Total Cost Model for Making Sourcing Decisions

by

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BASC Mechanical Engineering, University of Waterloo, 2001

Submitted to the MIT Sloan School of Management and the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for Degrees of

Master of Business Administration

and

Master of Science in Mechanical Engineering

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Abstract

This thesis develops a total cost model based on the work done during a six month internship with ABB.

In order to help ABB better focus on low cost country sourcing, a total cost model was developed for sourcing decisions. Because the products that ABB manufactures have a high material cost component, effective sourcing is critical to overall profitability. The model presented in this thesis is loosely based on financial statement projections, and uses that framework to help capture all of the relevant hidden costs. This model does not consider absolute cost, but instead analyzes the change in cash flows over time. The net present value of the future marginal cash flows is calculated to determine if changing suppliers will create value or destroy it.

The incentive issues surrounding supplier selection are discussed. Using this model can help to mitigate some of the incentive issues; however some managers may be incentivized to reject the model.

A case study that analyzes the benefit of sourcing a copper pin from China is presented to illustrate how the model works.

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Chapter 1: Introduction

1.1 Introduction and thesis overview

The model in this thesis was developed for ABB, a large manufacturing company. For the type of products that ABB manufactures, material costs make up a large percentage of the total cost. Focusing on low cost country sourcing is therefore of strategic importance to them. Because of the hidden costs, switching to a low cost supplier can sometimes end up costing more. This thesis presents a total cost model which helps in making supplier selection decisions. The model roughly categorizes costs into accounting based categories, and calculates the net present value of supplier change decisions.

This chapter describes company background, previous sourcing practices, and why a total cost model is needed. Chapter 2 reviews the other types of models that have been used in the past to make supplier selections. Chapter 3 describes the considerations made during the development phase of the model, such as ABB’s requirements, the development methodology, and the incentives issues. Chapter 4 discusses the issues with measuring costs, such as cost timing, marginal vs absolute costs, sunk costs, and the independence of different costs. Chapter 5 describes the main input variables used in the model. Chapter 6 presents a case study where the model was used to estimate the savings for switching the supplier of copper pins. Chapter 7 presents the conclusions.

1.2 Company Description and Sourcing Practices

ABB began in 1988 as the merger between ASEA and Brown Boveri, based out of Sweden and Switzerland respectively. After the merger the company has continued to rely heavily on acquisition for growth, acquiring 15 companies in the first year of operations. This has created an organizational culture with a high degree of independence.
ABB provides power products/systems to utilities, and automation products/systems to industrial customers. ABB now has over 100,000 employees and revenues of $24 Billion. The company is split into five divisions, and each division is split up into multiple business units (Figure 1).

![Figure 1: ABB corporate structure](image)

In 2002, ABB had financial troubles and came within hours of bankruptcy. The company focused on freeing up as much cash as possible through activities such as divesting businesses and selling land. The business climate has changed dramatically since then. Demand for power products has greatly increased, and is now larger than industry capacity. Plants have large backorders and are forced to turn down orders because of capacity constraints. Because of the favorable economic conditions, prices have been raised and profits have greatly improved. These favorable business conditions can make change difficult for two reasons. First, plants don’t see as much need for improvement because they are so profitable. Second, because of the high demand, they are focusing all of their resources on maximizing production, and not cost reduction.
At ABB there is no standard way of estimating the future cost savings when changing suppliers, which can make supplier selection difficult. Many managers stated that they use a simple rule of thumb that states one must save at least 40% to cover all of the hidden costs. This is troublesome because it ignores the inherently different amounts of hidden costs in different projects.

The trouble with the 40% method can be illustrated with an extreme example. If a plant currently orders 10,000 lbs/year of steel at a cost of $0.50 per lb, then they spend $5,000 per year. If they considered changing suppliers, they would need to be able to get the same steel for $3,000 to cover the implied 40% hidden cost of $2,000 a year.

If the same plant decides to change its supplier of gold bars, the 40% method will give a very different result. Just like the steel, the plant purchases 10,000 lbs of gold bar a year but the gold costs $625/oz or $10,000/lb. Using the same logic, the hidden costs for changing gold suppliers will be $40 million. It seems unlikely that the hidden costs of changing suppliers for 10,000 lbs of steel would be $2,000 while the hidden costs of changing suppliers for 10,000 lbs of gold would be $40,000,000. This example illustrates the problems with calculating costs based on a simple percentage. Table 1 lists the main cost categories that will be considered in this model.

