Electronic Product Assembly in the Global Marketplace: The Material Piece of the Competitive Puzzle

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ABSTRACT

In 2008, a paper was written to address the labor cost disparity between producing electronic products (i.e., those with highly automatable assembly) in high and low global manufacturing labor rate regions [1]. The paper concluded that implementing a new high labor rate operational and organizational model, replacing the one that has been traditionally used, could result in offsetting the cost advantage that a low labor rate assembly model naturally affords. This new, high labor rate model is competitive because, instead of fixating on the lowest labor hour *rate*, it significantly reduces labor cost through focusing on minimizing labor hour *content* by exploiting the available automation. In addition, factory *indirect costs* and *overhead* are minimized by dismantling the traditional hierarchal organizational structure and replacing it with one that best serves building products in an automated environment.

This paper addresses a second assembly cost consideration in competitive electronic product manufacturing – material cost. The paper concludes that any significant price differential between the cost of *purchasing* the same electronic components in high and low labor rate product assembly global regions is artificial. In other words, any relative pricing differences are not justified by the actual cost to manufacture and deliver the components to the assembly factories in different labor rate areas. In a similar sense to the unjustified difference in the price of purchasing the same piece of automation equipment in high and low labor rate markets (an historic anomaly that has never been adequately justified in terms of cost), this paper concludes that relative electronic component pricing is determined primarily by *what the local market will bear (read: is willing to pay)*, at best, and by political reasons, at worst. This has contributed to the exodus of electronic product manufacturing to low labor rate regions as much as, or more than, the well-publicized labor rate disparity. Inflated profit margins under the guise of higher prices caused by higher costs such as shipping and overhead have, in some cases, resulted in material manufacturers and distributors charging a 20-50% premium in high labor rate regions. These material cost differences can exacerbate labor cost differences, contributing to the allure of low labor rate electronic product manufacturing. Government protectionist policies, currency exchange rates and other non-labor or material related cost considerations while referred to, will be addressed in detail in the final paper in this series. Finally, the paper recommends that material procurers in high labor rate environments insist on equitable treatment – i.e., offered material pricing with the same cost markups, or be given a valid reason why they must pay a premium.

Key words: U.S. competitiveness, offshore manufacturing, Concurrent Education, electronic components

INTRODUCTION

In the U.S. (a high labor rate region), the 1975 contribution from all its value-added manufacturing as a percentage of its total GDP was ranked 16th in the world. In 2004, the U.S. ranking for this relative manufacturing *health* metric dropped to 73rd. In 1975 the contribution from all value-added manufacturing done in China (a low labor rate region) as a percentage of its total GDP was ranked 30th in the world. In 2004 China's manufacturing ranked 2nd in the world as a percentage of its total GDP (Table 1). *Manufacturing* refers to industries belonging to ISIC Section C: that is made up of manufacturing divisions 15-37 [2]. *Value-added* is defined as the net output for the ISIC Section after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. These statistics include all manufacturing – whether it can be easily automated, such as circuit board assembly, or labor intensive, such as installing shingles on the roof of a new home or fabricating and assembling a weather satellite (any manufacturing application where either the product design does not lend itself to automation or there are only low quantities required). The specific ISIC division that addresses electronic product manufacturing is division 26, *Manufacture of computer, electronic and optical products*, with Group 261 and Class 2160 addressing the *Manufacture of electronic components and boards*. The International Standard Industrial Classification (ISIC), revision 4, defines these categories. More detailed information on these defined classifications can be found in Appendices I and II. The example of the ascendency of manufacturing activity in low labor rate environments, accompanied by the exodus of manufacturing jobs out of high labor rate markets represented in Table 1, is well known. The consumer's constant reminder of this shift has been in the relentless trend of what is by the now the ubiquitous product marking: *Made in (pick your low labor rate country of choice).*

	1975	2004
U.S.	16	73
China	30	2

Table 1. Change in International Ranking from 1975 to 2004 between a High and Low Labor Rate Country in Terms of Value-added Manufacturing as a Percentage of Total GDP [3]

This paper attempts to determine the material suppliers' cost differences between locations in low and high labor rate regions. These differences are analyzed to see if they justify a difference in the material pricing quoted to the product assemblers in the different labor rate areas – and, if so, how much. Models are attempted established to determine the cost of doing business by polling the two primary sources of electronic components, the ODM (Original Device Manufacturers) and their franchised distributors. The users, OPMs (Original Product Manufacturers), also known as OEMs (Original Equipment Manufacturers), and the EMS (Electronic Manufacturing Service) providers were also polled to help comprehend the historic price difference between purchasing the same components in low cost and high cost labor markets, as well as, the current state of purchasing material. The paper concludes that while traditionally there may have been a significant price advantage to buying components in low cost labor environments, this material disparity has largely disappeared. In addition, the *indirect* material costs incurred by the product assembler (inspection, non-conformance, kitting, inventory, attrition, PPV, rework scrap, etc.) are analyzed, and a material management strategy is developed to minimize these elements of cost.

