A NEW MANUFACTURING MODEL FOR SUCCESSFULLY COMPETING IN HIGH LABOR RATE MARKETS

HOW TO MINIMIZE LABOR AND MATERIAL, THE CONTROLLABLE CONTRIBUTIONS TO A HIGH-TECH ELECTRONIC PRODUCT'S COST, AND ASSESS A MANUFACTURING REGION'S BUSINESS CLIMATE

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ABSTRACT

This paper presents the results of a study that challenges a widely accepted tenet of industry "wisdom." Specifically, the axiomatic claim that to be most competitive in the global high-tech electronic product marketplace, the assembly of the product must be done in the lowest available labor rate environment. This "given" is thought to be especially certain for high volume applications.

A new assembly high labor rate model is developed on the basis of the key cost variables, **LMNOP**: (**L**)abor, (**M**)aterial, and **NOP** (**N**)ational (**O**)ut-bordering (**P**)redisposition).

The paper demonstrates that for **L**:

1. The ratio of the labor cost to the total product cost can be made relatively small through the development of high yield, automated assembly processes, coupled with severely reduced non-value added costs (e.g., indirect labor, overhead, G & A, ICT, rework, et al.).
2. When labor content is minimized, the effect on total cost by even a large manufacturing labor rate disparity approaches zero. Labor rate difference in many applications is shown to be a distraction, a red herring of sorts, cloaking the true root causes of non-competitiveness and masking an understanding of the total competitive landscape.
3. To achieve this level of labor cost reduction, certain conditions must be present and several long-standing paradigms must be challenged, replacing them with principles arrived at through common sense and out-of-the-box thinking. These are:
   - The counterintuitive recognition that for automated, high-tech electronic product assembly it is more costly to hire low wage equipment operators than it is to hire multi-functional engineer/operators.
   - Achieving true yield rates of 99.6% through the development of statistically capable processes, and the control of these processes by employing proactive techniques, rather than using traditional reactive strategies.
   - Utilizing continuous flow manufacturing (CFM) for ALL production applications. This means work-in-process (WIP) is minimized by pulling, not pushing, the product through the factory, and balancing product flow by knowing takt times for all process steps.
   - Designing products using the Principles of **DF MATERS** (**D**)esign (**F**)or (**M**)anufacturing, (**A**)utomation, (**T**)est, (**E**)nvironment, (**R**)eliability and (**S**)erviceability)
   - Having a multi-skilled workforce that has been taught manufacturing skills in the real world must be available. The long-term vehicle for developing this leading edge, world class workforce is a system of education that can fertilize, incubate and hatch this talent, allowing the graduate to hit the ground running.
4. The traditional hierarchical organizational model with its pyramid of people into groups, groups into sections, sections into departments, and collections of departments under a director, must be totally dismantled. Just two groups replace it: a. self-managed product teams, and b. a leadership group

This paper demonstrates that for **M**:

1. Material cost includes raw and material management.
2. Since material cost is by far the greatest contributor to total product cost, minimizing labor cost without addressing material cost is like buying a car at a low price without an engine – you've saved money, but you will not be going very far.
3. Without publicizing it, material manufacturers and their distributors have been fairly and unfairly pegging component pricing to the regions where the components are being assembled. This is not an issue for multi-national corporations with global buying power, but becomes a heavy competitive burden for Tier 3, 4 and 5 companies that only purchase and assemble components in high labor rate regions.
4. A low maintenance, highly reliable material planning and management system must be part of the enterprise resource planning infrastructure.

Finally, the paper documents the results of an **NOP** analysis: the tendency of the business climate created by a country to cause a company to either manufacture or seek manufacturing outside of its borders. The conclusion is that the largely uncontrollable business climate where the manufacturing is conducted has a significant influence on cost and competition. Tax rates, cost of money, exchange rates, currency stability, regulations and other factors are addressed. The paper concludes with a discussion on the effect these factors have in typical risk/reward, cost/benefit studies by those whose capital is put at risk.

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INTRODUCTION

The TOTAL cost of producing a high-tech electronic product is what makes an assembly operation competitive or not. Chasing low labor rates around the world has been the sport of manufacturing mavens from high labor rate markets since Henry Ford developed his division of labor assembly model and production line workers' wages slowly increased. [1] "Labor, Labor, Labor, how can we compete with $--- per hour labor." (note: fill in the $ yourself). That drum beat has continued to be heard in the United States from New England starting in the 18th century, to the South, to the deep South, to Japan, to the Caribbean, to Mexico, to China, and on to Vietnam in the 21st century. For both Original Product Developers (OPD) who build the products they design themselves, and Electronic Manufacturing Service (EMS) providers who build OPD products on a contract basis, comparative models trying to characterize the relative cost of electronic product assembly should include ALL costs.

There are only two reasons to out-border production:

1. Your desire to sell your product into that country or nearby markets – Brazil is a good example, but not for shipping and other logistics reasons, but for national trade policy reasons – more on this in the NOP discussion.
2. You cannot compete on cost with a low labor rate country. Why are you unable to compete – is it L, M, NOP or some combination of all of these?

Today's manufacturing experts say that high volume product assembly applications will never return to high labor rate regions because of the labor rate issue. They say product assembly in these areas will be limited to low volume and prototype quantities. But what production requirement results in higher labor costs on a per unit basis – building one hundred or one million of a product? The economies of scale, amortizing set-up, non-recurring engineering and tooling labor costs should make building large numbers cost less. High volume production in high labor rate markets should be more competitive than low volume production. [2]

The Whole is Equal to the Sum of the Parts

All the contributors to the cost of producing an electronic product can be classified by putting them into three buckets: LMNOP (Labor, Material, and National Out-Bordering Predisposition). This paper identifies and analyzes each of these cost contributors in their respective buckets.

ANATOMY OF THE COST OF A HIGH TECH ELECTRONIC PRODUCT

Manufacturing companies producing electronic products are usually ranked in tiers according to sales volume. One such ranking is as follows (in USD):

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 [3]

Table 1 presents the cost structure for a very successful consumer electronic product. The OPD responsible for the product design out-borders all product assembly labor to a Tier 1 EMS, as opposed to doing the assembly internally. Some of the source material data presented in Table 1 have been reassigned into the categories used in this paper.

Table 1. Electronic Tablet Cost Breakdown, Source: Kenneth Kraemer, University of California, Irvine

Retail Price:	$499 (100%)
Costs to the OPD	
Bucket 1 (L)	
EMS Labor EMS):	$33 (6.6%)
OPD General, Selling & Administration	$75 (15.0%)
Bucket 2 (M)	
Material: Raw $154 (30.9%) + Material Markup $87 (17.4%) =	$241(48.4%)
Total Costs to the OPD:	$349 (70%)
OPD Net Profit before Taxes (EBIT)	$150 (30%)

What about cost bucket 3: NOP (National Out-Bordering Predisposition)? The costs associated with this variable are baked into the EMS labor rate and OPD overhead. An OPD in-border outsourcing often results in a lower overhead to absorb but requires buying EMS labor at a much higher rate. In 2008, using the most current data available, the spread in the fully burdened (including profit) electronic assembly EMS hourly labor sell rates between the high ($50.43) and low labor rate ($6.00) markets was a striking $43.57 per hour. [4]

One appropriate question is how much of this spread results from a raw hourly labor rate difference versus differences between fixed and variable overhead burdening in these low and high manufacturing labor rate regions? It is just these fixed overhead costs that in part form a nation's out-bordering predisposition (NOP).

Another important question in the in-border versus out-border decision-making process is whether there are other controllable ways to close the fully burdened labor cost disparity between high and low cost labor regions. Finally, what is the best value proposition for an OPD: building their own products or employing an EMS?

30% NET MARGIN: AN OPD VERSUS AN EMS AND IN-BORDERING VERSUS OUT-BORDERING

The previous section documents the cost structure for a real-world electronic product. In this case, the product's sell price minus its cost results in a net profit of 30%. This incredible return plays a significant role in making the OPD the most valuable company in the world.

