

# **A RESOURCE CONSUMPTION MODEL (RCM) FOR PROCESS DESIGN**

Richard Jerz

Ambrose Institute of Engineering  
St. Ambrose University, Davenport, IA 52803

## **ABSTRACT**

The resource consumption model for process design (RCM) was developed to better model the analysis and selection of process design alternatives for product manufacture. Several varieties of production economic models exist to aid production process design (e.g., return on investment analysis, break-even analysis, cost estimating, and design for manufacture). These models, however, fail to integrate sufficiently cost, production cycle time, production capacity, and economy of scale factors. These factors can become very important, especially when evaluating the benefits of new manufacturing technologies and strategies. RCM provides greater understanding, fidelity and sensitivity analysis for process design than other methods.

RCM concepts are applied to a manufacturing process design problem to show some of RCM's concepts and insights. A comprehensive modeling of process alternatives is now possible with RCM. Several questions about the problem are addressed. RCM demonstrates that mathematically intensive process design models can be developed and displayed using modern computers and software.

## **KEYWORDS**

Process planning, process costing, process design, cost estimating, capacity planning.

## **1. Introduction**

The manufacturing process involves a transformation of raw materials into finished goods. Customers express their needs, product designers transform customer needs into product and part specifications, manufacturing selects the processes and produces the products, and the customers purchase the products. The goal in the transformation process is to derive the best methods to produce the best product while maintaining customer and marketing functional requirements.

It has been estimated that as much as 70 to 80 percent of the total cost of producing a product is determined during the conceptual and detailed design stages; therefore, making product decisions at this point is critical. It is often assumed that product design, process design, and capacity planning are sequential decisions. In fact, these decisions should be considered simultaneously. The way the product is designed affects how many people buy it, which affects production capacity, which affects the process and the costs to produce the product, which affects how many people can afford to buy it. It becomes equally important to decide on the best production process as early as possible.

Managers in today's competitive environment should utilize the available technology to have better economic models available to them, and to integrate these systems with other information systems to maximize the company's competitiveness. The "Resource Consumption Model for Process Design" was developed with these goals in mind.

## **2. Problem Definition**

The methodologies of return on investment analysis, break-even analysis, cost estimating, cost accounting, and design for manufacture have been used to help analyze process design and selection. However, these methodologies do not integrate sufficiently the concepts of cost, production cycle time, production capacity, and utilization from within themselves, and the analyst is often left investigating these factors independently. There is no guarantee that all factors are considered. Some methodologies use a narrow production volume range, or worse, one production volume in their calculations, limiting additional insight into economies of scale. Sometimes the computational approach makes a methodology difficult to understand which also limits its application.

Management has learned that the lowest cost process design is not always best, and that sometimes production time or reserve capacity may become more important. RCM was developed to address this situation. It was believed that the relationships between cost, time, and capacity analysis could be developed mathematically, and when the formulae are applied across a production volume range and portrayed in simple to understand formats, that management will make better process design decisions.

### 3. RCM Overview

RCM's foundational concept is that part production consumes resources. RCM accounts for all resources, which can include equipment, labor, energy, material, tooling, and other consumables used by alternative process designs. It characterizes resources generically and avoids the need for terms such as "fixed costs," "variable costs," "overhead," and so forth. For each resource, RCM performs quantity-based, time-based, and system-based calculations for a production volume range and determines the controlling condition. Consumption can be translated into cost, time, and utilization metrics. Resource calculations are accumulated to compare alternatives. Results are shown in both tabular and graphical formats.

