRECIATION

- DEPRECIATION COSTS FOR CAR ASSEMBLY

	CAPITAL COST *	USEFUL LIFE	DEPRECIATION
BUILDING & EQUIPMENT	$151,000,000	30 YEARS	$ 5,033,333
PLANT FACILITIES	85,000,000	12 YEARS	7,083,333
BUILDING FACILITIES	45,000,000	30 YEARS	1,500,000
MACHINERY & EQUIPMENT	96,000,000	12 YEARS	8,000,000
			$21,616,666
TOTAL SQUARE FEET MANUFACTURING			1,880,000
DEPRECIATION PER SQUARE FOOT			$11.50
ESTIMATED SQUARE FOOTAGE USED FOR ADDITIONAL ASSEMBLY			6,000
INCREMENTAL DEPRECIATION 6,000 SQ. FT. x $11.50			$ 69,000
INCREMENTAL DEPRECIATION PER CAR $69,000 ÷ 250,000 =			$ .2760

TABLE 4-16. CALCULATION OF BURDEN FOR ASSEMBLY, TAXES AND INSURANCE AND OTHER

- TAXES AND INSURANCE (T&I)

  T&I = 4.6%* OF TOTAL WAGE AND FRINGE COSTS

- OTHER MANUFACTURING EXPENSES (OME)

  OME = 13.2%* OF TOTAL WAGE AND FRINGE COSTS

*CALCULATED FROM FACILITIES PLANNING DATA MANUFACTURING BUDGETS

TABLE 4-17. SUMMARY: TOTAL BURDEN COSTS (ASSEMBLY)

BURDEN ELEMENT	
INDIRECT LABOR & FRINGE BENEFITS	$3.6390
DEPRECIATION	.2760
TAXES & INSURANCE	.4197
OTHER MANUFACTURING EXPENSES	1.2042
TOTAL	$5.5389

TABLE 4-18. TOTAL MANUFACTURING COST (ASSEMBLY)

	ASSEMBLY COST ($)
● DIRECT LABOR AND FRINGE BENEFIT COSTS	$ 5.4840
● BURDEN COST	5.5389
● MATERIAL COST	0
TOTAL ASSEMBLY COST PER CAR	$11.0229

TABLE 4-19. TOTAL MANUFACTURING COSTS

		PART NO.	COSTS
STAMPING COSTS			
FOR 1 SET OF PARTS (2 EACH)		254	$ 1.3358
		255	1.6108
		146	1.2608
		147	1.5386
SUB-TOTAL			$ 5.7460
ASSEMBLY COSTS			
FOR 1 SET OF PARTS	SUB-TOTAL		$11.0229
TOTAL COST (PER CAR) FOR THE "A" POST CHANGE			$16.7689

4.2 CALCULATION OF COST TO ASSEMBLE A PASSENGER CAR

The procedure to be illustrated, using the surrogate plant data base and the facilities planning data base, calculates the cost per vehicle for final assembly or cost per vehicle for any of 30 major automotive subsystems. Table 4-20 shows the basic calculations and the bottom line of $794.55 per car. Starting at the beginning, the surrogate or typical assembly plant is designed to assemble a nominal 288,000 cars per year. The first section of the table shows the number of workers (direct labor, indirect hourly and indirect salary) that are employed in an assembly plant. The first column in the manpower subsection of the table is the number of hours worked by employee per year, and the second column is the number of employees. Multiplying these two sets of numbers yields the annual hours for each labor category. The number of hours per car for each labor category (last column) is obtained when each of these sums is divided by the total number of 288,000 cars per year.

The second subsection of the table, labeled Wage and Fringe Cost, is where the labor hours (per car) for each category are multiplied by the appropriate labor rate to produce the labor costs.

Under the investment section, each of the major building, equipment facility, and machinery costs is identified, based on the surrogate plant data base. Dividing these total costs by the number of years of depreciation and by the number of cars produced yields the investment cost per car.

The other two costs of Taxes and Insurance (T&I) and Other Manufacturing Expenses (OME) are figured as a percentage of the Wage and Fringe (Labor) Costs. These percentages are based on average U.S. values for a typical plant of this type. The total cost to assemble a typical car is obtained by adding up the T&I, OME, depreciation, and labor costs.

TABLE 4-20. SURROGATE PLANT PASSENGER CAR ASSEMBLY

TOTAL MANUFACTURING COST
(EXCLUDING MATERIAL)

PRODUCTION: 288,000 CARS PER YEAR, PLANT IN OPERATION 240 DAYS/YEAR

MANPOWER:	HOURS/YEAR		EMPLOYEES		ANNUAL HOURS	HRS/UNIT
- DIRECT LABOR	1920	x	2,788	=	5,352,960	18.59
- INDIRECT - HOURLY	1920	x	1,130	=	2,169,600	7.53
- INDIRECT - SALARY	2000	x	503	=	1,006,000	3.49
			4,421		8,528,560	29.61

ANNUAL HOURS ÷ 288,000 UNITS = HOURS PER UNIT = 29.61

WAGES & FRINGE COSTS:					
- DIRECT LABOR	$19.50	x	18.59	=	$362.51
- INDIRECT - HOURLY	$21.50	x	7.53	=	$161.90
- INDIRECT - SALARY	$23.50	x	3.49		$ 82.02
	TOTAL WAGE & FRINGE COSTS				$606.43

INVESTMENT: (1981$)	FACILITIES COST	DEPRECIATION	COST-PER-UNIT
- BUILDING & SUPPORT FACILITIES USEFUL LIFE - 30 YRS	$161,570,000	5,385,666	$18.70
- BUILDING FACILITIES USEFUL LIFE - 30 YRS	$ 38,160,000	1,272,000	4.42
- PLANT FACILITIES USEFUL LIFE - 12 YRS	$ 99,640,000	8,303,333	28.83
- MACHINERY & EQUIPMENT USEFUL LIFE - 12 YRS	$101,760,000	8,480,000	29.44
			$81.39

DEPRECIATION ÷ 288,000 UNITS = TOTAL DEPRECIATION PER UNIT = $81.39

TAXES & INSURANCE: 4.6 PERCENT* OF WAGE & FRINGE COST
T & I: $606.43 x 4.6% = $27.90
OTHER MANUFACTURING COST: 13.2 PERCENT* OF WAGE & FRINGE COST
OME: $606.43 x 13.2% = $80.05

TOTAL WAGE & FRINGE COSTS	$606.43
TOTAL DEPRECIATION COSTS	$ 81.39
TOTAL TAXES & INSURANCE	$ 27.90
TOTAL OME	$ 80.05
TOTAL	$795.73

*BASED ON MANUFACTURING BUDGET FOR ASSEMBLY PLANT IN 1980$: T&I $7.5M, OME $21.4M, LABOR $162.1M. DETAILED IN G. BYRON, SURROGATE PLANT DATA BASE, VOLUME 3, AUGUST 1982, PAGE D-35.

SOURCE: G. BYRON, SURROGATE PLANT DATA BASE, VOLUME 2, AUGUST 1982.

This procedure is somewhat different from that involved in the piece cost estimate made in the previous section. This macro approach is best used when looking at general changes in the makeup of a particular factory-based product such as the assembly of a car or a complete engine or transmission. The general effect of a labor rate change or a decrease in the labor content (due to automation or other reasons), for instance, can be easily computed by comparing different car designs, manufacturing processes, management techniques and/or other real or assumed scenarios.

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