PRE-DETERMINATION OF MANUFACTURING COSTS OF INJECTION MOULDED PART DESIGN

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ABSTRACT

This paper presents the development of procedures for estimating the manufacturing cost of an injection moulded part at the early stage of concept design. The procedures presented here highlights those manufacturing-related features or design attributes that significantly increase cost so that designers can minimise difficult to produce features. The procedures developed are not dependent on the creation of any geometric model, and can be used to quantitatively assess a preliminary concept sketch. A case example is presented to illustrate the application of the cost estimating procedures developed.

1. INTRODUCTION

Designers have come to realise that for a product to be competitive in the world market, they must not only design the products for function, safety, maintainability and reliability, the products designed must also be economically manufactured. For the past few years, considerable emphasis has been placed on the design of products, as product complexity significantly influences manufacturing cost¹⁻⁴. Design for manufacturing, concurrent engineering and simultaneous engineering, have been the buzz words of today and designers are forced to design the products correctly the first time round when the products are at the early development stage. Products that are designed for manufacture should require no or minimal changes to the design after it has been approved for production. The consequences of design changes at the production stage or at the stage when the products have been sold to customers will incur very high cost.

Manufacturing more and complex parts will incur more labour, inventory and capital costs as well as requiring more activities such as purchasing, documentation, supervision, quality control, part number maintenance, designing and programming. These additional activities will result in higher manufacturing overhead costs, thereby affecting profit and competitiveness.

This is one reason why design for assembly (DFA) methods are being used widely to reduce the part manufacturing costs. DFA forces designers to look at the product

design in order to reduce the number of parts in the assembly and to design the remaining parts so that they are easier to assemble⁵. Parts can be reduced either by the outright elimination of parts, by replacing screws, washers and nuts by press and snap fits, or more likely by combining several individual parts into one part. Plastic injection moulding is one of the methods frequently used for combining parts in an assembly. In order to realise that it is economical to replace several individual parts by a single more complex plastic part, design engineers need to obtain early cost information, both to make sound comparisons between material and process alternatives and to quantify the effects of design decisions on total manufacturing costs. Although the unit cost of injection moulded components is low, the fixed tooling costs are conversely very high, requiring manufacturers of low-to-medium volume products to pay careful attention to the trade-off between unit costs and tooling costs. To do this, the means to estimate the cost of the component and its associated tooling must be made available at the concept stage, before any design commitments are made. Early cost estimating is especially valuable to companies producing goods in low-to-medium volume, and those in industries, where product designs change rapidly and dramatically.

Some detailed cost analysis procedures for injection moulds and moulded parts have been developed previously⁶⁻⁸. Like conventional tool cost estimating methods, they are meant to be applied after the tooling system has been detailed. Therefore, they are inadequate as a measure of comparison to the costs of alternative parts and mould designs that can be proposed for a new product at the early stages of product design.

The main objective of the work reported is to establish procedures that enable product designers to select the material, and estimate the mould and processing costs of a plastic injection moulded part, before detailed engineering drawings have been generated. The procedures are based on simplified cost models and assume no user knowledge of process parameters or machine selection, but requires only designer-specified inputs, such as part size, description of geometry, and material specified.

2. COST ESTIMATION OF A PLASTIC PART

The costs of the various elements of the plastic injection moulding process were investigated in order to develop the manufacturing cost estimating procedures for plastic injection parts. The procedures will be used in the earliest product concept design stages in order to allow comparison with components produced by other competitive processes. The inputs required of this costing procedure have been chosen so that the user need not have extensive knowledge of the injection moulding process. The manufacturing cost of an injection moulded part is largely made up of three main cost elements, and they are: mould cost; material cost; and processing cost, as shown in Equation 1 below.

$$C_{pp} = \frac{C_{mc}}{V_{ol}} + C_{mt} + C_{pc} \quad (1)$$

where

$$\begin{aligned}
 C_{pp} &= \text{plastic part cost,} \\
 C_{mc} &= \text{total mould manufacturing cost,} \\
 C_{ml} &= \text{material cost per part,} \\
 C_{pc} &= \text{processing cost per part, and} \\
 V_{ol} &= \text{production volume of part.}
 \end{aligned}$$

These three costs are influenced by the part's size, geometric complexity and material. The cost per part is also influenced by the production volume. At low production volumes, the proportion of part cost due to the mould is high as the cost of the mould is amortised over a smaller volume. Conversely, as the production volume increases, the proportion of part cost due to the mould is low and the major cost elements are due to material and processing costs.