ELECTRONIC PRODUCT COST

The cost of producing an electronic product is simply the sum of labor cost and the material cost. In most electronic product assembly applications the material cost is generally somewhere between 50% and 80% of the total product cost. For a specific electronic product, the actual material/labor cost split depends primarily on a combination of the following factors:

1. The functionally of the product as it affects the requirement for high tech and custom (more expensive) material, both for the circuit board and higher level assemblies.
2. The amount of post-circuit board (higher level or box build assembly) that is required and the corresponding labor rates that are applied.
3. To the extent justified by production volume, the degree to which the labor intensive box build processes can be automated.
4. The design of the product as it affects the ability to successfully automate (with low yield loss) the assembly, test, etc. processes (DF MATERRS) [4]
5. The manufacturer's overhead and other indirect costs that are absorbed in the labor rate and cause it to be inflated – the higher these costs, the higher the labor rate, and hence, the lower the material cost as a percentage of the total cost.

The portion of total product cost that the circuit board(s) contribute is normally characterized with even higher material-to-labor cost ratios – generally, with material comprising 75-95% of the total circuit board cost because of the inherent level of standardized automation readily available (e.g., the automated placing and soldering of most electronic components). Factors 1, 4 and 5 apply in establishing where, within the 75-95% range, material cost as a percentage of total cost falls for a specific circuit board assembly.

Although the material portion of the cost dominates, it would seem reasonable to assume that the most controllable portion of the total cost is the smaller labor portion. This part of the cost can clearly be affected through good process development and control, competitive labor rates, and the extent to which labor content can be squeezed out through automation. This assumption would be true if the larger material portion of the cost for a given product assembly application was independent of where the product was assembled - in other words, the same bill of material (BOM) costs the same whether it is purchased in a high or low labor rate assembly environment – it's not. The question then becomes: why?

Electronic Product Assembly: Labor Cost

There are different methods of estimating and accounting for a product's labor cost. The labor cost is generally the number of direct labor hours needed to build the product multiplied by the loaded labor rate. The direct labor hours normally consist of the assembly and test *touch* labor (Raw "L"). The loaded labor rate is the average direct labor rate factored up to absorb the overhead (including consumable material such as solder), indirect and other non-product related labor costs, i.e., non-direct costs. The SG&A (Selling, General & Administrative) costs to pay for non-project related management, marketing, sales and other non-product related costs that are needed to sustain the business are also loaded on as a percentage of the labor cost. Finally, the loaded labor cost is marked up to establish the labor sell price. Over a year, selling enough product labor hours, through selling the assembled products they are part of, will pay for all the direct, indirect, overhead and SG&A costs incurred and provide the company with net earnings – in other words, a profit.

Other cost accounting systems, such as activity-based costing, convert more indirect and overhead costs into direct costs. For example, to estimate the cost to assemble a board with SMT components, all the direct labor (machine operators, etc.), indirect labor (process development engineering, etc.), overhead (SMT equipment depreciation, etc.) and other activity allocated costs are estimated. Then, a theoretical de-rated average SMTA placement rate and an equipment utilization rate are established. The total activity cost for SMT board assembly is divided by the number of SMT components for all products that the pick and place machine is expected to place. This, then, becomes the cost per component. For a specific board, the number of components is multiplied by the cost per component. For example, the labor cost estimate for a board with 500 components processed through the SMT activity cost center of $0.0025 per component would be $1.25. An accounting system is set up to collect the actual costs as they are incurred.

Whatever labor system is utilized, all labor costs must be accounted for. The success of paying for all the direct and absorbed labor costs and making the projected profit is pegged to the operation's ability to:

1. Assemble the product within the labor hours that are embedded in the product sales price.
2. Build and sell the volume of products on which the loaded labor rate was based.
3. Not exceed the estimated costs (both direct and non-direct) that determined the estimated labor rate, and hence, the labor cost.

The labor estimating and accounting process can seem complex and convoluted because of its mathematically indeterminate nature. A particular product's estimated labor cost is dependent on the overall operation's loaded labor rate. The loaded labor rate, in turn, is a function of the operation's estimated total labor cost and an estimate of the total labor hours that will be *sold*, in the products that are assembled – one of which is the product whose labor cost is being estimated. Mathematically expressed:

C_P = Cost of the Product ($)
C_M = Cost of the Material (in $)
C_{PL} = Total Labor Cost of the Product ($)
C_{DL} = Direct Labor Cost of the Product ($)
C_{PLT} = Total Annual Labor Cost ($)
C_{DLT} = Total Annual Direct Labor Cost ($)
R_L = Labor Rate ($/hr)
C_{IL} = The Portion of the Total Non-Product Specific Labor and Facility Overhead Cost that will be loaded or absorbed in the Total Labor Cost ($)
C_{ILT} = Total Annual Non-Product Specific Labor and Facility Overhead Cost that will be loaded or absorbed ($)
H_{RL} = Direct Labor Needed to Assemble the Product (hr)
H_{RLT} = Direct Labor Needed for all the Products that will be assembled over the year (hr)

$$C_P = C_{PL} + C_M$$

$$C_{PL} = C_{DL} + C_{IL} \quad \text{Eq. 1}$$
$$C_{PL} = H_{RL} \times R_L \quad \text{Eq. 2}$$
$$C_{PLT} = C_{DLT} + C_{ILT} \quad \text{Eq. 3}$$
$$C_{DLT} = H_{RLT} \times R_L \quad \text{Eq. 4}$$
$$C_{DL} = C_{DLT} \times (H_{RL} / H_{RLT}) \quad \text{Eq. 5}$$
$$C_{IL} = C_{ILT} \times (H_{RL} / H_{RLT}) \quad \text{Eq. 6}$$
$$R_L = (C_{DLT} + C_{ILT}) / H_{RLT} \quad \text{Eq. 7}$$