An OPD sells a product, and an EMS sells a service. For both an OPD and an EMS, competition drives price, not production cost. Part of the OPDs value is its intellectual property (IP) estate. In the EMS world there is little IP. An OPD can use its IP to separate itself from its competition. It can typically demand higher margins based on a more valuable IP position. This IP can translate into features that the consumer is willing to pay more for. An EMS does not have this leverage. Consequently, EMS companies generally operate at much lower margins than OPD companies. Like the low margins associated with food pricing in the retail supermarket business, they need high sales volume to compensate and make a reasonable return. Actual EMS margins, therefore, are established almost exclusively by cost. Costs incurred by an EMS are determined by:

1. How well they choose their OPD customers. EMS companies are constrained by the automated equipment capacity they own. If they fill that capacity with marginally profitable business they have nothing else to sell. Examples of *high cost* customers are those whose products are poorly designed, or are difficult and expensive to deal with.
2. Assembly yields, efficiencies, i.e., performance to standard cost, and equipment utilizations.
3. How well they manage material.
4. Payroll and direct labor overhead.
5. Whether they are "board stuffers" or full service providers

Because of fierce competition an EMS company is generally working on thin, booked business margins. There is not much operational room between a positive financial outcome and metaphorically wrapping a $5 bill around each unit you ship – the more product you ship the more money you lose – perhaps it is better to have the equipment lay idle. That is, unless things are so bad that shipping product at a loss at least contributes to some payroll and overhead absorption. This situation typically does not last long as this *death spiral* generally leads to a predictable bad terminal outcome.

There are exceptions to the customary EMS paper-thin margins. For example, an EMS company that specializes in providing leading edge assembly technologies and regulated product assembly can achieve higher margins (e.g., medical, military). Another area of margin expansion opportunity is being able to excel in a challenging scheduling and product mix environment. Dealing with low volume / high mix products and customers who change their ship schedule frequently are examples.

The OPD for the product in Table 1 is realizing a net profit of 30%. The EMS assembling the product may net 2-3%. All things being equal, there is no inherent process advantage for an OPD assembling a product they have designed, or contracting the assembly to an EMS. The process and the equipment are the same. The capital equipment depreciation and many of the other product assembly costs that are deferred by an OPD when out-sourcing to an EMS are paid indirectly since the EMS must imbed these in the burdened labor sell rate. In other words, the 30% net is not because the OPD is using an EMS for its product assembly. However, there is one category of overhead cost that may not be a dollar for dollar transfer for EMS to OPD. This is the NOP (National Out-bordering Predisposition). If any raw high and low labor compensation cost disparity can be reconciled (see "An Alternative High Labor Rate Cost Model" below), the cost of doing manufacturing in the OPD home country may be adversely burdened by government policy (e.g., taxes, regulation, ability to borrow money, etc.), this will dissuade production and encourage OPD out-bordering (and, ironically EMS out-bordering). Finally, there are several additional factors, that should be considered in the OPD outsourcing value proposition.

<u>Pro OPD outsource</u>:

1. An ODP may use an EMS to mitigate some risk:
   - Equipment is not at risk of sitting idle.
   - Material and labor cost adders based on poor product design and forecast weakness are reduced to the extent the liability for these items are not stipulated in the contract with the EMS.
   - An ODP controls its production schedule.

<u>Anti-OPD outsourcing</u>:

1. An EMS adds an additional layer of cost markup to the price of an OPD product.
2. Additional OPD costs associated with managing the EMS.
3. An OPD using an EMS stretches their supply chain, adding to the risk of supply and product fulfillment interruption.

THE COMPETITIVE LANDSCAPE

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, as a percentage of a country's total GDP, manufacturing in China ranked 2nd in the world (Table 2).

Table 2. World Change from 1975 to 2004 between a High and Low Labor Rate Country as a Function of Value-added Manufacturing as a Percentage of Total GDP [5]

	1975	2004
U.S.	16	73
China	30	2

In this table, *Manufacturing* refers to industries belonging to ISIC Section C and made up of manufacturing divisions 15-37. [6] *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.

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 as represented in Table 2 by China and the United States, 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).*

With progressively more and better assembly automation available, the other shift in high labor rate regions has been in a consistently decreasing labor contribution to total product cost – at least on paper. This has been a coping tactic used to combat the out-boarding low labor rate mania. Is the increased level of automation being fully exploited by high labor rate countries? This question is answered in the section of this paper entitled, *An Alternate High Labor Rate Model.*

If everything else is assumed equal between two companies, how does the material content of a product affect today's competitive landscape between high and low labor rate regions? The answer seems obvious. The cost of purchasing the material to build equal quantities of the product should be the same wherever the product is assembled – same material, same quantity, same cost. The shipping cost differential for large material quantities is negligible. However, the cost of managing the material, an overhead cost, is weakly influenced by the cost of the labor hours needed for this task. The material question is an important one because the material cost dominates the total product cost. But is the cost of material the same notwithstanding the location of product assembly? This question is answered in the section of this paper entitled *Procuring the Material*.

With the opening of the global marketplace, *competition* has come to mean primarily competition between nations. However, the individual states in the United States also compete with each other. Each state has the incentive to create the most attractive manufacturing business climate to lure and persuade OPD and EMS assembly operations to put down stakes within their boarders. This was a key component to what the founders called federalism: The concept that states that were free to compete with each other and were effectively independent laboratories to try out new ideas and policies. The states that create a less expensive business environment promoted manufacturing and were more successful. The techniques that work in one state could be copied by another state – the ones that do not work could be ignored. This concept has been replaced to a large extent by National government policy that equally burdens all states by imposing additional layers of regulation. State and local policies are still differentiators between the individual states, but not when competing with another country that may have much lower national regulation costs. National policy trumps state policy and cannot be defied by an individual state. This is part of the NOP (National Out-boarding Predisposition) and will be discussed in detail in the final section of the paper.

ELECTRONIC PRODUCT COST: A GENERAL VIEW

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 dictates 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 MATERS). [7]
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 material cost as a percentage of total cost falls for a specific circuit board assembly within the 75-95% range.

As stated earlier, 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 be affected by 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 were 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 – but it is not. The question then becomes: Why? In the section of this paper entitled *Procuring the Material,* an attempt is made 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 developed 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, OPD (Original Product Developers), also known as OEM (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 material section 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. Figure 1 shows how from an accounting perspective, value is added to the purchased material along the assembly process, the corresponding costs are credited and debited into and out of accounting centers, and used to absorb labor and overhead costs based on performance to standard costs (the basis of the selling price of the product to the customer). At the end of the process when the product is either shipped or put in finished goods inventory, the result is either a P (Profit) or L (Loss).

Electronic Product Assembly: Establishing 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

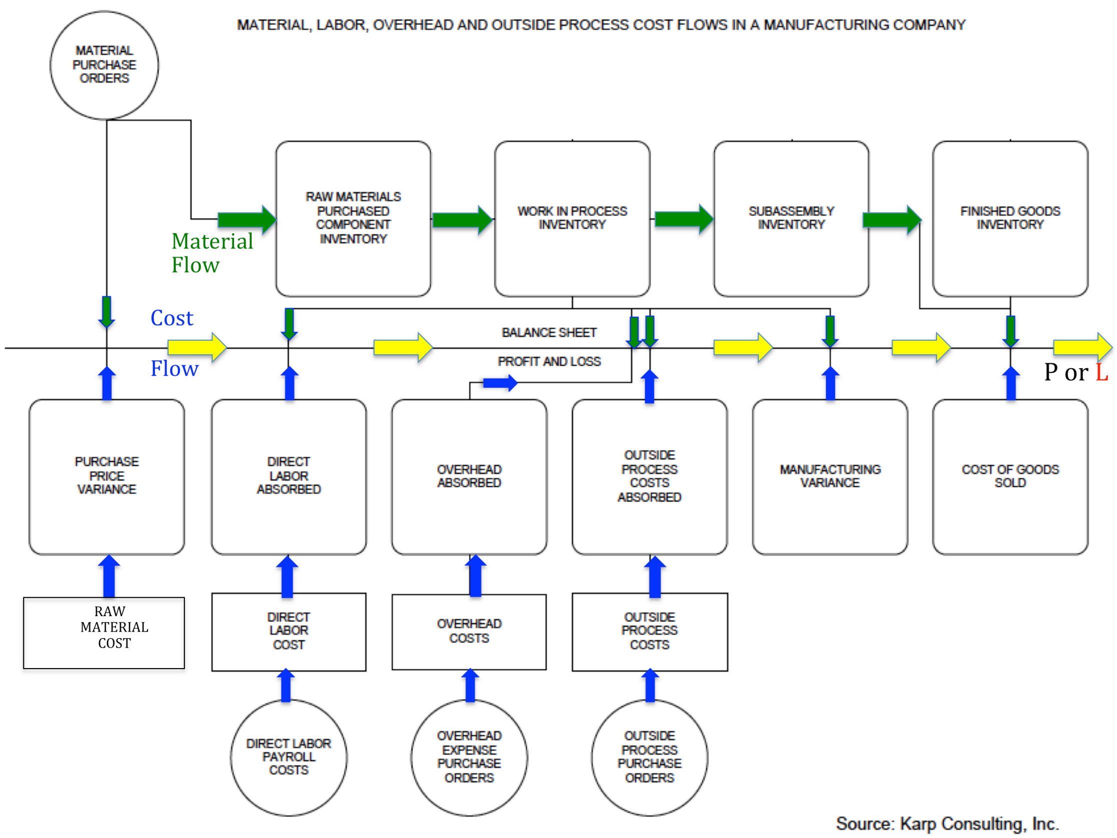


Figure 1. An Accounting Cost Flow From the Purchase of Material to the Sale of the Product

