

Tradeoff Curves for Target Costing of Assembly Processes

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Abstract

Tradeoff curves are a knowledge management tool used in Lean Product and Process Development (LPPD) to illustrate the known relationship of two design characteristics relative to each other. These characteristics are usually in conflict, whereby increasing one characteristic results in a decrease of the other, and the tradeoff curve defines the feasible limit for the design options. Target Costing is a practice used by firms to ensure that a future product meets and retains desired profit levels throughout its lifespan in the market. The allowable Direct Cost for the product is composed of Direct Material and Direct Assembly. In assembly process development, engineers face a tradeoff between labor and capital investment. A tradeoff curve can be used to illustrate the relationship between these two characteristics for given market conditions. This paper describes the development of a model that can be used to generate tradeoff curves to map the feasible solution space for assembly process alternatives in different economic environments with potentially different target costs. Understanding the tradeoffs and limits in advance of detailed development enables process designers to consider several solution sets to support better decisions and achieve desired levels of profitability.

Keywords

Lean Product and Process Development, Target Costing, Tradeoff Curves

1. Introduction

Target Costing is a business practice associated with Japanese firms, with its origin traced to Toyota in the 1960s as they attempted to implement the Value Engineering techniques developed in the United States after World War II (Feil, Yook, & Kim, 2004). The Japanese term for Target Costing is *Genka Kikaku*, but a more accurate translation might be “Strategic Profit Management” (Kato, 1993). When a new product is to be developed for the market, firms determine a desired profit level that is to be achieved over the product lifespan; then working backward from the market selling price, they calculate an allowable target cost that the product must not exceed in order to realize that profit (Cooper & Slagmulder, 1997). The target cost becomes a rigid specification for the product development team to ensure the future profitability of the firm. Although the practice is called target costing, it is not managed by the accounting department; most of the activity required to achieve the target is led by design and production engineers, as development decisions will determine the majority of costs incurred over the product lifespan (Majerus, 2016).

Lean Product and Process Development (LPPD) is also associated with Japanese firms, specifically Toyota, and is best summarized as a knowledge creation and management process for the efficient development of profitable operational value streams (A. C. Ward & Sobek II, 2014). One of the visual knowledge management tools used in Lean Development is the tradeoff curve. A tradeoff curve is typically a graph depicting a relationship between design parameters under consideration; usually, these parameters are in conflict, such that increasing one parameter results in a decrease of the other, hence the tradeoff to be resolved by the developer. These curves represent years of accumulated knowledge on performance characteristics and define the feasible limits of a solution space before any detailed design begins. This aspect enables the use of Set Based Concurrent Engineering (SBCE), whereby several feasible alternative solution sets are considered early in the process; development work continues on all alternatives until late in the process when market conditions become clear and the optimal solution emerges (Sobek II, Ward, & Liker, 1999).

The goal of LPPD is to create profitable operational value streams; as such, products and processes are developed simultaneously and the practice of Target Costing (or Profit Management) is an essential activity within that process. For many products, the Allowable Direct Target Cost can be subdivided into Direct Material Cost and Direct

Assembly Cost (Carr & Ng, 1995; Cooper & Slagmulder, 1997). Much of the Target Costing literature is focused on Direct Material, as this is usually the larger of the two components. However, for many suppliers of high volume complex products, the Direct Assembly cost will be significant over the product lifespan, and the literature is scarce on this topic. Firms may have several options for the installation of assembly capacity, and many strategic factors are considered in location decisions. Those firms operating in jurisdictions where labor cost is high must be cost competitive with low labor cost countries (LCC). These firms will generally seek to offset the cost of labor with automation, while maintaining Direct Assembly Cost targets. This paper aims to address this issue by presenting a simple model that can be used to generate tradeoff curves that illustrate the feasible limits of manpower and capital investment for an assembly process to achieve a target cost. Using this model, production engineers can consider several sets of feasible assembly alternatives during the development stage that can be refined as market uncertainty is eliminated, ensuring the optimal solution. The remainder of the paper is organized as follows. The next section is a brief exploration of the literature. Following that, a model that generates the Direct Assembly cost tradeoff curve is developed, and several iterations are explored by altering parameters within the model. Observations are noted, followed by Discussion of the implications. The last section is Conclusions, Limitations and Suggestions for future research.