- To determine the total labor cost of a product (C_{PL}), seven equations need to be solved. There are more unknowns than equations.
- For a given product, the number of direct labor hours it will take to assemble the product (H_{RL}) is determined during the quoting process, i.e., it is a known independent variable.
- The total amount of non-product-specific labor and facility overhead cost needed to run the operation over a year (C_{ILT}) is budgeted, i.e., it is an estimated independent variable. It is the material management variable that is loaded into the labor rate.

How is the total labor cost, C_{PL}, determined?

First, the labor rate is calculated (Eq. 7):
$R_L = (C_{DLT} + C_{ILT}) / H_{RLT}$

To solve for R_L, the total direct labor hours that will be expended (i.e., *sold*) for *all* products over the year, H_{RLT}, must be estimated. Also estimated is the total annual non-product-specific labor and facility overhead cost that will be absorbed or loaded, C_{ILT}, in the labor rate.

For example: It is estimated that a product assembly facility's non-direct cost for the year (C_{ILT}) will total $2.5 million. The facility employs 25 direct labor people who make an average of $20 / hr. Therefore, the yearly direct labor cost is $1M (Raw "L"). The direct assembly time estimated for the product being quoted (H_{RL}) is 0.50 hr. per unit. The business forecast for the year estimates all the products sold for the company will require 100,000 hrs, of direct labor (H_{RLT}). What should be charged for labor (C_{PL}) to assemble the product?

To calculate the labor rate:
$R_L = (C_{DLT} + C_{ILT}) / H_{RLT}$ (Eq. 7)
C_{DLT} = 25 x 2000 hr x $20 per hr = $1.0M
C_{ILT} = $2.5M
H_{RLT} = 100,000 hrs

R_L = (1M + 2.5M) / 100,000 = **$35 / hr**

For a product that will require 0.5 hr per unit,
The labor cost for the product is:
$C_{PL} = H_{RL} \times R_L$ (Eq. 2)
C_{PL} = 0.5 hr x $35 per hr. = **$17.5**

The non-product-specific cost absorbed in the total product cost:
$C_{IL} = C_{ILT} \times (H_{RL} / H_{RLT})$ (Eq. 6)
C_{IL} = 2.5M x (0.5 / 100,000) = **$12.5**

The direct labor part of the total product cost is:
$C_{DL} = C_{DLT} \times (H_{RL} / H_{RLT})$ (Eq. 5)
C_{DL} = $1M x (0.5 / 100,000) = **$5.0**

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Checking the result:
$C_{PL} = C_{DL} + C_{IL}$ (Eq.1)
C_{PL} = $5.0 + $12.50 = **$17.50**

To pay for the annual non-product-specific company costs (C_{ILT} = $2.5M), enough products must be sold over the year that contain at least the number of direct labor hours that the labor rate (R_L) was based on (H_{RLT} = 100,000). For every product sold, in the above example $5.0 of non-product-specific company cost is paid for. To pay for the total $2.5M in annual non-product-specific company costs through the sales of only the example product, 500,000 would have to be sold over the year.

Using an activity-based system, a total labor cost estimate for a product is done on an activity basis. For example, the SMT activity uses a cost per pick-and-placed component to absorb the SMT activity costs (including the indirect, overhead and other non-direct cost allocations). It relies on paying for those costs by *selling* the actual placements made through selling the products of which they are a part.

Product labor costs incurred for assembly in high labor rate regions of the world can compete with their low labor rate counterparts. The impact of the labor *rate* disparity on labor cost can be negated if the direct labor hour *content* is minimized. This can be done if the available automation is exploited and the controllable non-direct costs that inflate the labor rate are significantly reduced [5]. In fact, contrary to *industry expert* opinion, product assembly in high labor rate environments should be more competitive for high volume applications than for low volume applications [6]. That is, if the other larger part of the product cost is not dependent on where the assembly takes place.

Electronic Product Assembly: Material Cost

The material used for electronic products is some combination of electronic components, circuit boards, I/O devices (keypads, displays, speakers, microphones, etc.), molded plastic or metal housings, cables and other materials that create the product's functionality. The manufacture of these materials has largely tracked that of the assembly industry – continuously migrating to low labor rate localities.