<table>
<thead>
<tr>
<th>General Cost Categories</th>
<th>Cost Categories for foreign sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Investment in equipment or tooling</td>
<td>• Duties costs</td>
</tr>
<tr>
<td>• Relationship building</td>
<td>• Currency Risk</td>
</tr>
<tr>
<td>• Savings of raw part price</td>
<td>• Increased cost of business due to language and cultural differences</td>
</tr>
<tr>
<td>• Changes in transportation costs</td>
<td></td>
</tr>
<tr>
<td>• Operational Risk (e.g. late delivery)</td>
<td></td>
</tr>
<tr>
<td>• Quality Risk</td>
<td></td>
</tr>
<tr>
<td>• Inventory costs</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Cost categories for general and foreign suppliers
While there is no standard method of estimating future cost savings, there are some standards around measuring past savings. Managers stated that they typically make the following assumptions when reporting cost savings:\(^1\).

a) Managers may choose to ignore up front investment.

b) Managers can only consider cost savings in the first year. Cost savings in all subsequent years is assumed to be zero.

c) Customs duties costs are sometimes included. There is no standard.

d) Transportation costs are usually only partially considered\(^2\). For example, it was common to consider the cost of ocean freight but ignore land transportation costs to get to and from sea ports in both countries.

e) Soft costs\(^3\) are rarely included.

f) Tax considerations are not included.

Asking managers to choose projects based on the true full costs to ABB, but then evaluating them based on the crude assumptions above, can create some incentive issues. These and other incentive issues will be discussed in section 3.3.

1.3 Motivation and Objectives

For the type of products that ABB manufactures, more than 50% of the cost comes from material. Therefore even small changes in materials cost can make a large difference on profits. Low cost country sourcing is a key area that ABB can leverage to help achieve material cost savings. However the extremely rough method of calculating hidden costs outlined in section 1.2 makes it difficult for supply chain managers to determine if they are actually saving the company money when they change suppliers.

The objective of the model described in this thesis is to help ABB make better sourcing decisions by leveraging cost savings opportunities from low cost country sourcing. ABB

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\(^1\) Based on interview with various managers

\(^2\) "Partially considered" implies that not every step in transporting product from the supplier to the ABB plant is considered. For example, it was common to see ocean freight considered for international supplier, but the cost of transporting goods to and from the ports was ignored.

\(^3\) Also called hidden costs. These include items like the extra time spent dealing with a supplier because of language or time zone differences.
did not dictate exactly who the end user should be or what types of inputs or outputs the model should have. Therefore the objective is not only to create a model, but also to determine what type of model to create and for what type of user.

1.4 Chapter Summary
This chapter illustrated the need for a total cost model. ABB has a high percentage of materials cost and does not currently have a good method for sourcing selection. The next chapter will review some of the types cost models that others have presented in the past.
Chapter 2: Literature Review

This is not the first model to look at the full cost of sourcing. Many other models have been proposed that attempt to consider full costs. This chapter gives a brief review of the other types of models that are available. Section 2.1 categorizes supplier selection models into three different categories, and section 2.2 summarizes some of the previous models that have been proposed.

2.1 Model Types

Smytka\(^1\) (1993) identified three basic forms of supplier selection methods: Go/No-Go, Weighed Matrices, and Cost-based methods. Selection of one of these methods depends on the tradeoff that one wishes to make between simplicity and accuracy (Figure 2).

![Figure 2: Types of Supplier Selection Models\(^4\)](image)

Go/No-go methods require suppliers to meet minimum requirements, but do not provide any way of differentiating between different suppliers that meet the minimum requirements. They are simple, but not accurate. Weighted Matrices attempt to achieve

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\(^4\) Figure Taken from Daniel L. Smytka, Michael W. Clemens, “Total cost supplier selection model: A case study”, *International Journal of Purchasing and Materials Management*. Winter 1993, Vol. 29, Iss. 1; pg. 42, 8 pgs
a balance between accuracy and simplicity by assigning importance weightings to different evaluation criteria. Each supplier is given a raw score in each category. Each raw score is multiplied by the category weighting to give a total score. Cost-based methods have the most potential for accuracy, but can be quite difficult in practice. Ellram\textsuperscript{ii} (1995) emphasized the importance of good activity based costing when using total cost of ownership.

The model developed in this thesis is a cost based method. As mentioned earlier, cost-based methods can become quite complicated, so the model developed in this thesis aims to trade off some degree of accuracy for simplicity and flexibility.