Mould cost

The mould cost depends mainly on the cost of the mould base and the costs of manufacturing the cavity and core. It has been found that the cavity and core manufacturing costs are primarily dependent on the overall size and geometry of the part, complexity to fabricate the cavity and core, and tolerance and surface finish requirements⁹⁻¹⁰. The cost of manufacturing a mould is to some extent independent of the detailed dimensions of the part. From this outcome, the mould cost can be estimated reasonably accurately during the conceptual stage of design from simply a sketch of the part with some rough dimensions. In addition, mould cost estimation made during the concept design stage itself will help in identifying acceptable parts and mould configurations before actual investment in the mould is made. The total cost of manufacturing a mould can be obtained from Equation 2 below.

$$C_{mc} = C_{mb} + C_{cl} \times n^m + C_{oc} \quad (2)$$

where

$$\begin{aligned}
 C_{mc} &= \text{total mould manufacturing cost (\$),} \\
 C_{mb} &= \text{cost of mould base (\$),} \\
 C_{cl} &= \text{cost of fabricating 1 cavity and core inserts (\$ per inserts),} \\
 C_{oc} &= \text{other fabricating cost (\$),} \\
 n &= \text{number of cavities, and} \\
 m &= \text{multicavity cost index.}
 \end{aligned}$$

The first term is the purchase price of a mould base and custom work on the mould base to convert it into a working mould. The second term determines the cost of fabricating n identical cavities and core inserts. Reinbacher⁷ suggested that on a per cavity cost basis, two cavities provide little or no saving, eight cavities cost 25% less and 64 cavities have an associated cost reduction of 60%. The last term is the summation of the costs of ejector pins, special tools and machining the runner system. The cost of manufacturing the mould is described below.

Mould base cost

From a survey of currently available mould bases, it has been shown by Tan¹¹ that the cost of the mould base is essentially dependent on the volume of the mould base (i.e. surface area of the selected mould base plates and the shut height of the mould). Assuming the part size and number of cavities are known, the appropriate mould base size can be determined after considering the clearances that need to be provided between adjacent cavities and between cavity surfaces and the edges and rear surfaces of cavity plates. For moulds that require side pulls (slides) and unscrewing devices, additional clearances are necessary on the base plates to accommodate these devices. Figure 1 shows the costs plotted against the volume of the mould base. Graphical representations of the cost-volume relationship were then applied to curve fitting methods to obtain an approximate polynomial equation relating mould base cost to volume. The resulting formula is shown in Equation 3 below.

$$C_{mb} = k_1 + k_2 V_m + k_3 V_m^2 \quad (3)$$

where

$$\begin{aligned} C_{mb} &= \text{cost of mould base (\$),} \\ V_m &= \text{volume of mould base (mm}^3\text{), and} \\ k_1, k_2, k_3 &= \text{coefficients.} \end{aligned}$$

(Note: the values of k_1 , k_2 and k_3 are obtained from the graph of the cost-volume relationship of Figure 1)

The above formula is then modified to include custom work on the mould base to convert it into a working mould. The custom work mentioned includes drilling of cooling channels, milling of pockets to secure the cavity and core inserts, machining of the ejector plate and fitting of the cooling system.

Figure 1. Mould base cost versus mould base volume.

Cavity and core manufacturing cost

Essentially, the manufacturing phase of the mould comprises two stages. After the mould base has been purchased from the mould base supplier, the cavity and core inserts have to be machined and attached onto the respective plates. In addition, runners and gates (feed system) have to be machined into the plates. Several factors that affect the mould manufacturing cost were developed. These factors relate to the cost of cavity and core machining, the amount of extra operations to be done (in hours) depending on the relative difficulty in machining the cavity and core, and the volume of material that has to be removed. The factors are then multiplied by an appropriate cost rate to estimate the actual cavity/core manufacturing cost. The cavity and core manufacturing cost have been found to be a function of part size, geometric complexity, tolerance and surface finish requirements, side action complexity, and machining of a feed system. Equation 4 below shows the cost of fabricating one cavity and core inserts C_{cl}

$$C_{cl} = (T_s + T_g + T_t + T_f) R_{op} \quad (4)$$

where

T_s	=	machining hours due to part size,
T_g	=	manufacturing hours due to geometric complexity,
T_t	=	manufacturing hours due to part tolerance,
T_f	=	manufacturing hours associated with surface finish, and
R_{op}	=	cost or operation rate (\$/hr).