2. Literature Review

In the 1980s, Japanese automakers began establishing successful manufacturing operations in North America to support their increasing share of that market. Subsequently academic researchers began to study these companies, searching for the factors and business practices that enabled the Japanese success. A five year study of the global automotive industry led by researchers at the Massachusetts Institute of Technology (MIT) culminated in the publication of the book “The Machine that Changed the World”, which concluded that the Japanese automakers were generally more efficient than their global competitors, and Toyota specifically was the most successful of this group (Womack, Jones, & Roos, 1990). The Japanese production methods were described using the term Lean Manufacturing, which has since become a euphemism for the Toyota Production System (TPS), and several automakers and suppliers have since attempted to replicate it with varying degrees of success. The MIT study also highlighted the fact that the Japanese automakers were able to develop superior products and get them to market faster and more efficiently than their competitors. In the 1990s, a group of researchers at the University of Michigan began publishing their findings about Toyota’s system for product development. Their initial revelation was the counterintuitive idea that Toyota’s lead time was shorter than other automakers because they delayed detailed design decisions until as late in the development process as possible (A. Ward, Liker, Cristiano, & Sobek, 1995). Toyota used what the researchers termed Set Based Concurrent Engineering (SBCE), whereby several sets of design alternatives are explored simultaneously, with the weaker ones gradually eliminated as the process progresses (Sobek II et al., 1999). The key to the success of this method was that the feasible design space for the alternatives was clearly defined up front, using previously accumulated knowledge often captured in the form of tradeoff curves. Final design decisions were made by a Chief Engineer who had the technical acumen to understand the tradeoffs between competing performance parameters (Liker, Sobek, Ward, & Cristiano, 1996; A. Ward et al., 1995). Further work revealed Toyota’s extensive use of tradeoff curves to understand the relationship between performance characteristics, usually those in conflict with each other (Morgan & Liker, 2006). Ward emphasizes the importance of tradeoff curves as a knowledge preservation tool used to reduce development lead time (citing their contribution to the development of the P51 Mustang aircraft in World War II) and noting that they can be used to display several kinds of information to map the feasibility limits of a design (A. C. Ward & Sobek II, 2014). The name that the researchers used to describe the Toyota system holistically was Lean Product and Process Development (LPPD), extending the use of the term Lean. The analogy with Lean Manufacturing was that the aim of TPS is the elimination of waste of production resources (the value in the production process), whereas the aim of LPPD is the elimination of the waste of knowledge, which is the value created by the development process (A. C. Ward & Sobek II, 2014).

At the same time that the Michigan researchers were revealing the nuances of Toyota’s product development system, another literature stream was forming on the Japanese business practice of Target Costing. According to the literature, this practice is also acknowledged to have originated at Toyota, although it was not referenced in the MIT global study (Feil et al., 2004). Target Costing begins prior to product development, when firms determine a target cost for a new product that must be achieved at launch in order to support a desired profit level at an assumed market price and volume. Several seminal articles by Japanese authors that provided the details of this business practice were published in English language accounting journals. Monden and Hamada provide a detailed outline of

the system of target costing at Japanese automobile companies (Monden & Hamada, 1991) while Tanaka provides specifics about target costing at Toyota (Tanaka, 1993). Tanaka provides detail on how cost targets are determined, but acknowledges that the realization of the target cost is the responsibility of designers and engineers, and that this requirement is as important as any performance specification (Tanaka, 1993). Kato provides insight on the support systems required to achieve cost targets, such as cost tables and databases, but notes that the most powerful tools are Value Engineering and variety reduction (Kato, 1993). Kato suggests that the term Target Costing may lead readers to believe that the practice is exclusively for firms competing on lowest cost in the Porter strategy framework (Porter, 1980), and that a more appropriate description of the activity would be Strategic Profit Management, as even the differentiators in Porter's framework must understand costs to remain profitable (Kato, 1993).

Ultimately firms must determine a Target Direct Cost that enables a product to achieve profitability in the market. This Direct Cost consists of Direct Material and Direct Assembly, and most attention is given to the former through Value Engineering, as automakers like Toyota purchase up to 70% of components and materials from its network of suppliers (Cooper & Slagmulder, 1997). Direct Assembly Cost is primarily driven by labor and capital investment, and the literature is less conclusive regarding the evaluation of capital investment decisions in target costing. Sometimes it is considered to be a recurring expense captured in depreciation (Tanaka, 1993); other times the specifics of these costs are captured in cost tables as rates (Cooper & Slagmulder, 1997). Unlike physical properties, cost components change over time and these tables need to be updated frequently to remain effective (Kato, 1993). Capital Investment decisions often also include strategic considerations such as innovation or required levels of flexibility in addition to reducing labor cost through automation (Hino, 2006; Okano, 2005). Whatever the method of evaluation, all firms must be able to cover the costs of capital investment by the profit generated over the life of the products (Cokins, 2002).

In recent work, LPPD researchers have emphasized that cost is as important as any other product attribute and must be well understood as tradeoffs must be managed (Morgan & Liker, 2019). This paper addresses the literature gap in the area of target costing for Direct Assembly operations by proposing a tradeoff curve model to be used by engineers and managers to understand the limits of feasibility in advance of detailed process development. The model is flexible enough to compare options in different locations where wage rates for labor differ significantly.