to absorb the overhead (including consumable material such as solder), indirect and other non-product related labor costs, i.e., non-direct costs. Also loaded as a percentage of labor cost are the SG&A (Selling, General & Admin) costs. This labor loading is needed to pay for non-project related management, marketing, sales and other non-product related costs that are required to operate the business. Finally, the loaded labor cost is marked up with profit to establish the labor sell price. Over a year, *selling* enough loaded labor hours, by virtue of 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 – 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, hand solder personnel, 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)

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

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

- 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 50 direct labor people who make an average of $20 / hr. Therefore, the yearly direct labor cost is $2M (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 hours of direct labor (H_{RLT}). What should be charged for labor (C_{PL}) to assemble the product?

To calculate the labor rate:

$$R_L = (C_{DLT} + C_{ILT}) / H_{RLT} \qquad \text{(Eq. 7)}$$
$$C_{DLT} = 50 \times 2000 \text{ hr} \times \$20 \text{ per hr} = \$2.0\text{M}$$
$$C_{ILT} = \$2.5\text{M}$$
$$H_{RLT} = 100{,}000 \text{ hrs}$$
$$R_L = (2\text{M} + 2.5\text{M}) / 100{,}000 = \mathbf{\$45 / hr}$$

For a product that will require 0.5 hr per unit,
The labor cost for the product is:

$$C_{PL} = H_{RL} \times R_L \qquad \text{(Eq. 2)}$$
$$C_{PL} = 0.5 \text{ hr} \times \$45 \text{ per hr.} = \mathbf{\$22.50}$$

The non-product-specific cost absorbed in the total product cost:

$$C_{IL} = C_{ILT} \times (H_{RL} / H_{RLT}) \qquad \text{(Eq. 6)}$$
$$C_{IL} = 2.5\text{M} \times (0.5 / 100{,}000) = \mathbf{\$12.50}$$

The direct labor part of the total product cost is:

$$C_{DL} = C_{DLT} \times (H_{RL} / H_{RLT}) \qquad \text{(Eq. 5)}$$
$$C_{DL} = \$1\text{M} \times (0.5 / 50{,}000) = \mathbf{\$10.00}$$

✔

Checking the result:

$$C_{PL} = C_{DL} + C_{IL} \qquad \text{(Eq.1)}$$
$$C_{PL} = \$10.00 + \$12.50 = \mathbf{\$22.50}$$

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, \$12.50 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, 200,000 units 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. [8] 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. [9] That is, if the other larger part of the product cost is not dependent on where the assembly takes place.

Electronic Product Assembly: Establishing 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., 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 by the distributor to the component price 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" between the standard cost the product assembler's quote to the customer is based on, and the actual purchased price of the material.
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.

Establishing a price point for a product

There are three basic factors that influence the price point an OPD will set for a product:

1. What the OPD's targeted customer base is willing to pay (the higher the price, the lower the demand).
2. The cost of the product (based on a desired margin: the higher the cost, the higher the price).
3. Price of competing products

Item 2 is determined by the contents of cost bucket 1: (L), the labor, and cost bucket 2: (M), the material.

ELECTRONIC PRODUCT COST: THE MODELS

Generalized Labor Cost Model

It is difficult to develop a series of models that everyone can agree with. At best, we have to blend industry and government data. These data are themselves averages of different regions, industry sectors and assembly work that is done: either by an OPD - a company that designs and manufactures their product, or, an EMS provider - a contract assembler who builds products for OPDs. For example, the model for the automotive electronic assembly sector may be more heavily burdened with employee benefits if the assembly is being done by the OPD rather than at an EMS. Also, relative currency fluctuations and other NOP-related policies can play a significant role in assembly cost.

Table 3 provides some historical labor rate and trend data for China. Technically, the labor cost of a product does not include profit or fee. Adding the overhead costs that need to be absorbed, plus profit, to the raw material and labor of a product results in the selling price. For the purposes of this analysis, however, profit will be considered part of the overhead and loaded accordingly. Another way of saying this is that the models will result in the labor sell price. In addition, in China, the cost of labor is strongly influenced by whether the assembly is being done in urban areas or by TVEs (town and village enterprises).

Table 3. China Manufacturing Hourly Rates, 2002-04 [10]

Year	Basis (Yuan)	Basis (U.S. $)	Index (U.S. = 100)
2002	4.73	0.57	3
2003	5.17	0.62	3
2004	5.50	0.66	3

In 2012, data provided by the Chinese government updated the year-to-year change in electronic assembler compensation in China through 2008. These data are included in Table 4. In 2004 the hourly compensation (wages plus benefits - note: not the fully burdened labor sell rate) to an electronic product assembler in China was the equivalent of $0.66 USD. In 2008 this compensation rate almost double to $1.36 (about a 25% per year increase). The prediction is that this trend of global catch-up will continue. China is projected to experience compensation cost increases averaging 13.6% per year for the foreseeable future. [11]

Table 5 presents similar data for India, another low labor rate region. In India, the compensation rate rose from the equivalent of $0.85 USD in 2004 to $1.17 in 2007 (about a 13% per year increase). [12]

In the United States, a high labor rate region, the average hourly compensation (not the fully burdened labor sell

Table 4. Hourly compensation costs in manufacturing for China, in U.S. dollars, 2003-2008

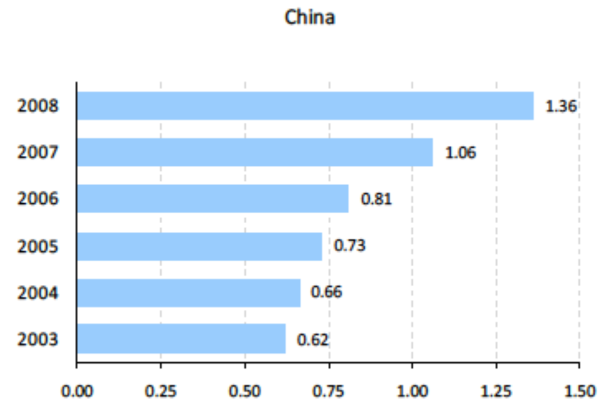
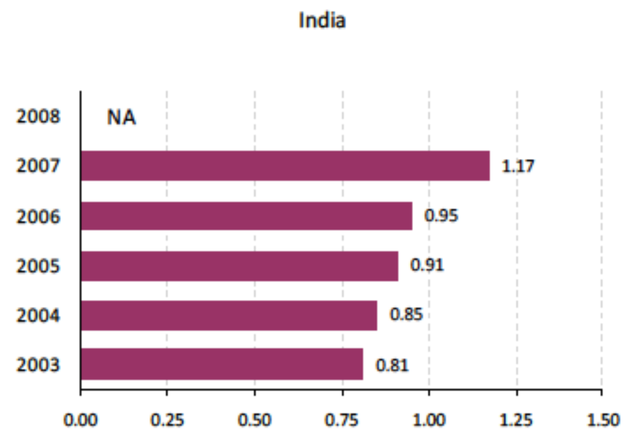


Table 5. Hourly compensation costs in manufacturing for India, in U.S. dollars, 2003-2008



rate) for electronic production and nonsupervisory employees went from $23.05 in 1997 to $34.74 in 2010 (about a 9% per year increase) [Table 6]. In 2007, the average US hourly compensation was $26.63 and the fully burdened labor sell rate was $50.43 [13]. In 2012, the average compensation rate for electronic production and nonsupervisory employees with a 32% benefit load was $23.58 x 1.32 = $31.13/hr., a drop of 1.8% from 2010. [14]

A better employment category to compare a high labor rate region with a low labor region is the region's mean earnings (wages) for electrical and electronic equipment assemblers. This is the category for most of the direct labor. In 2011 these earnings were $15.17/hr [15] in the United States. Applying a 32% benefit rate to these earnings results in a compensation rate of $20.02/hr. This is a good estimate of the direct labor before overhead burdening and will be employed in the high labor rate model that follows.