The material cost a product assembler incurs can be divided into two parts: raw material (raw "M") and material management. Material management costs (costs other than that of the "raw M") are analogous to indirect labor costs. These generally include:

1. Cost of Carrying the Inventory –
   The cost of the money needed to finance the material until the finished product is paid for. Usually this is expressed as a percent of the raw "M" cost, representing how much interest the dollar value of the material would have earned if it had been in an interest-bearing bank account. The most commonly used metric for this variable is the number of *inventory turns.* Inventory turns = the annual cost of the material / average value of the inventory over the year.
2. Material purchasing –
   This is the cost of the procurement personnel (buyers) who order the material.
3. Material planning –
   The cost of the MRP (Material Resource Planning) activity that is charged with scheduling material for manufacturing to meet product shipping requirements and minimizing inventory. This activity is generally a subset of the ERP (Enterprise resource planning) activity.
4. Incoming inspection – The cost of the labor used to in-ship and inspect the material after it is delivered.
5. Attrition – raw "M" lost because of:
   a. electrical, mechanical or cosmetic non-conformance due to damage or malfunction,
   b. loss of material in the assembly process (e.g., components dropped by the placement machine),
   c. inventory not reconciled,
   d. pilferage/theft.
6. Scrap –
   a. material lost in post-solder assembly related to issues such as manufacturing defects resulting in the need to discard components or entire assemblies,
   b. excess material that becomes obsolete (more material purchased than was required and/or cancelled customer orders).
7. Shipping – Since material is almost always FOB the manufacturer, the product assembler pays the freight. Also, any additional costs incurred to expedite deliveries versus normal freight charges must be included.
8. Distributor loaded cost – This is the cost that is added to the component price paid to the material manufacturer (ODM) to absorb the distributor's indirect costs and other operating expenses.
9. Distributor markup – This is the difference in the distributor's selling price and distributor's loaded cost. It represents the EBIT (earnings before interest and taxes). The resulting net earnings after interest and taxes are the distributor's profit.
10. Purchase price variance (PPV) – The difference in the raw "m" the product assembler pays between quoted cost and purchased cost.
11. Currency exchange rate – The cost of purchasing material with a currency other than the currency of the country where the material was produced.
12. Trade policy / Corporate tax rate – The policy between importing and exporting countries and the taxes the government imposes on earnings.

The Product Assembler's Material Management Cost as a Function of Product Assembly Location (Low Labor Rate vs. High Labor Rate Regions)

Some of the material management cost variables can be controlled by the product assembler. Others cannot. In addition, the material management cost of some of the variables is dependent on the labor rate in the assembly location.

1. Cost of Carrying the Inventory – This is largely a controllable cost that should not dependent on product assembly location.
2. Material purchasing – This is a controllable cost that has traditionally been tied to labor rates.
3. Material planning – This is a controllable cost that has traditionally been tied to labor rates.
4. Incoming inspection – This is a controllable cost that has traditionally been tied to labor rates.
5. Attrition rate – This is largely a controllable variable that is not dependent on product assembly location.

6. Scrap rate – This is largely a controllable variable that is not dependent on product assembly location.
7. Shipping – This is a controllable cost to the extent that good MRP can minimize the need for expedited shipping charges. There can be a cost premium for high labor rate regions since most material is manufactured in geographically distant locations. Either the product assembler's cost is F.O.B. the ODMs location, or this cost is embedded in the distributor's price. Higher material delivery cost is often given as the reason, or one of the reasons, for the higher material cost in high labor rate locations.
8. Distributor loaded cost – This is not controllable by the product assembler, but does affect the material price the assembler pays. The potential dependence of this variable on assembly location will be discussed later in this paper.
9. Distributor Markup – Historically, this has not been controllable by the product assembler, but does affect the material price the assembler pays. The potential dependence of this variable on assembly location will be discussed later in this paper.
10. Purchase price variance (PPV) – This is controllable to a limited extent by the product assembler, and does affect the material price the assembler pays. It is not dependent on product assembly location.
11. Currency exchange rate – This is an uncontrollable variable. However, material that is manufactured in China is priced in Yuan. Because of the unvalued nature of this currency, buying this material in the United States with US dollars is cheaper than buying it in China with the Yuan. This result is a net advantage for the product assembler in a high labor rate region like the U.S. buying material from China.
12. Trade policy / Corporate tax rates – The duties and tariff policy between importing and exporting countries and the taxes imposed on earnings. These costs are uncontrollable because they are government imposed.

Minimizing the controllable material management costs listed above is a critical success factor in assuring the competitiveness and profitability of a product assembly operation. Some of the elements required to establish a good material management strategy are:

1. The ability of the suppliers to provide the material in a just-in-time fashion. Maximizing inventory turns.
2. For EMS providers, relatively stable customer delivery schedules. For OPDs, a relatively accurate market forecast.
3. Minimal indirect labor (Manufacturing management cost variables 2, 3 and 4).
4. Statistically capable and in-control assembly processes – low yield loss.
5. A proactive process control strategy that identifies, in real time, processes that begin to vary in a non-random way. This will help avoid the all too common policy of including rework as part of the labor standard estimate.

Clearly, properly addressing these variables is more critical in high labor rate environments. However, except for variables 2, 3 and 4, the influence of these 12 variables on the total manufacturing management cost has little to do with the location of the assembly. And, organizational rethinking can mitigate the labor rate effect on variables 2, 3 and 4 [7].