3. Direct Assembly Cost

The two major determinants of cost for an assembly process are labor and equipment, and every assembly process alternative under consideration can be described by these two components. To determine the assembly cost per unit requires two additional parameters: the designed capacity of the process, measured in daily throughput, and the planned total volume over the lifespan of the product. The Direct Assembly Cost per unit for a proposed process is given by the following:

$$\text{Direct Assembly Cost}_{(u)} = \text{Direct Labor Cost}_{(u)} + \text{Capital Cost}_{(u)} \quad (1)$$

Each component can be computed using the aforementioned two parameters and the labor cost data for the proposed jurisdiction.

$$\begin{aligned} \text{Direct Labor Cost}_{(u)} &= \text{Daily Labor Cost} / \text{Daily Throughput} \\ &= (\# \text{ Workers}) * (\text{Daily wage}) / \text{Daily Throughput} \end{aligned}$$

$$\begin{aligned} \text{Capital Cost}_{(u)} &= \text{Total Capital Investment} / \text{Total Units Produced} \\ &= \text{Total Capital Investment} / (\text{Daily Throughput} \times \text{Days/Year} \times \text{Lifespan (yrs.)}) \end{aligned}$$

The total units produced will be the Daily Throughput multiplied by the total number of production days in the lifespan of the product. For most projects, the lifespan will be measured in years, so the number of production days per year is required.

The Direct Assembly Cost per unit calculation for an auto parts assembly facility where the hourly wage is \$20, the workday is 8 hours, and there are 240 working days per year is given by:

$$\text{DAC}_{(u)} = \$160 (\# \text{ Workers}) / (\text{Throughput}) + (\text{Total Capital Investment}) / [(\text{Throughput}) (\text{Lifespan}) 240] \quad (2)$$

For most assembly processes, a tradeoff exists between Direct Labor and Capital Investment. Firms in high labor cost jurisdictions seek to reduce the cost of Direct Labor by reducing the number of workers through the use of automation, which typically requires more Capital Investment. A tradeoff curve can be constructed to depict this relationship and define the region of feasibility for proposed assembly process alternatives to meet a Target Direct Assembly Cost per unit within a given context.

4. Constructing the Tradeoff Curve

To depict this tradeoff, a graph can be constructed with Headcount (number of workers) on the x axis and Capital Investment on the y axis.

Given a set of assumptions for Target Direct Assembly Cost (u), Throughput, and Lifespan, we can calculate and plot the x and y axis intercepts. These points represent two alternative assembly processes; a totally manual process that requires no capital investment (the x intercept), and a totally automated solution that requires no labor. Either of these alternatives may be impractical or even unrealistic, but they represent the extremes of the tradeoff. Since the tradeoff relationship is linear, the line connecting the two intercepts is the tradeoff curve between headcount and capital investment for the given target assembly unit cost in the given context. Any proposed assembly solution described as a combination of headcount and capital investment can be plotted as a point on this graph. Assembly solution alternatives that fall below the line are in the feasible region, while those above the line will not meet the target cost.

4.1 Baseline Case

A Headcount (x) vs Capital Investment (y) tradeoff curve can be constructed for the aforementioned auto parts assembly facility given the following contextual parameters:

- Throughput = 5,000 units per day
- Lifespan = 4 years
- Target Direct Assembly Cost (u) = \$1.00

The x intercept is 31 and the y intercept is \$4.8 million. The tradeoff curve is shown in Figure 1.

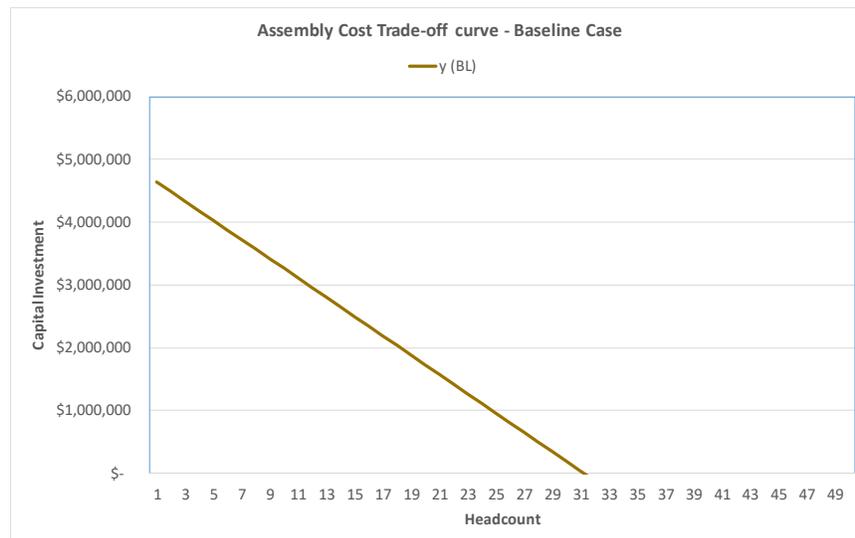


Figure 1. Tradeoff curve for the Baseline case

Any number of alternative assembly process options described by required Headcount and Capital Investment could be plotted as points on the graph, but only those below the curve would be considered feasible, as the resulting assembly cost per unit would be below target. The assembly unit cost for each alternative can be calculated using

equation (2). Tradeoff curves for different target assembly unit costs would be a series of parallel lines on the same graph for the same set of circumstances.