a) Part size effect

The part size effect considered here is independent of such factors as tolerance, surface finish requirements and geometric complexity. Ideally, the larger the surface area of the part, the longer it takes to machine the cavity or core. This is closely related to the amount of material that has to be removed. Analysis of a current estimation method¹¹ showed that the cost due to part size has a linear relationship with the part projected area. Preliminary testing of the manufacturing hours versus area relationship given by Dewhurst and Archer with those obtained from local industries revealed that a simple formula could be substituted and is shown in Equation 5.

$$T_s = k_4^{+4} k_5 V_p \quad (5)$$

where

T_s	=	machining hours due to part size,
V_p	=	part volume (mm^3), and
k_4, k_5	=	coefficients.

(Note: the values of k_4 and k_5 are obtained from the graph of manufacturing hours versus area relationship for part size effect)

b) Part geometric complexity

The number and type of features (i.e. number of holes, ribs, bosses, pockets, etc.) contained in a part will affect the manufacturing cost of the mould as more tool changes and machining hours are required. To permit designers to assess the cost impact of fairly minor design changes, a method of counting the number and type of features was developed. The machining times for the type of features were obtained from Ostwald¹² and the following equation describes the mould manufacturing hours, associated with the geometric features of the part, for one cavity and matching core.

$$T_g = \sum_{f=1}^8 (n_f x t_f) \quad (6)$$

where

$$\begin{aligned} T_g &= \text{manufacturing hours due to geometric complexity,} \\ n_f &= \text{number of type } f \text{ feature, and} \\ t_f &= \text{manufacturing hours for type } f \text{ feature.} \end{aligned}$$

c) Part tolerance

As the tolerance becomes finer, the level of care during machining has to increase. Also, if it is determined that the mould is out of tolerance or could not produce a part to tolerance, the mould may have to go through one or more rework loops until the discrepant features are corrected. The manufacturing time associated to part tolerance has been studied by Sors et al⁸ which presented a plot of tolerances value versus additional cost (in hours) and in Dewhurst and Archer¹⁰. Based on these works and on suggested trends from mouldmakers, the effect of part tolerances on cavity and core manufacturing times can be represented by the following empirical relationship.

$$T_t = k_6 + k_7(t_t) + k_8(t_t)^2 \quad (7)$$

where

$$\begin{aligned} T_t &= \text{manufacturing hours due to part tolerance,} \\ t_t &= \text{minimum tolerance specified by designer (mm), and} \\ k_6, k_7, k_8 &= \text{coefficients.} \end{aligned}$$

d) Surface finish

Finishing of the cavity and core impressions is normally carried out manually. When a high gloss appearance is required, finishing will form a significant element of mould cost. Finishing cost also depends on the surface area of the part, as finishing must be carried out on the entire surface of the cavity and core impressions. A general relationship, which describes the extra mould manufacturing hours for different surface finish requirements, is shown below.

$$T_f = k_9 + k_{10} x A_s x f_s \quad (8)$$

where

$$\begin{aligned} T_f &= \text{manufacturing hours associated with surface finish,} \\ A_s &= \text{surface area of the part (mm}^2\text{),} \\ f_s &= \text{surface finish factor, and} \\ k_9, k_{10} &= \text{coefficients.} \end{aligned}$$

The surface area of the part can be approximated by dividing the part volume with the average wall thickness. The values for the surface finish factor in this work are: 1 for normal finish, 2 for polish finish, 3 for texture finish and 4 for mirror finish.

Other fabricating cost

This section describes the costs of machining the runner system, ejection system and the cost of adding special tooling such as the unscrewing devices and side cores.

a) Runner system

Runners are grooves or channels connected to the sprue through which material flows to the individual cavities. The runners (normally trapezoidal in shape) are machined into one-half of the mould and the machining hours associated with the runner system depends on the number of cavities in the mould. For even number of cavities, the volume of material to be machined is:

$$V_r = \{(n-1)T_p + (\frac{n}{2}-1)L\}W_r^2 \quad (9)$$

where

$$\begin{aligned} V_r &= \text{volume of runner system machined off (mm}^3\text{),} \\ T_p &= \text{minimum clearance between adjacent cavities (mm),} \\ L &= \text{projected length of moulded part (mm),} \\ W_r &= \text{width of runner (mm), and} \\ n &= \text{number of cavities.} \end{aligned}$$