Table 6. **Hourly compensation costs in manufacturing, U.S. dollars, and as a percent of costs in the United States [16]**

	Hourly Compensation Costs			
	in U.S. dollars		U.S.=100	
	1997(1)	2010	1997(1)	2010
Norway	26.38	57.53	114	166
Switzerland	30.00	53.20	130	153
Belgium	29.12	50.70	126	146
Denmark	24.09	45.48	105	131
Sweden	24.97	43.81	108	126
Germany	29.15	43.76	126	126
Finland	22.35	42.30	97	122
Austria	25.52	41.07	111	118
Netherlands	23.40	40.92	102	118
Australia	19.10	40.60	83	117
France	24.88	40.55	108	117
Ireland	17.03	36.30	74	104
Canada	18.84	35.67	82	103
United States	**23.05**	**34.74**	**100**	**100**
Italy	19.67	33.41	85	96
Japan	22.28	31.99	97	92
United Kingdom	18.50	29.44	80	85
Spain	13.92	26.60	60	77
Greece	11.56	22.19	50	64
New Zealand	12.37	20.57	54	59
Israel	12.32	20.12	53	58
Singapore	12.15	19.10	53	55
Korea, Republic of	9.36	16.62	41	48
Argentina	7.43	12.66	32	36
Portugal	6.38	11.72	28	34
Czech Republic	3.24	11.50	14	33
Slovakia	2.86	10.72	12	31
Brazil	7.07	10.08	31	29
Estonia	NA	9.47	NA	27
Hungary	3.05	8.40	13	24
Taiwan	7.04	8.36	31	24
Poland	3.13	8.01	14	23
Mexico	3.47	6.23	15	18
Philippines	1.28	1.90	6	5

NA=data not available.
(1) With the exception of Estonia, 1997 is the first year data for all countries are available to BLS.

TOTAL L

The "labor rate" or "compensation cost" for a region of the world is the manufacturing statistic that is primarily publicized by the media. It is usually given as the reason a region either attracts or repels manufacturing activity. It is clearly part of the total L, but by no means all of it. All other non-product specific material related indirect and overhead costs must be absorbed into the compensation cost to result in the fully burdened labor rate. If profit or fee is included in the loading, the result is a fully burdened labor sell price in $ / labor hour. Total labor cost is driven by four factors:

1. Direct assembly labor rate: compensation cost ($/hr.)
2. Labor content (hr)
3. Overhead Absorption: including costs imposed by the government where the production is taking place or NOP costs (% of direct labor $/hr)
4. Labor management: efficiency and yield (%)

Direct Labor

Product assembly including functional test is a value-added enterprise. The direct labor used to assemble and test a product clearly adds value to the OPD or the EMS customer. The cost of this part of the labor is a function of the direct assembly labor rate and is driven by the region of the world where the assembly is being done. However, Factors 2, 3 and 4 are largely controllable. Not only is direct labor the value-added part of the total labor cost, it is necessary because it is the basis for absorbing indirect and overhead labor costs (Factor 3). These costs are often of questionable value. Without direct labor, who pays for the management of an assembly operation? Certainly not the customer.

COST BUCKET 1: L (LABOR)

There are several ways to account for cost, e.g., activity based costing and labor-loaded costing. The point is that regardless of the system that is used, all the costs must be included, resulting in Total L. For this exercise, a labor loading system will be used. The same hypothetical circuit board is costed in both the high and low labor rate companies. Two generalized labor cost models that represent the existing low and high assembly labor environments will establish the gap between the models, define the elements that contribute to the gap, and provide visibility to which elements, if any, are controllable.

The Existing High Direct Labor Rate Model

Assumptions (in USD):

1. Wage (earnings): $15.17/hr [17]
2. Benefits are 32% of wages (earnings or raw labor rate: $4.85/hr)
3. Employee Compensation (Earnings + Benefits) for U.S. manufacturing: $20.02/hr
4. Overhead rate for full labor burdening is 250% of wages (earnings or raw labor rate)
5. Benefit cost is included in overhead rate
6. All indirect labor is included in overhead rate
7. Overhead includes SG&A (sales, general and administrative costs – generally, a percentage of labor and material)
8. Overhead includes material handling, inspection and attrition (usually loaded as a percentage of the raw material cost)
9. Profit or fee is included in overhead rate to result in a fully burdened labor selling price
10. Assumptions 3 through 8 produce a fully burdened labor selling rate of $37.93/hr
11. Fixed overhead (facility/equipment) is 4% of fully burdened labor
12. Variable overhead (increases with increased product volumes) is 56% of fully burdened labor and includes all indirect labor
13. Touchup labor cost is $5.00/solder joint
14. In-Circuit Test (ICT) yield loss labor costs are $25.00/ board to troubleshoot, rework and retest
15. Functional test yield loss labor costs to troubleshoot, rework and retest are $50.00/board

Indirect Labor and Overhead Absorption

Some of the other non-direct labor that is typically included in the indirect labor costs and need to be absorbed into the fully burdened labor sell price include:

- Personnel to load bills of material into ERP/MRP
- A procurement department to get quotes and order material
- Industrial engineers who quote labor
- A master scheduler and planners who plan and release work orders to production
- Material handlers (in-shipping, material inspectors, pack and ship)
- Inventory and stock room personnel
- Production planners who release work orders
- Process engineers who develop assembly process and write methods sheets
- Kitting people who pull and kit material for released work orders
- People who deliver the kits to the appropriate equipment and work stations
- People who set up the stencil printers
- Set-up people who load material on component placement equipment
- In-process inspectors
- Technicians who troubleshoot the automated equipment process when it is producing defects
- People who perform maintenance on the production equipment
- Supervisors and managers for procurement, production, process engineering, test engineering, and quality assurance
- Human resources
- Factory safety officer
- Office and manufacturing cleaning personnel
- IT people to maintain and upgrade computer equipment

For each of these indirect labor employees described above, besides salaries and hourly wages, the following costs and benefits for each employee must be absorbed in the fully loaded labor selling rate:

- Medical insurance
- Unemployment compensation tax
- Worker compensation insurance
- Social Security tax
- Medicare taxes
- Holiday pay
- Vacation pay and O.T. premium
- Sick pay
- Pension or retirement plan contributions
- Training costs

Fixed overhead includes:

- Building costs
- Utilities: Power, natural gas, water, and sewer for the operation
- Computer and communication systems for the facility
- Spare parts for the operations and facilities
- Depreciation on the assembly equipment and facilities
- Insurance and property taxes on the assembly equipment and facilities
- Safety and environmental costs

Applying these high labor rate assumptions to a business model for a hypothetical Tier 2 circuit board assembly operation (in USD):

- Sales/year = $1B
- The circuit boards have a 75% to 25% raw material-to-fully burdened labor ratio cost mix
- Of the 25% fully burdened labor cost, 50% is machine-based labor, 50% is hand-based labor

- Raw material cost/year = $750M

- Total burdened labor cost/year = $250M
- Total unburdened (raw) labor cost/year = $100M
- Total absorbed overhead cost/year = $150M

- Average board price **$100**
- Number of boards/year 10M

- Material $/board = $75
- Labor $/board = $10
- Overhead $/board = $15
- Fully burdened labor rate = $37.93/hr
- Raw direct labor (compensation) rate = $15.17/hr
-
- Total absorbed overhead (includes material related labor and attrition costs, SG&A and profit) = $22.76/hr
- Standard labor hr/board = $10 per board/$15.17 hr = 0.6592 labor hr/board

- Fully Burdened Labor Price/board = $37.93/hr x 0.6592 hr = $25/board

The Existing Low Labor Rate Model
2012 Employee Compensation Rates for Manufacturing in China: Average in USD: $1.67/hr [18]

Compensation is defined as whatever is paid to or for the workers in money or in kind according to relevant regulations, including:

- Wages
- Bonuses
- Free Medical Services
- Medicine
- Transport subsidies
- Social insurance
- Housing fund

With the weakening of the dollar, the willingness of the Chinese government to float their currency, and the continued upward labor cost pressure in urban centers, we will use an employee compensation rate of $4.00/hr. USD.