4.2 Comparison with a LCC jurisdiction

The Baseline case graph can be augmented with the addition of a curve depicting the limits of feasibility for assembly process options for the same set of parameters but in a low labor cost country (LCC). The only change to the variables in the above set of equations is the daily cost of Direct Labor. For this example assume an hourly wage rate of \$5 and a working day of 9 hours. The augmented tradeoff curve is shown in Figure 2. The y intercept does not change, but the x intercept has moved to 111, revealing a much larger range of feasibility for assembly process solutions. Options that would exceed the target cost in the high cost country are now in the feasible range for the low cost country. While there may be other technical considerations for such process options, from a target costing standpoint they are within the limits of feasibility.

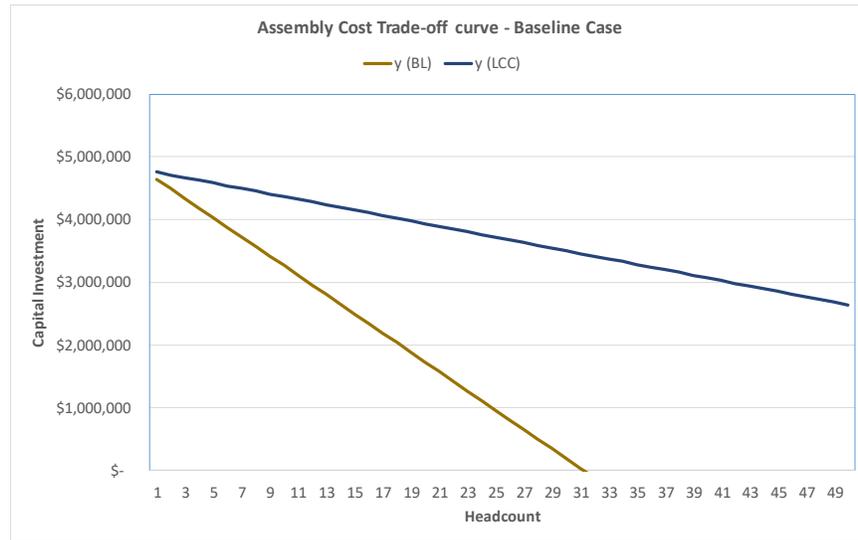


Figure 2. Tradeoff curve for Baseline case and LCC

4.3 Tradeoff Curve Model

In the globally competitive environment for assembly, firms in high cost countries are encouraged to seek less labor intensive solutions (automation) which tends to require higher levels of capital investment. Of interest is how the tradeoff curve changes as circumstances change, and what set of circumstances may favor automation over manual assembly. As shown in equation (2), higher levels of Throughput and Lifespan will reduce the Capital Cost per unit. Additionally, higher levels for Target Direct Assembly Cost per unit may be amenable to assembly processes in high labor cost environments. A model can be constructed to show different tradeoff curves for different sets of these parameters.

As the tradeoff curve is linear, it can be modelled in the form $y = mx + b$, where the capital investment (y) is expressed as a function of headcount (x). The slope (m) and intercept (b) are influenced by the contextual parameters described earlier. The equation for the tradeoff curve expressed in the form $y = mx + b$ is:

$$y = -1(\text{Daily Wage}) (\text{Lifespan}) 240x + (\text{Target Assembly Cost}_{(u)}) (\text{Throughput}) (\text{Lifespan}) 240$$

Simplified, we have:

$$y = 240(\text{Lifespan}) [(\text{Target Assembly Cost}_{(u)}) (\text{Throughput}) - (\text{Daily Wage}) x] \quad (3)$$

Equation (3) reveals that for a solution to be feasible, the product of the Target Assembly Cost per unit and the daily Throughput must at least exceed the Labor cost of the solution; therefore, lower volume products with low target assembly costs will necessitate low daily wages or few workers. If this difference is positive, a long product Lifespan will have a multiplicative effect, increasing the allowable Capital Investment to achieve target cost.

A model to generate tradeoff curves was created with Microsoft Excel. A sample of the model is shown in Table 1. The parameters describing the context circumstances (Target Assembly Cost per unit, Daily Throughput, Product Lifespan) can be changed and the Headcount vs Capital Investment tradeoff curves will be created for each scenario.