During the product assembly quoting process, some of the controllable material management costs, such as variables 1 through 6, can be added as a small percentage of the BOM cost. The degree to which this can be done is largely a function of what the customer will tolerate. Those material management costs that are not embedded in the material cost, are added to the non-product-specific labor and facility overhead cost and become part of the loaded labor rate.

This brings us to the final element of material cost, the cost of the material itself, raw "M."

PROCURING THE MATERIAL

Electronic product assembly companies are generally classified in tiers based on annual manufacturing sales activity (USD) [8]:

Tier 1: greater than $2.0 billion
Tier 2: between $500 million and $2.0 billion
Tier 3: greater than $100 million and less than $500 million
Tier 4: greater than $30 million and less than $100 million
Tier 5: less than $30 million

Companies in Tiers 1, 2 or 3 may have manufacturing operations in both high and low labor rate regions. This can provide material purchasing leverage (See paragraph below: *The Big Guy Versus The Little Guy*). Regardless of the product assembly locality there are four principal categories of sources for purchasing electronic material:

1. Direct from the Original Device Manufacturer (ODM) – Purchasing directly from the component manufacturer should result in the lowest material pricing. Usually an electronic product assembler must offer the component manufacturer an annual business opportunity in the $5-10 million USD range. This type of purchasing power is generally only possible for Tier 1 and 2 assembly companies.
2. Component distributors – Distributors provide the most common source of electronic components for lower volume product assemblers who don't have the purchasing power to buy directly from the ODM. There are two basic types of distributers:
   a. Franchised – These companies are contracted by ODMs to distribute their components.
   b. Independent (Brokers) – These companies have no formal contracts with ODMs. They buy and sell components on the open market.

As part of a supply chain, distributors can add significant value by providing the logistical advantage of *one-stop shopping* to fulfill a product assembler's BOM, as well as the opportunity to approach or achieve just-in-time component deliveries. This service can reduce the cost of inventory and purchasing for a product assembler, but increases the purchased material cost since the distributor must load his price from the ODM to absorb these additional costs.

3. Component catalog distributors – This source is used primarily for prototype and low volume assembly applications, as well as short lead-time situations.
4. Third party after-market sellers – These are companies that buy up excess inventory, discontinued stock and other after-market material. The *reward* for the product assembler is that the material is generally offered at a discounted price, or it may be the only source of discontinued components. The *risk* is in the material's *gray market* nature (counterfeit potential) and the material's history as it affects the component's quality (e.g., solderability).

Material Cost for the Electronic Product Assembler: A Case Study

In 2006, an OPM (OEM) in the United States who had been manufacturing all of their own products decided to test the offshore manufacturing waters with a new product they had just designed. They first took their BOM for the new product and had the material quoted stateside: The circuit board components from a local distributor, the circuit board and mechanical parts from sources they had often used in the past. The initial quantity quoted was enough material to build 3000 units. The total costed BOM came to $7.44 per unit. They sent the same BOM and a set of product assembly drawings to a contract manufacturer in China for pricing. The quote received was $7.30 – for the completely assembled and tested product! There was nothing the OPM had to do but ship the completed product to their customers. In addition, the associated material management costs that would have incurred by the OPM if they built the product themselves were eliminated.

No matter what the material/labor cost split was for the product, no reduction in labor rate would reconcile the total assembled price difference. A significant portion of the assembly price disparity between the two quotes *had* to be in an inflated cost of the stateside quoted BOM. This fact suggests that an investigation in material pricing as a function of assembly location is in order.

Establishing The Cost Models: Sources of Material Manufacturing Cost Data

The most significant challenge in trying to reconcile any global electronic material cost disparity between low and high labor rate assembly regions is unearthing the material manufacturer and distributor cost data. It is a difference in the cost of doing business that is often used as the explanation for the difference in price for the same material.

Unlike relative labor cost data that are widely available through government and other labor tracking sources, cost structures for material manufacturing companies and their distributors are very difficult to obtain. The competitive reasons for this are obvious. Many sources were contacted to acquire cost data for this paper. Those that contributed did so only with the understanding that everything they said was off the record. And the *data* provided were anecdotal, since there were no sources that could be referenced. Therefore, a different strategy was needed to establish a detailed relative cost data set that could be analyzed. The financial disclosure data that public companies are required to file provide an oblique way to back into a model. It is these data combined with the off the record information that supplied the pieces to this puzzle.

Material Manufacturing Versus Product Assembly: Cost and Location

The same market forces that affect the product assembly industry drive the material manufacturer. However, there is a significant distinction. Electronic product assembly can fall back on manual labor for their standard and rework processes much more frequently than electronic component manufacturing, for example:

- SOT 23 transistors can be hand placed on a circuit board, but you can't *hand place* the thin film transistors on a silicon wafer.
- It is much easier to manually touchup a SOIC solder joint that connects it to a circuit board, than to manually rework the solder-bumped or wire bonded connection between a component's silicon die and lead frame.