Assumptions: (in USD)

1. Employee Compensation (Earnings + Benefits) for China manufacturing: $1.67. As stated above, this analysis will use an employee compensation rate of $4.00.
2. Overhead rate of 300% will be used for full labor burdening and "reality" factor considerations.
3. Since it is difficult to know what part of the $4.00 compensation rate is raw labor and what part benefits, the entire compensation rate will be burdened with the 300% overhead rate
4. Overhead rate includes SG&A (sales, general and administrative costs – generally, a percentage of labor and material)
5. Overhead rate includes material handling, inspection and attrition (usually loaded as a percentage of the raw material cost)
6. Profit or fee is included in overhead rate to result in a fully burdened labor sell price
7. Assumptions 1 through 5 produce a fully burdened labor sell rate of US $12.00 / hr.
8. Average touchup labor costs $0.10 per solder joint

These assumptions are now applied to the same general business model used for the high labor rate circuit board assembly operation:

- The standard labor hour usage per board is 2 times greater than in the high labor rate cost model because of the availability of inexpensive labor versus the cost needed to develop, control and maintain an automated process capability =
  2 x 0.6592 = 1.3184 hr/board

- Unburdened labor rate = $4.00/hr
- Fully burdened labor rate = $12.00/hr
- Unburdened labor cost/bd =
  1.3184 hr x $4.00/hr = $5.27/board
- Fully burdened labor price/board =
  1.3184 hr x 12.00/hr = $15.82/board

- Overhead absorbed/board = $10.55/board

- Average board price = $75 + $15.82 = $**90.82**/board
- Number of boards assembled/year = 11.0M
- Sales / year = $1B
- Total raw material/year = $826M
- Total burdened labor cost/yr = $174M

OBSERVATIONS ON THE EXISTING MODELS

The result of this modeling is that a $100 circuit board assembled and tested in a high labor rate environment sells for $90.82 if it is made in a low labor rate environment. To demonstrate the viability of a high labor rate region successfully competing with a low labor rate region it is necessary to show that the resulting $9.18/board gap in price can be overcome.

Examining the cost elements of the two current models, the following observations are made:

1. The labor selling rate gap between the two models permits the low labor rate companies to *throw* a lot more labor at the assembly. In this low labor rate model, higher skilled (and cost) labor that can develop capable and controllable assembly processes may or may not be available. Whether they are or not, an alternate strategy is to merely address in-process quality issues with labor-intensive, post-automation rework touch labor.
2. When faced with low yields in a high labor rate environment, the high cost of troubleshooting, reworking and retesting assembly defects (and scrapping material) can be a significant factor in the inability to compete. The low labor rate competition may simply mask this root cause of the failure to compete.
3. Of the elements that contribute to the labor cost in the high labor cost model, the largest controllable elements are direct raw labor cost and indirect labor absorption cost.

4. Soft considerations such as the logistics challenges of assembling products in remote locations, the cost of doing business (increased travel costs and time), measuring and analyzing performance in real time and the cost of changes to products are difficult to quantify, but are real.

AN ALTERNATE HIGH LABOR RATE COST MODEL

Can we develop an alternate high labor rate model that closes the cost gap between the current high and low labor cost models (about a 37% labor cost reduction using the low labor rate model for our hypothetical board)? The industry today answers emphatically: No! But, before accepting this conclusion an attempt to drill down into the two primary cost differentiators is in order: the difference in the raw labor and the difference in overhead rates.

Those who have been working in a high labor cost electronic product assembly environment have been working at cross-purposes. On one hand, they have embraced an assembly technology that continues to get more and more complex. This complexity is a function of three factors that have emerged primarily as a result of the evolution in electronic component design and packaging (Figure 2). These are:

1. Advances in robotics and other forms of machine automation.
2. An increased complexity in the assembly process.
3. The requirement to understand the physics involved in the process. When we were exclusively hand soldering, the terms *thixotropic*, *rheology* and even *hydroscopic* were terms rarely heard around the workbench.

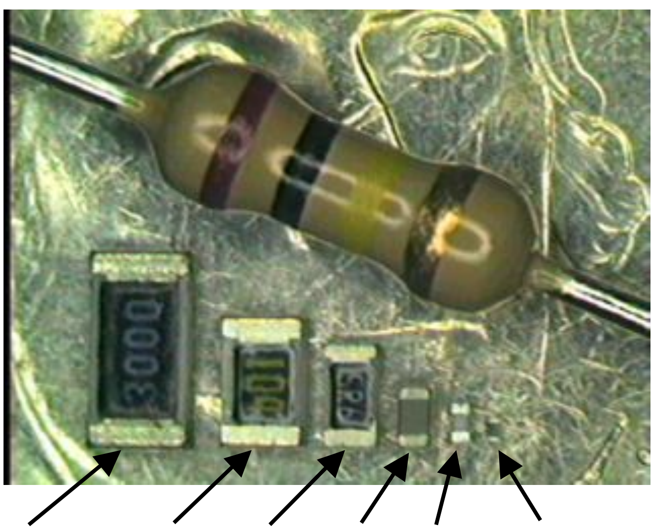


Figure 2. Passive SMT Component Family & Their Patriarch: The Axial-leaded Resistor (All on a Jefferson Nickel)

With these requirements comes the need to develop a statistically capable process for the automation. A process window must be developed that is wide enough to contain the natural variation that will occur over time in the process variables. To do this successfully for automation, the physics that underlies the process and the equipment that conducts the process must be well understood. Hand inserting and hand soldering the two leads of an axial leaded resistor to a circuit board might take 30 seconds of labor. Having a high speed robot place an SMT resistor in solder paste that was printed by machine, and then melt the solder in a reflow oven, might take 0.1 seconds when processed with the rest of the components on the circuit board – and the raw labor cost for this operation, if the board is handled by machine and travels on automated conveyors, is $0.00! This is only true if the resistor was soldered correctly. If not, and the solder joints need to touched up or the wrong value resistor was soldered to the board, the labor rework cost, especially in a high labor rate location, will add up rapidly. These defects have a much lower cost impact if the rework is done in a low labor rate operation. Therefore, in high labor rate regions process capability and control is paramount. A C_{pk} of 1.33 minimum is required (4 sigma, 63 ppm defect rate).

Ironically, this added complexity has been addressed by a relentless management quest to find less expensive, low skilled labor to deal with the low labor rate competition! Some of that inexpensive labor is needed to accommodate a circuit board design that can't be fully automated. But, unfortunately, even for the part of the design that can be automated, the advanced skill sets required to create capable and controllable assembly processes are either not available, or management is unwilling to pay for them. The result in many cases is increased cost for touch-up, rework and material scrap. "Keep looking for that low cost direct labor. We have no choice! Build! Build! Build! Rework! Rework! Rework! Ship! Ship! Ship! Ah, we met our monthly sales goals, maybe by wrapping a $5 bill around each board that was shipped!" In this case, the goal should be to ship LESS next month since the more boards shipped, the more money is lost. A company in this mode of operation becomes trapped in a death spiral. They will either go under, be sold or go offshore. Do you think the consolidation that we have seen over the last 10 years, companies gobbling up other companies – is a result of good fiscal performance? In most cases, it's a quick way to affect the bottom line. Add someone else's puny net profit to our puny net profit and survive another year.

Increase profit by reducing cost? How about having the direct labor pay the company to work here? Both have about the same chance with the existing management team hard at work steering this ship. The way they see it: "It's that cheap labor we have to compete against. Let's move offshore or get sold." What if we take a deep breath, take a step back and consider a new labor strategy.

The new strategy has three basic elements:

1. *Transformation of the direct labor workforce.*

U.S. industry has a history of assembling products in geographic areas whose labor costs can successfully meet competitive pressures. It is interesting to note that in most cases this happens only when a particular industry is threatened by the competition's lower prices. For example, shoemaking and textile industries thrived in New England in the 19th and early 20th centuries. Prices rose. Organized labor put further pressure on cost. Manufacturing continued. Southern U.S. companies and foreign factories began to produce products for lower costs because of the availability of cheap hourly labor. Automation reduced labor content, volume production increased and costs decreased, but the industries were still basically labor intensive. It was then that textile and shoe manufacturing left New England and moved to the South – then, they moved to the Deep South, then the Caribbean, then Mexico, then South America, then the Pacific Rim, China and Vietnam.