Table 1. Tradeoff curve model for Headcount vs Capital Investment

x	BL (m)	BL (mx)	LCC (m)	LCC (mx)	Target DAC / unit (\$)	Throughput (Units/day)	Lifespan (years)	Total Cost (b)	y (BL)	y (LCC)
	\$ 20.00		\$ 5.00							
	8.0		9.0		\$ 1.00	5,000	4			
	\$(160)		\$(45)							
	\$(153,600)		\$(43,200)					\$ 4,800,000		
1	\$(153,600)	\$(153,600)	\$(43,200)	\$(43,200)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 4,646,400	\$ 4,756,800
2	\$(153,600)	\$(307,200)	\$(43,200)	\$(86,400)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 4,492,800	\$ 4,713,600
3	\$(153,600)	\$(460,800)	\$(43,200)	\$(129,600)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 4,339,200	\$ 4,670,400
4	\$(153,600)	\$(614,400)	\$(43,200)	\$(172,800)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 4,185,600	\$ 4,627,200
5	\$(153,600)	\$(768,000)	\$(43,200)	\$(216,000)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 4,032,000	\$ 4,584,000
6	\$(153,600)	\$(921,600)	\$(43,200)	\$(259,200)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 3,878,400	\$ 4,540,800
7	\$(153,600)	\$(1,075,200)	\$(43,200)	\$(302,400)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 3,724,800	\$ 4,497,600
8	\$(153,600)	\$(1,228,800)	\$(43,200)	\$(345,600)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 3,571,200	\$ 4,454,400
9	\$(153,600)	\$(1,382,400)	\$(43,200)	\$(388,800)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 3,417,600	\$ 4,411,200
10	\$(153,600)	\$(1,536,000)	\$(43,200)	\$(432,000)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 3,264,000	\$ 4,368,000
11	\$(153,600)	\$(1,689,600)	\$(43,200)	\$(475,200)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 3,110,400	\$ 4,324,800
12	\$(153,600)	\$(1,843,200)	\$(43,200)	\$(518,400)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 2,956,800	\$ 4,281,600
13	\$(153,600)	\$(1,996,800)	\$(43,200)	\$(561,600)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 2,803,200	\$ 4,238,400
14	\$(153,600)	\$(2,150,400)	\$(43,200)	\$(604,800)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 2,649,600	\$ 4,195,200
15	\$(153,600)	\$(2,304,000)	\$(43,200)	\$(648,000)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 2,496,000	\$ 4,152,000
16	\$(153,600)	\$(2,457,600)	\$(43,200)	\$(691,200)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 2,342,400	\$ 4,108,800
17	\$(153,600)	\$(2,611,200)	\$(43,200)	\$(734,400)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 2,188,800	\$ 4,065,600
18	\$(153,600)	\$(2,764,800)	\$(43,200)	\$(777,600)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 2,035,200	\$ 4,022,400
19	\$(153,600)	\$(2,918,400)	\$(43,200)	\$(820,800)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 1,881,600	\$ 3,979,200
20	\$(153,600)	\$(3,072,000)	\$(43,200)	\$(864,000)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 1,728,000	\$ 3,936,000
21	\$(153,600)	\$(3,225,600)	\$(43,200)	\$(907,200)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 1,574,400	\$ 3,892,800
22	\$(153,600)	\$(3,379,200)	\$(43,200)	\$(950,400)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 1,420,800	\$ 3,849,600
23	\$(153,600)	\$(3,532,800)	\$(43,200)	\$(993,600)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 1,267,200	\$ 3,806,400
24	\$(153,600)	\$(3,686,400)	\$(43,200)	\$(1,036,800)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 1,113,600	\$ 3,763,200
25	\$(153,600)	\$(3,840,000)	\$(43,200)	\$(1,080,000)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 960,000	\$ 3,720,000
26	\$(153,600)	\$(3,993,600)	\$(43,200)	\$(1,123,200)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 806,400	\$ 3,676,800
27	\$(153,600)	\$(4,147,200)	\$(43,200)	\$(1,166,400)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 652,800	\$ 3,633,600
28	\$(153,600)	\$(4,300,800)	\$(43,200)	\$(1,209,600)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 499,200	\$ 3,590,400
29	\$(153,600)	\$(4,454,400)	\$(43,200)	\$(1,252,800)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 345,600	\$ 3,547,200
30	\$(153,600)	\$(4,608,000)	\$(43,200)	\$(1,296,000)	\$ 1.00	5,000	4	\$ 4,800,000	\$ 192,000	\$ 3,504,000

4.4 Generating tradeoff curves for different scenarios

To visualize how the feasibility range changes for different scenarios, the model was used to generate some sample curves for high and low values of each of the parameters. The chosen values are shown in Table 2.

Table 2. Parameter values for Model experiment

	Target DAC / unit (\$)	Throughput (units/day)	Lifespan (years)
Low	\$ 0.50	2,000	2
High	\$ 2.00	15,000	8

The results from running the model for the 8 possible scenarios are shown in Table 3.