This means that the degree of automation at the component level must be at least as high as that at the circuit board level. Typically it is much higher. Direct labor *content* on a manufacturing process basis is always smaller when manufacturing electronic components than when assembling a circuit board, regardless of location. This tends to lessen the effect of a location's labor rate. It also means that because the workforce skill level must be higher to manage the required automation, it has taken longer for component manufacturing to gravitate to low labor rate areas. However, it also means that once the skills are available and the shift in location has taken place, expenses such as facility costs weigh more heavily and favor the lower cost environments.

When an assembled circuit board fails in-circuit test it usually will be troubleshot, reworked and retested. Why? Because the value of the material (components and circuit board) and value-added labor applied up to this point in the assembly offset the rework costs. Or worse, the quantity of product that must be shipped requires this board. If neither of these is true, the board should be scrapped to cut losses. Whether the inability to develop a capable process that can be kept in control is caused by lack of skill, lack of proactive process control, or an inherently poor board design, the same production mentality often occurs: *We need to ship 1000. The kit size needs to be 1300*.

When a silicon wafer is probe tested, the dice that fail are marked and discarded. No rework. Of course, the probe test results are statistically treated in the spirit of continuous wafer fab process improvement.

In other words, a significant level of statistical yield loss in wafer fab is accepted. Assuming the circuit board design is robust from an assembly point of view, a small statistical yield loss due to random defects is acceptable (<0.5%). However, larger ICT yield losses caused by manufacturing process defects are not. It's a matter of what is controllable in the respective wafer fab and circuit board assembly environments.

The shift of electronic component manufacturing to low labor rate areas, mirroring the shift in product assembly, seems to make sense logistically – to provide the material close to the point of its assembly. But, the decision to move solely because of the labor rate differential is belied by the same reasoning that challenges the decision to move the assembly [9].

THE MATERIAL MANUFACTURING COST MODEL

If the material pricing to product assemblers is dependent on the assembler's location, either:

1. the ODM is charging their distributors more in high labor rate regions, or
2. the distributor is marking up the material more in high labor rate regions, or
3. some combination of 1 and 2.

The Material Manufacturing Cost Model: The ODM

If the product assembler has enough purchasing power to buy directly from the material manufacturer, the pricing received should be independent of the assembler's location, regardless of the ODM's cost model. The only cost variables related to product assembly location that could have a cost impact on raw "M" are:

1. Shipping
2. Currency exchange rate
3. Trade policy.

What follows is a brief analysis of each ODM cost variable:

1. Shipping – Any adverse shipping cost differential between the material manufacturer and the location of the high volume product assembler is negligible. For example, just divide the difference in shipping cost by the number of SOIC-8 components (2500 on a 330mm diameter reel), or the number of 0402 components (10,000 on a 178mm diameter reel) and the increase is normally less than a few percent of the component cost. Whatever the difference in shipping, this increased cost will be reduced or offset by the difference in cost to ship the finished product to the assembler's primary consumer markets – in many cases, high labor rate markets.
2. Currency Exchange Rate – If the components are being manufactured in China (or, any country with an undervalued currency), a product assembler buying those components with a currency valued correctly will, effectively, be buying at a discount when compared to an assembler operating in the same country where the components are being manufactured.
3. Trade Policy – Wide variation exists in international trade policies. They are dependent on the countries or the trading blocks that are conducting the trade. For example, it is very difficult for any other country to sell electronic products into the Brazilian market. This is because of the tariff policy applied to importing finished products. Product assembly companies (both OPMs and EMS providers) who have wanted to sell into this market have had to establish a product assembly capability in Brazil.

Therefore, the product assembler in a high labor rate market should pay no significant premium for material if buying directly from the ODM.

The Material Manufacturing Cost Model: The Distributor

The only justified reason for a material cost difference based on a product assembler's location would be because a distributor's indirect or overhead costs are more in high labor rate regions.

Using a composite of Security and Exchange Commission (SEC) financial filing data for a number of component distributors with multiple global locations, the following generalized cost model can be developed:

<u>Distributor Location Average</u> (USD/year)
Sales = $50 million
Gross Profit = $4.65 million
Net Profit = $0.50 million
Indirect and Overhead Costs = $4.15 million

The average facility indirect and overhead cost as a percent of sales = $4.15M/$50M = 8.3%

Assume the following difference in indirect and overhead cost as a percent of sales/year:

High labor rate region = 12% ($6 million)
Low labor rate region = 4% ($2 million)
i.e., $4 million (200%) more per year to do business in high labor rate regions.

Using this model, a BOM that is priced by distributors at $100 in a high labor rate location would be priced at $92 by distributors in a low labor rate region.

The Material Manufacturing Cost Model: Summary
The analysis suggests if buying directly from the ODM the product assembler in a high labor rate market should pay no significant premium for material.

Conservatively speaking, the analysis indicates about an 8% increase to buy components from a distributor in a high labor rate area is justified because of a higher indirect and overhead cost base. While not an insignificant amount, 8% is certainly not the 20 to 50% or even higher premiums reported by certain product assemblers since the exodus of both material and product manufacturing from the U.S. began.