The first term determines the total length of the runner system. The second term W_r^2 is the cross-sectional area of the runner. The width of the runner can be approximated as the sum of the maximum wall thickness of the part and 1.5mm¹³. From the above equation, the cost of machining the runner system can be obtained.

$$C_r = k_{11} + k_{12} \times V_r \quad (10)$$

where

$$\begin{aligned} C_r &= \text{cost of machining the runner system ($) and} \\ k_{11}, k_{12} &= \text{coefficients.} \end{aligned}$$

b) Ejection system

The number of ejector pins used in a mould will determine the cost of the ejection system. Sors et al⁸ estimated a time of 2.5 hours per ejector pin which include making the pin, and drilling and reaming the hole. In this work, it is assumed that the ejector pins can be purchased as a standard component and only the holes need to be drilled and reamed to accommodate the pins. Assuming the number of ejector pins to be used in a mould is known, the following equation provides the cost for the ejection system.

$$C_p = p_1 \times n \times n_c \quad (11)$$

where

- C_p = cost associated with the ejection system (\$),
- p_1 = Cost of using one ejector pin (\$/pin),
- n_c = number of pins required per cavity, and
- n = number of cavities.

While it is recognised that ejector pins are not the only means of part removal, the equation outlined above should provide a reasonable estimate of the ejection costs at the concept design stage. As the number of ejector pins are usually not available at the early stages of part design, an approximate relationship based on projected cross-sectional area of the part at right angle to the direction of moulding can be used to estimate the number of pins required per cavity¹⁰. The number of ejector pins per cavity can be estimated using the following relationship.

$$n_c = \left\lceil 2 + 0.1 A_p^2 \right\rceil \quad (12)$$

where

$$A_p = \text{projected part area (mm}^2\text{)}.$$

c) Special features

Holes and undercuts produced in the moulded part at an angle other than parallel to the mould opening axis are impossible to eject by the conventional ejection system. Slides or side cores which are mounted to the mould base pull out these core pins before the mould opens at the parting line. For those parts that have female screw threads, unscrewing devices are most commonly used to free the moulded screw threads before the parts are ejected. The core containing the thread impressions is rotated relative to the moulded threads, and thus retracts out of the moulded part. These cores are activated by a rack and pinion mechanism. Thus the cost for including these special features in the mould is shown the equation below.

$$C_s = k_{13} \times n_s + k_{14} \times n_u \quad (13)$$

where

- C_s = cost for using special features (\$),
 n_u = number of unscrewing devices,
 n_s = number of side cores, and
 k_{13}, k_{14} = coefficients.

2.2 Material cost

One of the important factors in making a part successful is by using the appropriate type and grade of material. A good selection of plastic material will not only facilitate the usability of the part, it will also affect the final part cost. The main elements comprising material cost per part are the price per kilogram and the weight of plastic material required for one part. The weight of the part is determined by the part volume and the specific gravity of the material. Figure 2 shows the various elements that constitute the material cost per part. The material cost per part can be determined using Equation 14 assuming that the material has already be chosen, that its purchase price is known, and that an estimation of part volume is available.

$$C_{mt} = C_{kg} \cdot \rho \cdot V_p \left(1 + \frac{f_1}{100} \right) \quad (14)$$

where

- C_{mt} = material cost (\$/part),
 C_{kg} = price of material (\$/kg),
 V_p = part volume (mm³),
 f_1 = percentage of material loss, and
 ρ = density of material (kg/mm³).

Figure 2. Various elements that constitute the material cost per part.

2.3 Processing cost

The part processing cost is the sum of the setup cost and the product of the machine cycle time and the operation rate. In order to determine the operation rate, the machine size must be known. This in turn can only be determined if the number of die cavities is known. Assuming the number of cavities is known at the early design stage, the processing cost per part is shown in the following equation.

$$C_{pc} = \left(\frac{T_{su}}{N_{bs}} + \frac{T_{cy}}{ny} \right) R_{op} \quad (15)$$

where

- C_{pc} = processing cost per part (\$),
- T_{su} = set-up time (hr),
- T_{cy} = machine cycle time (hr),
- N_{bs} = batch size,
- R_{op} = operation rate (\$/hr),
- y = production yield (< 1), and
- n = number of cavities.