\section{2.2 Summary Of Previously Proposed Models}

Ferrin\textsuperscript{iii} (2002) points out that Total Cost, Life Cycle Costing, Product Life Cycle Costs, and Total Cost of ownership are all similar. In principle, the goal of a full cost model is to be inclusive and to consider the effect of any change that results from the sourcing decision. Otherwise it would be a partial cost model instead of a full cost model. In practice, there are many different ways to approach the calculation of full costs.

The choice of the correct model depends on the specific application. There is no single best model for all scenarios, nor is there a standard method for calculating costs. Ellram\textsuperscript{iv} (1994) shows that there is no standard procedure for Total Cost of Ownership.

We can list some of the different ways the previous literature has modeled costs.


b) Ellram\textsuperscript{vi} (1993) suggested splitting costs by transaction sequence, starting with pre-transaction cost components, then transaction cost components, and finally post-transaction cost components.

c) Degraeve\textsuperscript{vii} (1999) suggested splitting costs into three categories: Supplier level activities, Order-level activities, and Unit-level activates.
d) Smytka (1993) worked with a cross-functional team to categorize costs into 3 categories: risk factors, business desirable factors, and measurable cost factors.


The model presented in this thesis models costs loosely based on accounting categories. This has the advantage of making the model easier to understand for new users.

2.3 **Chapter Summary**

This chapter presented the different types of models available. It gave some examples of previous models and described how the model presented in this thesis is different. The next chapter describes how the model in this thesis was developed, and some of the incentive issues involved with supplier selection.
Chapter 3: Development Considerations

The previous chapter laid out some of the methods that have been used to calculate full cost in the past, and described how the model in this thesis fits into that framework. This chapter describes the practical considerations encountered when developing this model. Section 3.1 describes the requirements mandated by ABB. Section 3.2 describes the methodology used to gather information and develop the model structure. Section 3.3 describes the incentive issues surrounding a model that estimates future costs, and describes how managers may still make the wrong decisions even when they have better models.

3.1 Requirements

The primary purpose of this model is to allow ABB to make better sourcing decisions, and take advantage of low cost country sourcing. ABB has simply categorized all countries into low cost countries and high cost countries. While this does not capture the full complexity of the different cost structures in different countries, it does make firm wide target setting easier. Others have used the concept of Total Landed Cost to ensure that sourcing from low cost countries is actually lower cost to the firm. Like the total landed cost, the model presented in this thesis also aims to consider all of the costs related to supplier changes.

ABB did not specify the end user of this model or the required inputs. The key requirement was to create a tool that could help ABB to maximize the benefits of global sourcing. Because of the vague requirements, a flexible model was designed which could accommodate the needs of different users. A very targeted model could be better for a specific user, but such a model would not have the ability to permeate through the organization and gain acceptance. The model is flexible enough to allow quick high level analysis or detailed in-depth analysis all within the same framework.
3.2 Model Development Methodology

There were three main steps in developing the model presented in this paper. First many people across the firm were interviewed to get a comprehensive list of the different types of costs to consider. No single person is aware of all the consequences of sourcing decisions, not even the supply chain managers. Engineering was able to give more insight into the cost of supplier qualification, and costly redesigns. Quality was able to give more insight into warranty claims. Sales and marketing was able to give insight into the effect of lost sales, and the costs required to keep the customer happy. Operations was able to give insight into the cost of disruptions to the production line.

The second step was to combine all of the different types of costs into useable categories so that they could be presented in a useable model. It was very difficult to come up with categories that not only included all relevant costs, but also made it clear how to avoid double counting. Eventually we settled on a framework that resembled GAPP financial reporting. The financial reporting framework was chosen because it has already been carefully laid out to avoid double counting, and because it would be easier to communicate results.

The final step was to test the model with users. This helped to develop the user interface, and to verify the accuracy of the model.

3.3 Incentive Issues

A clear distinction should be made between forward looking models that attempt to predict the full cost and benefits of supplier changes, and backwards looking models that attempt to evaluate past performance. Incentive issues are created when a firm wants managers to make decisions based on forward looking models that consider hidden costs, but evaluate those managers based on backwards looking models that ignore hidden costs. Because managers know that they will be evaluated on a backwards looking model, they may have a tendency to ignore or over emphasize the metrics in the backwards looking model and ignore important hidden costs that are only considered in the forward looking model.
The manager's behavior illustrates the fundamental balance between information and control. If a manager believes that his total compensation is totally independent of his performance, then he will have no incentive to distort information and will make decisions that to the best of his knowledge are in the firm's best interest. However, with this incentive structure, or lack of incentive structure, he is also not motivated to work very hard. In fact he could do nothing at work without fear of recourse. In this case we have very good information but no control. It should be noted that total compensation does not only include monetary compensation, but also promotions, recognition, and anything else the manager values.