The Big Guy Versus the Little Guy
There is one other consideration when discussing the material cost disparity – the size and the geographic mix of the product assembler's locations. To provide flexibility and to maximize competitiveness, many large product assemblers have established a global presence – assembly operations in both high and low labor rate regions. In addition, many of these large OPMs and EMS providers have established a central or corporate group to buy material for all their assembly facilities. This, along with the volume purchasing power they offer, provide significant pricing leverage with material distributors. It often gives them the ability to receive low labor rate distributor pricing for their high labor rate assembly locations. The smaller, lower volume assemblers in only high labor rate regions are at a disadvantage – they are bound to the distributor pricing in that region.

Material Other Than Electronic Components
The material discussed to this point has been associated with the electronic functioning of the product. But the mechanical parts used for the *box build* or *higher level assembly* must be considered as another principal category of material for electronic products. These parts are unique to the specific product. They consist of custom machined parts, castings, molded parts and standard hardware. For these parts, the non-recurring labor the supplier needs to develop the tooling – an injection mold, for example – is strongly tied to labor rate. It is significant, giving the low labor rate source an advantage. However, if the production quantities of the finished product are high, this cost advantage is reduced as the savings are amortized over a large number – similar to the shipping cost discussion.

CONCLUSIONS
Market economies depend on the freedom to contract, a free price system and the principle of supply and demand for their vitality. This means that companies have the right to do business and set prices without the interference of government. Without interference, as Adam Smith said, the *invisible hand* of the free market would naturally establish the price of goods and services [10]. So, it should be clear that material manufacturers and their distributors have the right to charge whatever prices they want. The check and balance against this pricing is competition and the customer.

The rapid change in manufacturing locations brought about by access to the global marketplace has caused pricing *tradition*, *expectation* and *willingness to pay* in the high labor rate regions to be additional price setting factors for material manufacturers and distributors.

Over time, the effect of this perturbation has dampened out and the market's invisible hand has once again begun to be the predominant force in establishing material pricing.

Is there a non-cost-justified, inflated material price paid by product assemblers in high labor rate manufacturing regions? Anecdotal information and case studies indicate there is. However, it also appears the disparity in material pricing between these high and low labor rate locations has declined significantly over the last ten years as the pricing policy continues to migrate toward free market principles.

Where does all of this leave the product assembler in high labor rate environments? Attention must be paid! Material pricing challenges must be made. The following questions must be asked:

1. Do low labor rate assemblers receive material pricing favoritism that is *not* related exclusively to component manufacturers and distributors lower indirect and overhead cost bases?
2. Why do material manufacturers charge *more* for the same components when the product assembler or franchised distributor is in a high labor rate environment whether selling to a distributor or directly to the product assembler?
3. Do the distributors in high labor rate regions mark up the material more than their 8% higher operating costs?
4. Is 8% an accurate number? If not, what is the increased cost of doing business in high labor rate environments, and how should this cost be reflected in material pricing?

Caveat emptor!

APPENDIX I
United Nations Statistics Division for International Standard Industrial Classification (ISIC Rev. 4), Section C: Manufacturing
ISIC Rev.4 code C [11]

Hierarchy
- **Section: C – Manufacturing**

Breakdown:
This Section is divided into the following Divisions:
10 - Manufacture of food products
11 - Manufacture of beverages
12 - Manufacture of tobacco products
13 - Manufacture of textiles
14 - Manufacture of wearing apparel
15 - Manufacture of leather and related products

16 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17 - Manufacture of paper and paper products
18 - Printing and reproduction of recorded media
19 - Manufacture of coke and refined petroleum products
20 - Manufacture of chemicals and chemical products
21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations
22 - Manufacture of rubber and plastics products
23 - Manufacture of other non-metallic mineral products
24 - Manufacture of basic metals
25 - Manufacture of fabricated metal products, except machinery and equipment
26 - Manufacture of computer, electronic and optical products
27 - Manufacture of electrical equipment
28 - Manufacture of machinery and equipment n.e.c.
29 - Manufacture of motor vehicles, trailers and semi-trailers
30 - Manufacture of other transport equipment
31 - Manufacture of furniture
32 - Other manufacturing
33 - Repair and installation of machinery and equipment

Explanatory note

This section includes the physical or chemical transformation of materials, substances, or components into new products, although this cannot be used as the single universal criterion for defining manufacturing (see remark on processing of waste below). The materials, substances, or components transformed are raw materials that are products of agriculture, forestry, fishing, mining or quarrying as well as products of other manufacturing activities. Substantial alteration, renovation or reconstruction of goods is generally considered to be manufacturing.

Units engaged in manufacturing are often described as plants, factories or mills and characteristically use power-driven machines and materials-handling equipment. However, units that transform materials or substances into new products by hand or in the worker's home and those engaged in selling to the general public of products made on the same premises from which they are sold, such as bakeries and custom tailors, are also included in this section. Manufacturing units may process materials or may contract with other units to process their materials for them. Both types of units are included in manufacturing.

The output of a manufacturing process may be finished in the sense that it is ready for utilization or consumption, or it may be semi-finished in the sense that it is to become an input for further manufacturing. For example, the output of alumina refining is the input used in the primary production of aluminium; primary aluminium is the input to aluminium wire drawing; and aluminium wire is the input for the manufacture of fabricated wire products.