2.3.1 Machine cycle time

The cycle time can be divided into three main phases namely the injection or filling phase, the cooling phase and the resetting phase. The injection stage consists of the forward stroke of the plunger to force the molten materials through the nozzle and into the mould. The fastest fill rate for a particular moulding cycle is limited by the available power in the machine injection unit. Based on elementary fluid mechanics, an estimation of the injection time using the available power can be obtained as follows.

$$T_{in} = \frac{(n \times V_p \times P_{in})}{W_{mc}} \quad (16)$$

where

- T_{in} = injection time (s),
- V_p = part volume (mm³),
- P_{in} = injection pressure for the polymer (N/mm²), and
- W_{mc} = available power for injection (W).

It should be noted that the above injection time estimate ignores the actual flow behaviour in the mould channels and is based on the assumption of a constant ram pressure during injection.

The cooling phase starts with the withdrawal of the plunger and the resulting removal pressure from the nozzle area. The cooling time is a function of the part wall thickness, the material used and the mould temperature. In the calculation of cooling

time, it is assumed that cooling in the mould takes place almost entirely by one dimension conduction and no heat is transferred by convection and radiation. The cooling time can be estimated based on the Fourier's law of heat transfer¹⁴ and is shown in Equation 17.

$$T_c = \frac{F_o \times h^2}{\alpha} \quad (17)$$

where

$$\begin{aligned} T_c &= \text{cooling time (s),} \\ F_o &= \text{Fourier's number,} \\ h &= \text{wall thickness of part (mm), and} \\ \alpha &= \text{thermal diffusivity of the polymer (mm}^2/\text{s).} \end{aligned}$$

In the resetting phase, the mould is opened, the part is ejected, and the mould is then closed again in readiness for the next cycle to begin. Although it is economical to have quick opening and closing of the mould, rapid movements may cause undue strain and vibration on the equipment. Also, adequate time must be allowed for part ejection. A badly designed mould with insufficient draft angle, improper runner size and gating will result in long resetting time. Also, the resetting time will be affected if the part requires careful handling and attention. Discussions with plastic part manufacturers suggest that the resetting time can be estimated as follows: opening time = 2s, ejection time = 6s, and closing time = 2s.

2.3.2 Operation rate

The operation rate R_{op} includes the direct labour rate and equipment rate and is shown in Equation 18. The operation rate varies depending on the types of injection machine used for moulding the part. If an operator operates two machines simultaneously, then R_{dl} would be split proportionately according to the times the operator spent on each machine. This method of calculating the operation rate is simple, easy to understand and it emphasises the early return of capital. However, it ignores the time value of money and tax effects.

$$R_{op} = R_{dl} + \frac{C_{eq}}{(Y \times N_{sh} \times I_d \times 2000^*)} \quad (18)$$

where

$$\begin{aligned} C_{eq} &= \text{equipment cost (\$),} \\ N_{sh} &= \text{number of shifts per day,} \\ R_{dl} &= \text{direct labour rate (\$/s),} \\ Y &= \text{equipment pay back (years),} \\ R_{dl} &= \text{\% of time equipment is in operation, and} \\ I_d &= \text{\% of idle time equipment is in operation.} \end{aligned}$$

(* The total available hours per shift per year, with 50 working weeks and 40 hours per week is 2000.)

The equipment cost depends on the size (tonnage) of the machine used and is a function of the part volume, number of cavities and the type of polymer used. The machine tonnage necessary for moulding n parts in one shot can be calculated from the following equation.

$$M_t = \frac{n \times A_p \times P_{in} \times S_f}{9810^*} \quad (19)$$

where

$$\begin{aligned} M_t &= \text{machine tonnage required,} \\ P_{in} &= \text{injection pressure for the polymer (N/mm}^2\text{),} \\ A_p &= \text{projected part area (mm}^2\text{), and} \\ S_f &= \text{safety factor.} \end{aligned}$$

(* multiplying factor for converting newtons to metric tons)

3. VALIDATION OF COST ESTIMATES

A spreadsheet program was developed to assist in the plastic part cost calculation based on the cost models stated earlier. The software program is then used to estimate the cost of producing a plastic gear shown in Figure 3. Basically, the program consists of a variable input section, which allows the user to enter data relating to the production requirements and characteristics of the plastic part. The data entered includes the batch size, life volume, part characteristics and features, and the type of material used.