Table 3. Scenario inputs for Tradeoff curve Model

Scenario	Target DAC / unit (\$)	Throughput (units/day)	Lifespan (years)	y intercept (b)	x intercept BL	x intercept LCC
1	\$ 0.50	2,000	2	480,000	6	22
2	\$ 0.50	2,000	8	1,920,000	6	22
3	\$ 0.50	15,000	2	3,600,000	46	166
4	\$ 0.50	15,000	8	14,400,000	46	166
5	\$ 2.00	2,000	2	1,920,000	25	88
6	\$ 2.00	2,000	8	7,680,000	25	88
7	\$ 2.00	15,000	2	14,400,000	187	666
8	\$ 2.00	15,000	8	57,600,000	187	666

5. Observations

From equation (3) it is observed that a feasible solution exists only when the product of the Target Assembly Cost and the Throughput are sufficient to overcome the labor cost for the proposed assembly process. The product lifespan has a multiplicative effect on this difference, thereby increasing the allowable capital investment for the proposal. The results in Table 3 illustrate this sensitivity for 8 different scenarios, listing the intercepts, or the extreme ends of the tradeoff curves; the y intercept is the maximum allowable capital investment and the x intercept is the maximum allowable headcount for a proposed assembly process. The two x intercepts are for the Baseline case (BL) and the Low Cost Country case (LCC).

In Scenario 1, both the Target Direct Assembly Cost and the Throughput are set to the low extreme for this experiment. Unless the product is extremely simple, this situation would favor an assembly process located in a low cost country (LCC) as the feasible region for solutions for the Baseline operation is very small. The tradeoff curves for Scenario 1 are shown in Figure 3. Increasing the lifespan (Scenario 2) expands the feasible region by allowing a higher limit for capital investment, but does not increase the allowable headcount.

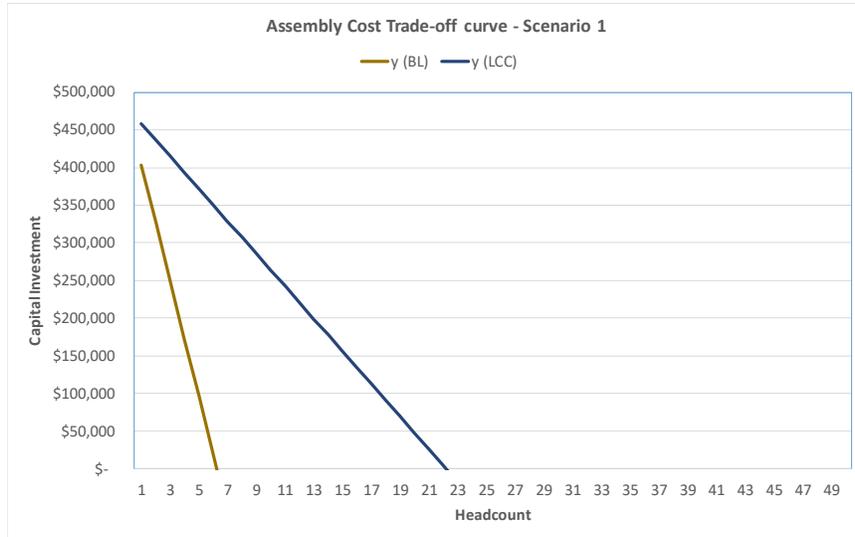


Figure 3. Tradeoff curves for Scenario 1

In Scenarios 3 and 4, the Target Direct Assembly Cost remains low, but the high Throughput greatly increases the feasibility range for the Baseline case. The tradeoff curves for Scenario 3 are shown in Figure 4. Again, increasing the Lifespan in Scenario 4 expands the feasibility region by allowing greater capital investment only.

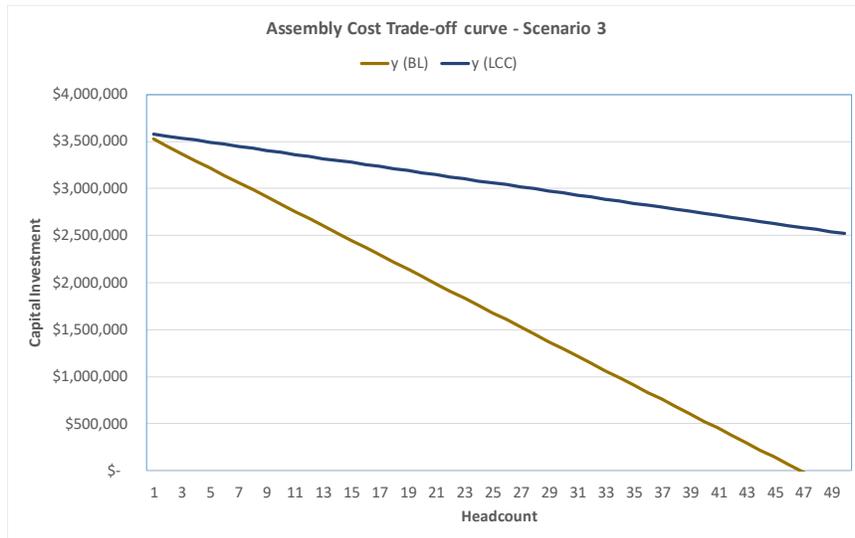


Figure 4. Tradeoff curves for Scenario 3

Scenario 5 and 6 depict a higher Target DAC but a low Throughput. However, the feasibility range for the Baseline case may be sufficiently large for assembly proposals that meet the Target DAC when the Lifespan is high, as shown in Figure 5.