Manufacture of specialized components and parts of, and accessories and attachments to, machinery and equipment is, as a general rule, classified in the same class as the manufacture of the machinery and equipment for which the parts and accessories are intended. Manufacture of unspecialized components and parts of machinery and equipment, e.g. engines, pistons, electric motors, electrical assemblies, valves, gears, roller bearings, is classified in the appropriate class of manufacturing, without regard to the machinery and equipment in which these items may be included. However, making specialized components and accessories by moulding or extruding plastics materials is included in class 2220.

Assembly of the component parts of manufactured products is considered manufacturing. This includes the assembly of manufactured products from either self-produced or purchased components.

The recovery of waste, i.e. the processing of waste into secondary raw materials is classified in class 3830 (Materials recovery). While this may involve physical or chemical transformations, this is not considered to be a part of manufacturing. The primary purpose of these activities is considered to be the treatment or processing of waste and they are therefore classified in Section E (Water supply; sewerage, waste management and remediation activities). However, the manufacture of new final products (as opposed to secondary raw materials) is classified in manufacturing, even if these processes use waste as an input. For example, the production of silver from film waste is considered to be a manufacturing process.

Specialized maintenance and repair of industrial, commercial and similar machinery and equipment is, in general, classified in division 33 (Repair, maintenance and installation of machinery and equipment). However, the repair of computers and personal and household goods is classified in division 95 (Repair of computers and personal and household goods), while the repair of motor vehicles is classified in division 45 (Wholesale and retail trade and repair of motor vehicles and motorcycles).

The installation of machinery and equipment, when carried out as a specialized activity, is classified in 3320.

Remark: The boundaries of manufacturing and the other sectors of the classification system can be somewhat blurry. As a general rule, the activities in the manufacturing section involve the transformation of materials into new products. Their output is a new product. However, the definition of what constitutes a new product can be somewhat subjective. As clarification, the following activities are considered manufacturing in ISIC:
- milk pasteurizing and bottling (see 1050)
- fresh fish processing (oyster shucking, fish filleting), not done on a fishing boat (see 1020)
- printing and related activities (see 1811, 1812)
- ready-mixed concrete production (see 2395)
- leather converting (see 1511)
- wood preserving (see 1610)

- electroplating, plating, metal heat treating, and polishing (see 2592)
- rebuilding or remanufacturing of machinery (e.g. automobile engines, see 2910)
- tire retreading (see 2211)

Conversely, there are activities that, although sometimes involving transformation processes, are classified in other sections of ISIC; in other words, they are not classified as manufacturing. They include:
- logging, classified in section A (Agriculture, forestry and fishing);
- beneficiating of agricultural products, classified in section A (Agriculture, forestry and fishing);
- beneficiating of ores and other minerals, classified in section B (Mining and quarrying);
- construction of structures and fabricating operations performed at the site of construction, classified in section F (Construction);
- activities of breaking bulk and redistribution in smaller lots, including packaging, repackaging or bottling of products, such as liquors or chemicals; sorting of scrap; mixing of paints to customers' order; and cutting of metals to customers' order, producing a modified version of the same product, are classified to section G (Wholesale and retail trade; repair of motor vehicles and motorcycles).

APPENDIX II [12]

United Nations Statistics Division: International Standard Industrial Classification (ISIC Rev. 4),

- Section C: Manufacturing
- Division: 26 - Manufacture of computer, electronic and optical products
- Group: 261 - Manufacture of electronic components and boards
- Class: 2610 - Manufacture of electronic components and boards

Explanatory note

This class includes the manufacture of semiconductors and other components for electronic applications.

This class includes:
- manufacture of capacitors, electronic
- manufacture of resistors, electronic
- manufacture of microprocessors
- manufacture of bare printed circuit boards
- manufacture of electron tubes
- manufacture of electronic connectors
- manufacture of integrated circuits (analog, digital or hybrid)
- manufacture of diodes, transistors and related discrete devices
- manufacture of inductors (e.g. chokes, coils, transformers), electronic component type
- manufacture of electronic crystals and crystal assemblies
- manufacture of solenoids, switches and transducers for electronic applications
- manufacture of dice or wafers, semiconductor, finished or semi-finished
- manufacture of interface cards (e.g. sound, video, controllers, network, modems)
- manufacture of display components (plasma, polymer, LCD)
- manufacture of light emitting diodes (LED)
- loading of components onto printed circuit boards

This class also includes:
- manufacture of printer cables, monitor cables, USB cables, connectors etc.

This class excludes:
- printing of smart cards, see 1811
- manufacture of modems (carrier equipment), see 2630
- manufacture of computer and television displays, see 2620, 2640
- manufacture of X-ray tubes and similar irradiation devices, see 2660
- manufacture of optical equipment and instruments, see 2670
- manufacture of similar devices for electrical applications, see division 27
- manufacture of lighting ballasts, see 2710
- manufacture of electrical relays, see 2710
- manufacture of electrical wiring devices, see 2733
- manufacture of complete equipment is classified elsewhere based on complete equipment classification

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