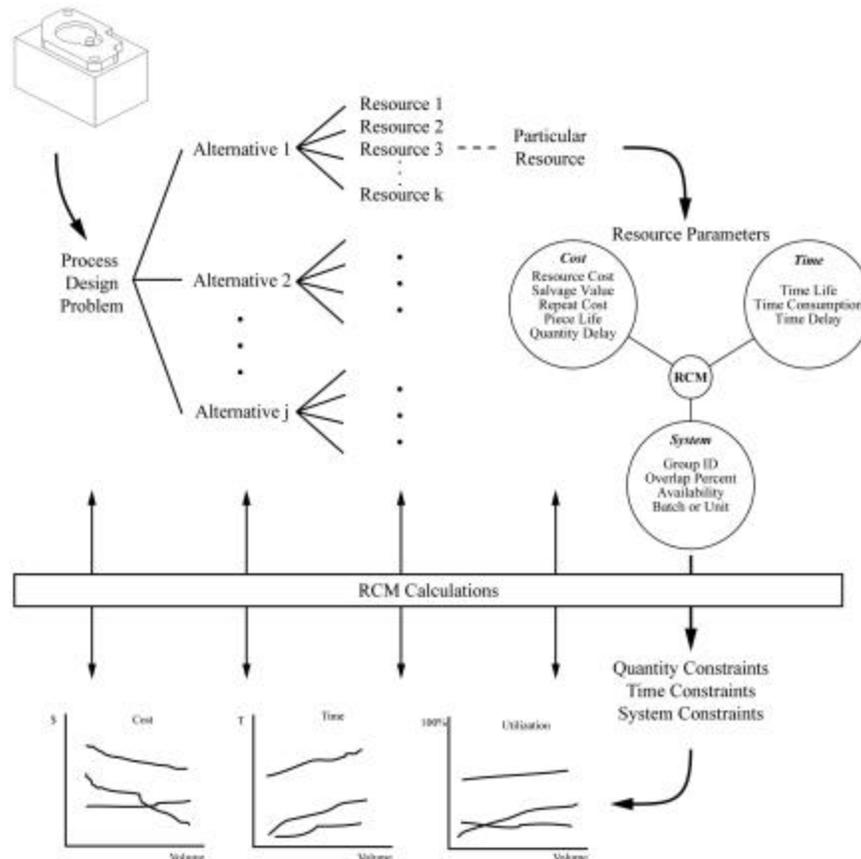


Figure 1. Model Overview

Figure 1 depicts the many elements that compose RCM. When a product is designed, process design decisions must be made as to how it will be manufactured. Manufacturing alternatives are identified that satisfy the product's functional requirements. For each alternative, resources consumed are identified. Within RCM, each resource is defined by fifteen parameters. Some parameters are cost-based, some are time-based, and some are system-based. Alternatives and resource information are managed using a database system. RCM calculations determine whether quantity, time, or system constraint conditions control the resources' results. Depending upon the detail required, RCM can display cost, time, and utilization results for any individual resource, multiple resources, any individual alternative, or for up to six alternatives. The nature of the graphs and tabulated results change depending upon the

analyst's selection. For example, Figure 2 illustrates an average part cost comparison for three alternatives. Figure 3 shows the average cost detail for six resources that compose one alternative's cost.

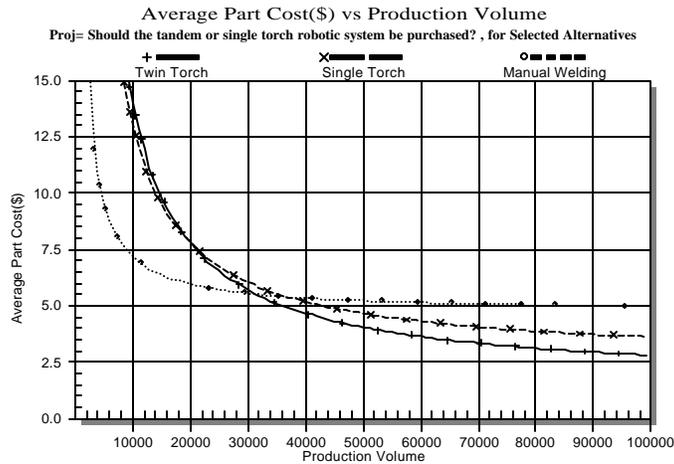


Figure 2. Average Cost for All Alternatives, Including Welding

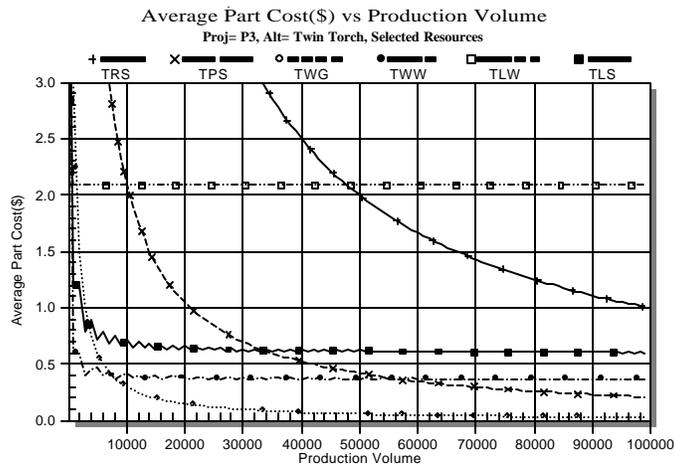


Figure 3. Average Cost for Tandem Torch, High Cost Resources

These figures show cost information, but RCM also produces time and utilization graphs. A database and a computer model were developed for RCM so that many scenarios could be quickly understood. RCM is an iterative process, which means that the analyst may reinvestigate alternatives or resources as necessary by changing parameter values.