Cars and electronics followed. Again, improvements in automation slowed the transition, but still the drumbeat continued, *reacting* to the low labor rates that the competition acquired access to – not *anticipating* them. "It's time to move manufacturing again." This process was, and continues to be, repeated over and over even though the capability and quality of the automation in some industries provides the opportunity to reduce the theoretical labor content to a very small percentage of the total product cost. When this happens, the labor rate plays a relatively small competitive role. This is certainly true of most electronic circuit boards – but we don't exploit the automation fully. Why? The answer is: it's harder than looking for cheap sources of labor, we don't have the time, we don't have skills and we certainly don't have the vision and courage. No one ever says this, of course.

Notice also that the companies that are most successful in high labor cost regions seem to be small operations with flat organizations (*lean*, we like to say these days). This creates the perception that high labor cost operations are good at competing on low volume and prototype work, but the industry experts maintain, "Sorry, with those labor rates we need to go offshore for the high volume stuff."

The Low Volume / High Volume Paradox

In *Paper or Plastic? Choosing to Move Offshore* [19] a challenge is made to the logic of those who have relegated all future high volume manufacturing to low labor rate geographic regions. "…Finally, think about this – the 'experts' say, 'Future volume manufacturing will all be done 'over there' - we just can't compete in high volume manufacturing.' Oh, really? I thought high volume manufacturing requires LESS labor per assembly, not more, since NRE, fixture cost, set-up time etc. is spread over a large number. Since we pay more for domestic labor (for example, in a high labor rate region like the U.S.), we should be able to compete more effectively when building products domestically with less labor dollars per assembly. If we automate and just let the line run, doesn't the offshore *low cost* labor advantage asymptotically go to zero?"

The unspoken little secret is that for high labor rate cost environments, the higher the volume, the greater the impact poor yields have on their ability to compete. The answer to the paradox is that the higher the volume, the more defects there are that need touch up and rework – and it costs high labor rate operations a lot more for rework because of its labor intensity.

Figure 3 illustrates the two basic paths to reduce raw (unloaded) labor costs:

1. Reduce the hourly labor rate applied to the unit labor hours. ($/hr.)
2. Reduce the unit labor hour content. (hr.)

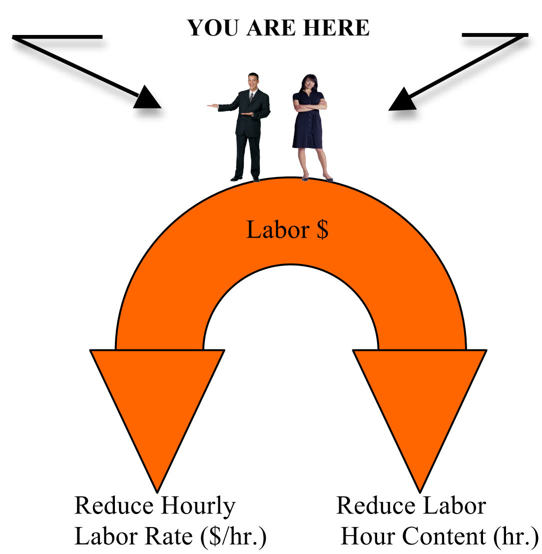


Figure 3. Two Paths to Reduce Labor Cost

Traditionally, we have tried to compete (reduce labor cost), primarily by taking the left path.

Do We Sell In-Circuit Test or Products?

In-circuit test (ICT) adds no value to the customer. The customer wants a product or circuit board that does what the product or board performance spec. says it should do. This is usually determined by a functional test. Why, then, do we do ICT? Unfortunately, it is usually used as a way to separate the good boards from the bad boards we build. In other words, we use ICT as a coping strategy to deal with an assembly process that is not capable or in control, or both.

If ICT yield rates above 99% can be achieved, the cost to do the test does not pay back; i.e., finding one defective board for every 100 that are built. Without the need to do ICT, the need to do post ICT troubleshooting, rework and retest is eliminated.

2. *A corporate model that focuses on the assembly of the customers' products and not on technical disciplines or departments within the organization.*

We have evolved into an industry of indirect labor specialists. We have a corporate structure that puts each of us into our own silo. Our particular silo (department) tells us what specific role we will play in the company's operation.
This is consistent with the division of labor and assembly line product flow of the early electronic assembly factory floor. Operator Number One inserted components R6, C12, U4, U16, and Operator Number Two inserts R1, R5, C6, U2 and so on, as downstream operators continued the process until the board was complete. In a similar way, a marketing person generates a product specification. From the specification, the electrical engineer designs the circuit, creating a schematic, and passes it on to the CAD person who lays out the board. The CAD person passes the design package to an industrial engineer who methodizes the design for production. The bill of material goes to someone in the procurement department to order the bare board and components. The design package goes to the electrical test department to have in-circuit and functional test developed, etc. Each department is like an island or a community with its own identity – success being measured by how well they do their specific jobs. The customers do not buy specific jobs – they buy products.

This organizational fiefdom promotes department focus and competition, many times at the expense of the customers' products. This structure is very expensive with much of the indirect labor adding questionable value.

Instead of trying to cope with these issues as we have a history of doing, the new model dismantles the traditional hierarchical structure. Just two groups replace all departments. The new multi-skilled, engineering-based direct labor is organized into self-managed customer product teams. A small leadership group serves as an enabling function, providing the product teams with the skill sets and tools they need for success. This permits a dramatic reduction (20%) in overhead cost because of a combination of the reduction of indirect labor, and the aforementioned significant increase in yield.

3. *Creating an educational environment that serves the needs of the new model.*
This type of fundamental change described above does not come easily. It is a daunting task to reduce labor cost sufficiently to compete with labor rates in the order of a few dollars per hour by taking the right path in Figure 3 (reducing labor hour content). A prerequisite is having a labor force that meets the demands of the new model. The current academic community is incapable of providing this workforce. Educating in one community (academia) and sending the educated to work in another community (the real world) has created an ever-increasing gap between academic preparation and industry need. High tech electronic product assembly simply changes too quickly to have its needs provided in an environment where it can take 2 – 3 years to get a curriculum changed. We need to create a *teaching hospital* of sorts for the high tech electronic assembly industry. A learning community should be established that wraps a school around a for-profit contract manufacturing facility, where students can be taught in a real-world environment for the full tenure of their post-secondary education [20].

The High Labor Rate Cost Model Revisited
Assumptions (in USD):

1. Median Raw labor wage (Project Engineer with BS in Engineering: 10-19 years experience): \$39.05/hr [21]
2. Benefits are 32% of raw labor: \$12.50/hr
3. Employee Compensation (Earnings + Benefits) for U.S. Project Engineer: \$51.55/hr
4. Overhead rate for full labor burdening is 200% of raw labor
5. All indirect labor is included in overhead rate
6. Overhead rate includes SG&A (sales, general and administrative costs – generally, a percentage of labor and material)
7. Overhead rate includes material handling, inspection and attrition (usually loaded as a percentage of the raw material cost)
8. Profit or fee is included in overhead rate to result in a fully burdened labor selling price
9. Assumptions 3 through 8 produce a labor selling rate of \$78.10/hr
10. Fixed overhead (facility/equipment) is 4% of fully burdened labor
11. Variable (controllable) overhead is 26.1% of fully burdened labor and includes all indirect labor
12. Touchup labor costs \$5.00 per solder joint
13. In-Circuit Test (ICT) yield loss labor costs \$25.00 per board to troubleshoot, rework and retest
14. Functional Test yield loss labor costs \$75.00 per board to troubleshoot, rework and retest

Applying these assumptions to the same Tier 2 high labor cost circuit board assembly operation business model (in USD):

- Sales/year = \$1B

- The circuit boards have a 75% reduction in direct labor hours from the original high labor model because of:
  1. Full exploitation of automation (boards designed for automation)
  2. The near elimination of touchup and rework: Assembly yields of 99.5% - only 1 board in 200 requires touchup or rework – statistically capable processes are developed and kept in control by proactively monitoring process parameters in real time
  3. high functional test yields eliminating the value of In-Circuit Test

- Overhead rate is reduced 20% by organizational restructuring
- Fully burdened labor rate = \$78.10/hr
- Raw direct labor rate = \$39.05/hr

- Total Absorbed Overhead (includes material related labor and attrition costs, SG&A and profit) = \$39.05/hr
- Average Labor hr/board = 0.6592 x 0.25 = 0.1648 labor hr/board

- Material \$/board = \$75
- Unburdened Labor \$/board = \$6.44
- Overhead \$/board = \$6.44

- Average board price = \$75 + \$6.44 + \$6.44 = **\$87.88**

The revised high labor rate model replaces the large, low rate labor force with a small, high rate group of mostly engineers who are multi-skilled and self-managed. This results in an increase in average labor compensation rate (from \$20.02/hr to \$51.55/hr), but reduces overall labor cost by reducing labor content, including the elimination of in-circuit test as part of the assembly process. The cost components for the three labor rate models are summarized in Table 7.