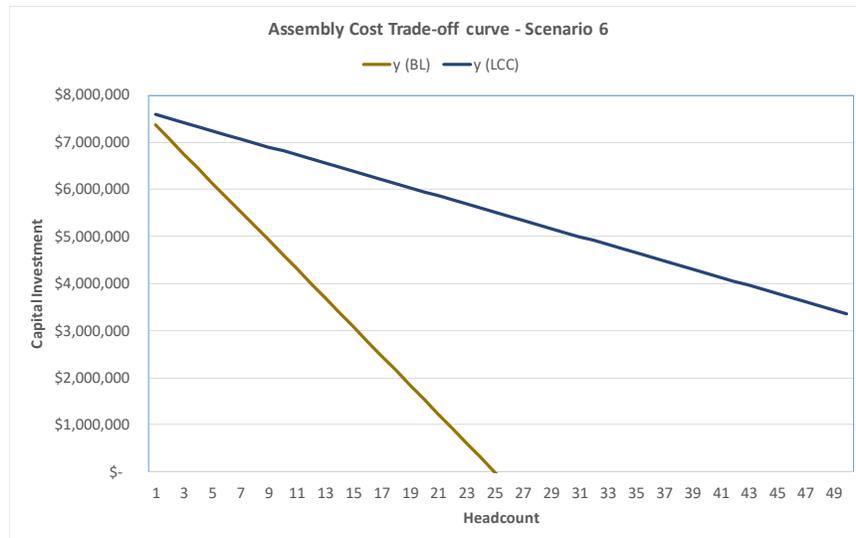


Figure 5. Tradeoff curves for Scenario 6

In Scenarios 7 and 8, both the Target DAC and Throughput are high, which gives the greatest feasibility range for assembly solutions in the Baseline case.

6. Discussion

Process developers can use these tradeoff curves to define feasibility ranges for sets of assembly process alternatives in advance of any detailed development work. Engineers and managers in high labor cost environments can clearly understand the tradeoff between headcount and capital investment under various economic circumstances. This is important because there may be strategic considerations for capital investment, such as innovation, quality, flexibility and technical support; by incorporating capital investment into Direct Assembly target cost, management can understand the limits on capital spending for anticipated profit to be realized. In other circumstances there may be limits imposed on capital investment for specific projects; in that case, the tradeoff curve can be modified with the addition of a horizontal line at the maximum capital investment allowable, further defining the feasibility range for proposed solutions.

In all of the experimental scenarios the feasibility region defined by the LCC curve is greater than that defined by the BL curve. Any proposed assembly process described by the required headcount and capital investment can be plotted on the graph, and the Direct Assembly Cost per unit for that process will always be lower in the LCC. Although it may be tempting from a Direct Cost perspective to utilize a solution with higher headcount in a LCC to achieve a desired throughput, this may have an adverse effect on Indirect Costs, as higher headcount requires more levels of supervision and potentially greater factory floor space. Additionally, when considering assembly process options in low cost countries, firms must be cognizant of other factors, termed the Total Cost of Ownership (TCO) by the Reshoring Initiative, a non-profit organization that helps companies understand the true cost of offshore operations in low cost countries (Moser, 2011). Some of these factors are easily quantified in terms of direct unit cost, such as productivity, logistics, inventory, packaging, and tariffs; others fall into the realm of supply chain risk management and may be more subjective. For example, the recent COVID-19 pandemic has managers reconsidering the location of some elements of their supply chains, but operations must remain cost competitive regardless of location. If these risk management factors are properly quantified and applied to Target Costing activity, the result may be that the Target Direct Assembly Cost per unit should be lower in the LCC to account for these other TCO factors (for example, $DAC_{(u)LCC} = DAC_{(u)BL} - TCO_{(u)}$). The Tradeoff curve model can be augmented to accommodate a comparison of different targets for different jurisdictions. Figure 6 shows the same scenario as Figure 2, but with a Target $DAC_{(u)LCC} = \$0.75$ versus a Target $DAC_{(u)BL} = \$1.00$.