A set of default data is also provided. The default values are mainly used for calculating the operation rates of machine and worker and for calculating the size of the mould base. Users can change the default values to suit their own working requirements.

The machine and material databases are also provided in the program. From Equation 19, the machine tonnage required for the moulding of the plastic part is derived. From this, a suitable machine can be selected from the machine database and the operation rate and process information can be calculated. The machine chosen should have sufficient clamping force and shot size for the given number of cavities. The material used should be decided before the costing calculation, as the material selected will affect the cycle time and cost. The information provided in the material database is sufficient for the user to calculate the machine cycle time, machine size and material cost for a given part volume.

The cost model output section gives the cost of the mould base (including custom work on the mould), the cost of manufacturing the mould, the part processing cost and the material cost. From these costs, the cost of producing a plastic part is derived. Table 1 shows the input, default and the output data for the plastic gear shown in Figure 3. The industrial cost estimate for this gear is \$0.225, which is in close agreement with that obtained using the software program.

Table 1. Input and output data for plastic gear

Part characteristics	No. of cavities	4	Mould default data	No. of base plates	3
	Length of part (mm)	24.5		Clearance between cavities (mm)	50
	Width of part (mm)	24.5		Clearance bet. cavity and plate edge	50
	Depth of part (mm)	6.0		Length of mould base	198
	Part maximum thickness (mm)	2.7	Mould base (calculated)	Width of mould base	498
	Part volume (mm ³)	957		Height of mould base	306
	Part tolerance	0.03			
	Surface finish of part	normal			
Ejector pin	No. of round/flat pins	8	Default input data	No. of skill worker (for set-up)	1
	No. of square pins	0		Skill worker rate (\$/hr)	10.8
	No. of taper, ring or sharp pins	0		Machine set-up time (hrs)	2
Part feature	No. of through circular hole	1		Machine pay-back (years)	3.5
	No. of blind circular hole	0		Work-weeks per year	50
	No. of bosses	0		Work-hours per week per shift	40
	No. of ribs/non-circ. protrusion	50		No. of shifts per day	3
	No. of circular features	0		Production yield	0.9
	No. of through pockets	0			
	No. of blind pockets/grooves	0		Machine tonnage selected	35
	No. of external corner radii	2		Cycle time calculated	39
	No. of additional inserts	0			
	No. of side pulls per mould	0		Mould base cost (\$)	2 696
Material	No. of threaded feature per mould	0	Output data	Mould manufacturing cost (\$)	10 365
	Type of plastic material	PCA40		Processing cost (\$/ part)	0.063
	Batch size	5 000		Material cost (\$/part)	0.028
	Part life volume	100 000		Plastic part cost (\$/unit)	<u>0.222</u>

Figure 3. A plastic gear

The cost model developed has been tested on a number of plastic parts from industry, by comparing the cost estimates determined with the software program with those estimates from industry. Table 2 provides a brief description of the plastic parts used for the cost estimation. The parts ranged in size from the smallest having a volume of 1,730 mm³ to the largest with a volume equal to 119,600 mm³. Figure 4 provides the comparison of the estimated part costs obtained from the software program and that of industry. Analysis results include mould, plastic material, and processing costs per part, which together added up to total part cost. It can be seen that agreement is generally good.

Table 2. Plastic parts used to substantiate the accuracy of the software program.

	projected length (mm)	projected width (mm)	projected depth (mm)	max. thickness (mm)	part vol. (mm ³)	tolerance (mm)	surface finish
Cap	20	20	10	3	1730	0.15	texture
Plate	50	45	13	2.5	4920	0.2	normal
Bracket	70	50	50	4	31100	0.3	normal
Phone	150	60	20	3	52000	0.2	texture
Holder	80	80	45	5	48100	0.1	polish
Cover	100	80	30	3	60500	0.2	polish
Bar	145	50	50	5	119600	0.3	normal

Figure 4. Comparison of industry part costs with estimated costs from software program.

4. CONCLUSION

The methodology outlined in this paper has been developed for use by designers to enable the cost of a proposed injection moulded part to be established prior to the availability of detailed drawings. The software developed can highlight those manufacturing-related features or design attributes that significantly increase cost so that designers can minimise difficulty to produce features. Because the designer can estimate the cost of manufacturing a plastic part in the conceptual design stage itself, he/she can make modifications on the part to reduce part costs. The methodology has been tested on a range of plastic parts from industry and the results obtained indicate that accurate cost predictions can be obtained.

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