#### 4. RCM Methodology

The key to RCM's analysis is its ability to perform time-based, quantity-based, and system-based calculations across a production volume range when calculating cost, time, and utilization. It can calculate these metrics on individual resources or on alternatives. An example of one equation used to calculate the average part cost under the time-based constraint is shown in equation 1. In this equation,  $C_{Ar}$  = average cost for resource  $r$ ,  $Q$  = production volume,  $C_r$  = resource cost,  $t_r$  = production time (hrs) for resource  $r$ ,  $I_r$  = life (hrs) for the resource, and  $p_r$  = number of parts produced in time  $t_r$ . The brackets [ ] denote the ceiling function that is used for discrete calculations. RCM calculates cost, either average or total, across one hundred production volume points within a specified range.

$$C_{A_r} = \frac{C_r}{Q} \left[ \left[ \frac{Q}{P_r} \right] \frac{t_r}{l_r} \right] \quad (1)$$

Several unique features in RCM's analysis include: discrete calculations are used; resource replenishment rates are automatically determined so that over-utilization does not occur; integrated time, cost, and utilization calculations are performed; system effects, namely determining which resource is the bottleneck, are included; and both batch and unit consumption rates are available.

### 5. An Application Example

Genesis Systems Group, integrators of robotic welding systems, developed a robotic welding system called "tandem torch." Tandem torch welding (GMAW) uses two welding torches instead of one and essentially welds twice as fast as single torch systems. Tandem welding has existed for many years in dedicated welding systems, but the application of tandem welding principles with robots is a newer idea.

RCM was used to answer many questions about the comparison between the tandem and single torch systems. Figure 2 shows the average part cost comparison for tandem, single, and manual welding alternatives based upon one set of conditions. It depicts which process is most economical at different production volumes. In this graph it appears that the cost difference between tandem and single torch systems may not be very significant. However, looking at how they compare in time, as shown in Figure 4, illustrates that the tandem torch process has a significant advantage. A more detailed investigation into cost produces the graph shown in Figure 3. It shows that at lower production volumes the robotic system (TRS) and the power supply (TPS) costs are most significant. At higher production volumes, welding labor (TLW) is most significant. Welding wire (TWW), welding guns (TWG), and setup labor (TLS) costs are less significant. Knowing detail about cost, throughput, and utilization at various production volumes provides management the information needed to make better process selection decisions.

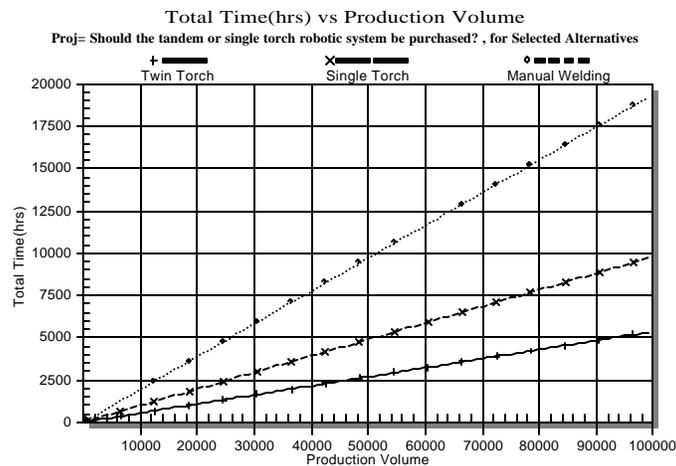


Figure 4. Total Time for All Alternatives, Including Welding

### 6. Results and Conclusions

The comprehensive process modeling that RCM achieves is very difficult, if not impossible to duplicate using cost accounting, engineering economics, cost estimating, break-even analysis, or other methodologies. RCM demonstrates that mathematically intensive analysis can be performed and the results communicated effectively. RCM provides cost, time, and capacity metrics to help manager decisions.

### REFERENCES

Jerz, R., "A Resource Consumption Model (RCM) for Process Design," Ph.D. Dissertation, The University of Iowa, Iowa City, Iowa, December 1997.