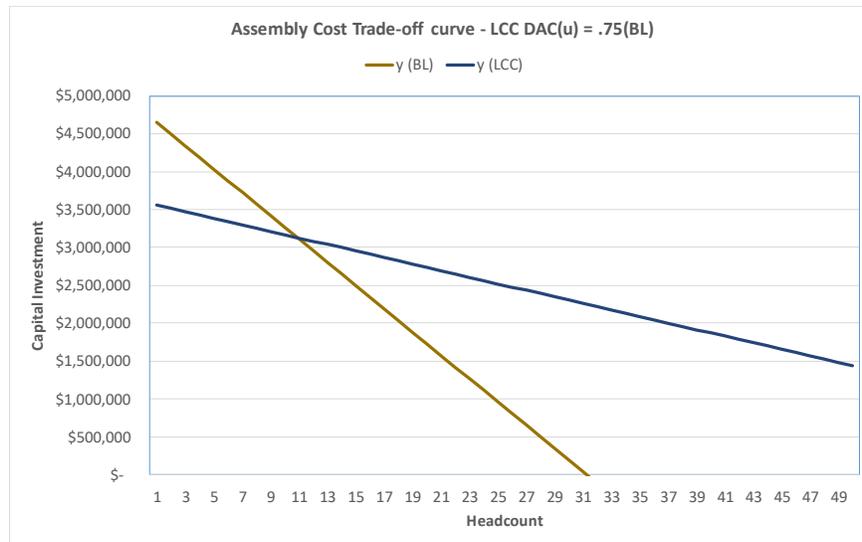


Figure 6. Tradeoff curves for Different Target Costs by jurisdiction

For the first time the tradeoff curve reveals a region where proposed assembly processes would be feasible in the BL case, but not feasible in the LCC, albeit a small region requiring high levels of automation.

7. Conclusions, Limitations, and Recommendations

Tradeoff curves are a useful tool to define a feasibility range for competing design characteristics before detailed development begins. This paper has shown that tradeoff curves can be used in the Target Costing process for Direct Assembly operations for the characteristics of headcount and capital investment. A simple model created in MS Excel can produce tradeoff curves for these characteristics under different scenarios for labor cost, throughput, product lifespan, and target cost.

This tradeoff is of great interest to firms operating in high labor cost jurisdictions, such as automotive suppliers who face pressure from their customers for price reductions and innovative solutions. One solution for assembly cost reduction is to reduce the cost of labor by locating assembly operations in LCCs, but there may be other strategic reasons for not taking this approach. An alternative is to reduce the need for labor through the pursuit of higher levels of automation, which requires capital investment. The tradeoff curve is a simple and direct way for managers and engineers to understand the feasible limits of capital investment necessary to achieve a target assembly cost.

The tradeoff curves developed in this paper show that the conditions most favorable to higher levels of capital investment are high target assembly cost, high throughput, and long product lifespan. This may seem obvious, but understanding these conditions in advance may allow process designers to influence product engineering decisions when development is being done concurrently. For instance, if product designers have the opportunity to reduce product line variation, higher throughput may be the result for the assembly operation. Similarly, a strategy of modular product architecture could realize larger throughput for modules that might be shared between divisions, or longer product lifespan for modules that don't change frequently.

Another type of decision that could result from the understanding revealed through the tradeoff curves is the composition of capital investment being considered. For example, operations that require expensive functional test equipment could be redesigned to find alternate methods to assure quality of the product. Additionally, some investments such as robots, or simple material handling units are flexible and reusable. Since the tradeoff curve method allocates the acquisition cost to the original project, reusing capital equipment on subsequent projects reduces further capital investment cost to that of retooling and refurbishment for a new purpose.

The present paper limits the analysis of Direct Assembly cost to the two characteristics of headcount and capital investment once a target cost has been established. There is a great deal of analysis and understanding of product cost required to derive a target, and other sources provide sufficient guidance in this respect (see Cooper and

Slagmulder (1997)). Such analysis would include the treatment of other direct and indirect costs pertaining to assembly operations, such as consumable usage items, utilities, material handling, and direct supervision. However, as long as these costs can be allocated on a per unit basis for the product and process under development, then the Target Assembly cost per unit can be adjusted accordingly before tradeoff curves are produced. Another limitation in the model is the use of a single wage rate for headcount. In reality, all required headcount for the successful operation of an assembly process may not have the same rate of compensation, nor would it remain constant over the product lifespan. Before using the model to generate tradeoff curves, the wage rate would need to be adjusted to reflect the weighted average of wage rates for the various workers involved in the process, and how it may change over time.

A recommendation for future research would be to explore the actual tradeoff relationship between headcount and capital investment as proposed solutions approach the intercepts of the graph. It was suggested earlier that assembly solutions requiring a large labor component in low cost countries may increase the indirect cost of supervision and technical support. At some point, this tradeoff relationship will no longer be linear. Further research is required to determine the circumstances under which a point of inflection appears on the curve.

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Biography

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