Table 7. Labor Rate Model Comparison (USD)

Model	Material Cost per Board	Direct Labor Cost/Bd	Absorbed Overhead Cost/Bd	Circuit Board Price
High Labor	75.00	10.00	15.00	100.00
Low Labor	75.00	5.27	10.55	90.82
Revised High Labor	75.00	6.44	6.44	87.88

L – SUMMARY OF RESULTS

This exercise has demonstrated that even a large disparity in labor compensation rates between high and low labor rate regions can be neutralized. This is possible because of the ability to reduce labor content by exploiting the available automation and achieving a significant reduction in yield loss with the corresponding labor costs reductions involved in troubleshooting, rework and retest. The yield improvements are a result of a small, multi–skilled workforce that has been educated in a real world production environment. The product team that is comprised of this world-class workforce understands process capability and has the skill sets to develop robust assembly processes that contain process variation well within the upper and lower process spec limits. They have a solid foundation in the physics of soldering, are fluent in material science and understand circuit theory. This permits rapid root cause failure analysis. They understand statistics and the theory of variation, as well as team dynamics. Their collective output is greater than the sum of their parts. An operational infrastructure is in place that among other things permits real time measurement and proactive process control. This labor content reduction is accompanied by a significant reduction in overhead costs. It is accomplished by breaking free of the traditional manufacturing corporate model. Quantitatively, in many applications these improvements create the ability to reduce the labor content by 75% and reduce the non-direct labor overhead burden by 20%. However, in some particular applications it may not be possible to reduce the labor content by 75%. For example, a circuit board may have many large, analog devices that require hand insertion, or the design requires discrete wiring (e.g., coax) be hand soldered, or the higher level, box build assembly requires significant hand labor. In these cases, reduced potential for reducing labor content in the product must be offset by further reductions in overhead. The 37% reduction in labor cost using the low labor rate model can be neutralized in a high labor rate environment for many product applications. If labor were the only cost factor involved in the *high* versus *low* labor rate competition the analysis would be complete. Unfortunately, it is not.

COST BUCKET 2: M (MATERIAL) INTRODUCTION

A revised high labor rate model has been established to demonstrate that, for many electronic product assembly applications, low labor rate competition can be neutralized through automation, organizational rethinking and changing how we educate our workforce. 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 hierarchical organizational structure and replacing it with one that best serves building products in an automated environment.

Attention is now given to analyze the second assembly cost consideration in competitive electronic product manufacturing – material cost. The conclusion is 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 will be addressed in detail in the final section of this paper on NOP: National Out-bordering Predisposition. Finally, it is recommended 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.

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

The product assembler can control some of the material management cost variables. Others cannot be controlled. 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 ODM (Original Device Manufacturer) 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:

a. The ability of the suppliers to provide the material in a just-in-time fashion. Maximizing inventory turns.
b. For EMS providers, relatively stable customer delivery schedules. For OPDs, a relatively accurate market forecast.
c. Minimal indirect labor (Manufacturing management cost variables 2, 3 and 4).
d. Statistically capable and in-control assembly processes – low yield loss.
e. 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 [22].

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

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 distributors:
   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 OPD 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 been 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. [23]

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. Items 2 and 3 are part of the manufacturing business environment a country establishes. It is discussed in the final section of this paper entitled, *Cost Bucket 3: NOP (National Out-Bordering Predisposition*).

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.

M – SUMMARY OF RESULTS
Market economies depend on the freedom to contract, a free pricing 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. [24] 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 begun once again 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?

The elements of the two controllable cost buckets, labor and material, as they affect assembling products in high and low labor rate regions have now been analyzed. The final section of this paper addresses how the degree of friendliness (or, animosity) a region presents to business in general, and manufacturing specifically, affects high tech product assembly cost.

COST BUCKET 3: NOP
(NATIONAL OUT-BOARDERING PREDISPOSITION)

There are several national conditions that must exist to create a climate for an electronic product manufacturing business to compete on a national basis successfully:

1. Good access to capital: Bank policy
2. A reliable supply chain
3. A trained workforce
4. A reliable source of utilities
5. A competitive regulatory environment
6. Competitive corporate tax laws

The degree to which a country or state excels at creating a positive environment that includes these attributes is a good predictor of whether manufacturing will thrive or wither.

These conditions are grouped under the banner NOP (National Out-Bordering Predisposition): the tendency of the business climate created by a country to cause a company to either manufacture or seek manufacturing outside of its borders. It represents the least controllable of the three assembly cost buckets this papers addresses.

An OPD or EMS that builds high tech electronic products normally does not consciously seek out the country that provides the least government and financial burden. However, since national policies in areas such as regulation, taxation and access to capital, affect the cost of doing business wherever the production takes place, the NOP costs are embedded in the total overhead cost and, hence the product cost or service.

Small companies usually confine manufacturing and sales to the country in which they reside. However, if they are located within countries like the United States, Switzerland or China the potential exists for an intra-border variety economic climate. In a country like the United States, this variety manifests itself in another level of economic competition that occurs between the states. America's founders called it *federalism*. In Switzerland, the states are called cantons and are relatively autonomous.

Centrally controlled economies such as China have much less opportunity for business competition within their boundaries. Hong Kong is an exception. The central government in Beijing has largely left what historically has been the bastion of free markets and capitalism from the end of the Second World War under English rule through its return to China in 1997 largely unencumbered. (It is called a *special administrative area*, or SAR, within China.) It continues to be a cash-generating dynamo for the country.

The Economic Freedom of the World (EFW) index [25] is a much broader measure of a nation's economic freedom than the six conditions listed above. However, they are proportional, and the six conditions of NOP can be thought to be a subset of the EFW. Both contribute to a healthy manufacturing climate. The higher the EFW index of a country, the less predisposed a company located in that country is to out-border its manufacturing. The EFW index uses 24 metrics that are organized into 5 major categories to rate each country:

1. Size of Government
   a. Government consumption
   b. Transfers and subsidies
   c. Government enterprises and investment
   d. Top marginal tax rate
      - Top marginal income tax rate
      - Top marginal income and payroll tax rate
2. Legal System and Property Rights
   a. Judicial independence
   b. Impartial courts
   c. Protection of property rights
   d. Military interference in rule of law
   e. Integrity of the legal system
   f. Legal enforcement of contracts
   g. Regulatory restrictions on the sale of real property
   h. Reliability of police
   i. Business costs of crime
3. Sound Money
   a. Money growth
   b. Standard deviation of inflation
   c. Inflation: most recent year
   d. Freedom to own foreign currency bank accounts
4. Freedom to Trade Internationally
   a. Tariffs
      - Revenue from trade taxes (% of trade sector)
      - Mean tariff rate
      - Standard deviation of tariff rates
   b. Regulatory trade barriers
      - Non-tariff trade barriers
      - Compliance costs of importing and exporting
   c. Black-market exchange rates
   d. Controls of the movement of capital and people
      - Foreign ownership/investment restrictions
      - Capital controls
      - Freedom of foreigners to visit
5. Regulations
   a. Credit market regulations
      - Ownership of banks
      - Private sector credit
      - Interest rate controls//negative real interest rates
   b. Labor market regulations
      - Hiring regulations and minimum wage
      - Hiring and firing regulations
      - Centralized collective bargaining
      - Hours regulations
      - Mandated cost of worker dismissal
      - Conscription
   c. Business regulations
      - Administrative requirements
      - Bureaucracy costs
      - Starting a business
      - Extra payments/bribes/favoritism
      - Licensing restrictions

What is the current EFW landscape, how has it changed over the last 25-years and do the changes track with global manufacturing activity? Table 8 ranks countries by the

Table 8. 2010 EWF Index Ranking By Country (source: Economic Freedom of the World: 2012 Annual Report) [16]

Hong Kong	1	8.90
Singapore	2	8.69
New Zealand	3	8.36
Switzerland	4	8.24
Australia	5	7.97
Canada	5	7.97
Bahrain	7	7.94
Mauritius	8	7.90
Finland	9	7.88
Chile	10	7.84
United Arab Emirates	11	7.83
Ireland	12	7.75
United Kingdom	12	7.75
Estonia	14	7.74
Taiwan	15	7.72
Denmark	16	7.71
Qatar	17	7.70
United States	18	7.69
Kuwait	19	7.66
Cyprus	20	7.64
Japan	20	7.64
Oman	20	7.64
Jordan	23	7.63
Peru	24	7.61
Malta	25	7.57
Norway	25	7.57
Austria	27	7.56
Lithuania	28	7.54
Montenegro	28	7.54
Sweden	30	7.53
Germany	31	7.52
Luxembourg	32	7.47
Slovak Republic	33	7.45
Spain	34	7.43
Armenia	35	7.42
Romania	36	7.41
Korea, South	37	7.40
Netherlands	37	7.40
Panama	37	7.40
Bahamas	40	7.36
Belgium	41	7.35
Albania	42	7.34
Costa Rica	42	7.34
Georgia	42	7.34
Bulgaria	45	7.33
Rwanda	45	7.33
France	47	7.32
Poland	48	7.31
Zambia	48	7.31
Uganda	50	7.30
Uruguay	51	7.29
Honduras	52	7.24
Israel	52	7.24
Nicaragua	52	7.24
Guatemala	55	7.21
El Salvador	56	7.20
Fiji	56	7.20
Cambodia	58	7.16
Czech Republic	58	7.16
Portugal	60	7.14
Latvia	61	7.12
Philippines	61	7.12
Dominican Republic	63	7.09
Hungary	64	7.08
Iceland	65	7.06
Saudi Arabia	65	7.06
Jamaica	79	6.84
Tunisia	80	6.81
Greece	81	6.78
Paraguay	81	6.78
Italy	83	6.77
Croatia	84	6.76
Moldova	85	6.75
South Africa	85	6.75
Thailand	87	6.70
Belize	88	6.68
Kyrgyz Republic	88	6.68
Malawi	88	6.68
Mexico	91	6.66
Slovenia	92	6.63
Bosnia & Herzegovina	93	6.61
Namibia	94	6.59
Russia	95	6.56
Vietnam	96	6.54
Colombia	97	6.50
Haiti	97	6.50
Egypt	99	6.49
Sri Lanka	100	6.48
Madagascar	101	6.42
Morocco	102	6.41
Serbia	102	6.41
Bolivia	104	6.39
Brazil	105	6.37
Cameroon	106	6.36
China	107	6.35
Tanzania	107	6.35
Bangladesh	109	6.34
Nepal	110	6.33
India	111	6.26
Iran	111	6.26
Pakistan	111	6.26
Guyana	114	6.24
Benin	115	6.18
Azerbaijan	116	6.17
Mali	117	6.12
Burkina Faso	118	6.09
Syria	119	6.08
Nigeria	120	6.07
Sierra Leone	121	5.99
Ukraine	122	5.94
Gabon	123	5.88
Senegal	123	5.88
Lesotho	125	5.81
Ecuador	126	5.80
Argentina	127	5.79
Niger	128	5.78
Côte d'Ivoire	129	5.76
Central African Rep.	130	5.73
Ethiopia	131	5.72
Mauritania	132	5.67
Togo	133	5.59
Burundi	134	5.45
Mozambique	134	5.45
Chad	136	5.41
Algeria	137	5.34
Guinea-Bissau	138	5.23
Congo, Dem. Rep. of	139	5.18
Angola	140	5.12
Congo, Republic of	141	4.86
Zimbabwe	142	4.35
Myanmar	143	4.29
Venezuela	144	4.07

Economic Freedom Index, a compilation of 24 factors in 5 areas that indicate the relative level countries shackle private business development primarily through regulation, monetary policy, trade barriers, and tax rates. As described in the report, the most significant increases in economic freedom have been in former Communist nations that were characterized by centrally controlled economies to economies that are more free market based. This occurred in Europe and Asia in 1990 with the collapse of the Soviet Union, and in formerly Communist countries in Africa over the last 10 years.

Based on the EWF index, since 2000 Venezuela, Argentina, Iceland and the United States have shown the biggest declines in economic freedom [26]. Table 9 compares the changes in the Economic Freedom Index to manufacturing output for several selected countries. In the U.S., the EWF index dropped from 3rd best in 2000 to ranking 18th in 2010. At the same time, the U.S. manufacturing output has continued on a precipitous slide as a percentage of its total GDP. It has declined from being ranked 16th in 1975 to 75th in the world in 2004. The opposite effect was experienced in the former Soviet bloc country of Slovakia. As its EWF index continued to improve from the fall of the Soviet Union in 1989 to its independence as part of the dissolution of Czechoslovakia in 1993, its manufacturing output has improved as well. The Slovakian world ranking for manufacturing GDP as a percentage of total GDP has improved from 77th in 1975 to 30th in 2005.

These examples seem to show a correlation between a country's economic freedom index and manufacturing activity – but is there causation? The data for China belie the causation hypothesis. In China, the meteoric rise in manufacturing ranking from 30th in 1975 to 2nd in 2005 has occurred without any significant change in the EWF index. Logic suggests that the relatively low EWF index is overwhelmed by the manufacturing activity spawned in 1978 when the government began to convert its 1.4 billion-person population from a centrally planed economy to a quasi-market economy. To prove causation would require a statistical analysis that is beyond the scope of this paper.

Table 9. Selected Country Comparisons for Changes in Nominal GDP, EWF and Manufacturing Output (Current USD)

Country	Nominal GDP per Capita / Ranking, 1990 Source: World Bank	Nominal GDP per Capita / Ranking, 2011 Source: World Bank	EWF Index / Ranking. 2000 [28]	EWF Index / Ranking, 2010 [27]	Manufacturing GDP (per $1000 of GDP) / Ranking, 1975 [29]	Manufacturing GDP (per $1000 of GDP) / Ranking, (Year) [29]
United States	23,198 / 10	48,442 / 16	8.65 / 3	7.69 / 18	547.17 / 16	132.32 / 75 (2004)
China	341 / 125	5,445 / 91	5.75 / 101	6.35 / 107	381.23 / 30	334.82 / 2 (2005)
Singapore	12,387 / 27	46,241 / 19	8.61 / 2	8.69 / 2	223.54 / 57	268.21 / 7 (2005)
Venezuela	2,482 / 56	10,810 / 63	5.83 / 82	4.07 / 144	151.54 / 94	171.08 / 39 (2003)
Slovakia	2,527 (1993) / 159	17,646 / 44	6.20 / 83	7.45 / 33	184.47 / 77	187.83 / 30 (2005)
Greece	9,073 / 31	26,427 / 34	6.91 / 45	6.78 / 81	562.23 / 14	99.15 / 102 (2004)

NOP – SUMMARY OF RESULTS

Is the manufacturing robustness of a country influenced by government size, regulation, monetary policy, and availability of capital? Any condition or policy that adds cost to a manufacturing operation must be absorbed in its price structure. Therefore, countries or states that create a climate that is averse to manufacturing produce a competitive disadvantage to manufacturing operations.

Outliers like China suggest that although there is a significant relationship between EWF index and manufacturing activity in a region, it is not a totally predictable indicator.

CONCLUSION

Can an electronic product assembler in a high labor rate market that sells labor for $37.93/hour compete with an assembler selling labor at $12.00/hour? This paper has demonstrated that in many applications it can. However, as this paper also demonstrates, the critical success factors rely on addressing many subjects on many fronts. Exploiting the automation, dismantling the traditional organization, changing the nature of the direct workforce, and challenging material cost are some of the areas requiring action. Over the last ten years, the dramatic increase in manufacturing activity in low labor rate areas has been accompanied by the development of a middle class. This, along with worker unrest and currency inflation, has produced upward pressure on labor rates in these regions as the middle classes develop. Consequently, the cost gap between high and low labor rate regions has narrowed. It will continue to close, but there will be other low labor rate areas to seduce production. Cambodia and Vietnam are the latest countries to attract disciples from the church of the low labor rate. [30] High yield automation is the counterweight to low labor rate manufacturing. However, following the automation route is more difficult than seeking low labor rates, but more prudent. Finally, governments can play a positive role in encouraging manufacturing in high labor rate regions. Reducing NOP, challenging unfair labor and material practices, assisting in the formation of a world class workforce, and developing a high EWF index are all ways in which governments can create a positive manufacturing environment. Things are not always the way they seem. This is certainly the case when making the decision on where to assemble electronic products.

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