If we consider the scenario where a manager's total compensation is heavily based on his performance, the manager will be highly incentivized to take actions that will improve his performance evaluation even if it is not the right thing for the company. The manager will be less willing to report hidden costs, and will be more likely to underestimate future savings so that his future performance will exceed expectations. In this case the firm has some control to motivate the manager to work hard, but the firm has poor information about what the best course of action actually is.

The previous discussion on incentives did not consider the importance of the status quo. Designing incentives for a new organization is different from changing the incentive structure in an existing organization. When a new model is introduced that considers many more hidden costs, employees get nervous and resist the change because they fear that it will cause their performance to appear worse. Of course in the long run, if the new model systematically predicted lower savings then savings targets in the future would also be lower. However, during the transition the employees worry about the clash between targets that were set with an old measurement system and an evaluation method based on a new system. Therefore, even employees that support the new model in general often do not want to be the ones to first try it out.
If we look at the amount of resistance employees give from a game theory perspective, we discover an interesting dynamic. Because of information asymmetries and signaling issues employees have to be careful how much resistance they put up. Employees who have been acting in the best interest of the firm will know that there is no reason for them to be systematically discriminated against in the new measurement system, and will be more likely to support it. However, employees who have been purposely manipulating the measurement system know that their performance relative to their peers will suddenly appear to be much worse, and will be more likely to resist the new model. Therefore, the willingness to accept the new model provides some signal as to how honest employees have been in the past. This could be the reason that we observe many people who claim that they support the change, but act in ways to block or slow down that change, such as not providing data, or resources.

The size of the company also has an effect in how strongly employees are incentivized. Employees need to balance their desire to see the firm succeed with their desire to see themselves succeed. Even employees who don't care about the company at all must realize that when the firm is doing poorly, promotions, raises, bonus, etc will be harder to get. In a small firm, the action of any individual can have a noticeable effect on the value of the firm, however in a very large firm the actions of a single individual have virtually no effect on the value of the firm as a whole.
3.3.1 Inappropriate risk behavior

When the chance of failure is small compared to the chance of success, managers are incentivized to pay little attention to the down side. This is because managers might be able to blame bad outcomes on bad luck, and credit themselves in the case of good outcomes. For example, steel shortages, poor supplier quality, and rising energy prices are examples of events that can be called bad luck.

This can be illustrated with a hypothetical example.

![Decision tree for managers taking on new projects](image)

Figure 3: Decision tree for managers taking on new projects

In Figure 3, even though no numerical values are given for the payouts it is clear that the manager will choose to start the project. However, for the firm no amount of blaming will be able to reverse the losses that are caused in to failure scenario. Because of this difference, it would be possible for the project to have a positive expected value for the manager, and a negative expected value for the firm.
Instead of looking at the simple binomial case, we could look at the way managers and the firm value success across a continuous range of outcomes. If we assume that the firm is risk neutral about a given project\(^5\), then the firm will value projects linearly with the project’s gain or loss. The manager, on the other hand, has a highly non-linear perceived value. Figure 4 shows an example of what this relationship might look like.

![Figure 4: Payoff for managers taking on new project with uncertain gains](image)

For managers, the slope of the curve is very steep close to zero monetary gain. This is because management will be judged quite differently if their project is a minor failure compared to when their project is a minor success. As the monetary gain becomes quite large, it is clear that their project is a success. They will only be judged marginally different if the project is a big success or a slightly larger success. We see a similar flattening of slope for large monetary losses. However, as discussed in the binomial example, the magnitude of the negative perceived value in the worst case scenario is not as large as the magnitude of the positive perceived value in the best case scenario because of the ability to blame poor outcomes on bad luck and unforeseeable circumstances.

\(^5\) Firms care about the risk of their portfolio of projects, and much less about the specific risk of individual projects. To assume complete risk neutrality about a project we must assume that the risk of the project has zero correlation with the type of the risk the firm is trying to minimize.
The difference in the way management and the firm value projects presented in Figure 4 can lead to agency problems in two key ways. The first way is when management is considering a project that will most likely have a small monetary gain, but has a small chance of a large monetary loss. Managers will overvalue the small monetary gain, and undervalue the large monetary loss, and therefore take on projects that they should not. Changing suppliers can be an example of this. A small price reduction has the potential save a modest sum of money, but if the new supplier has quality problems that cause massive warranty claims the monetary loss can be enormous.

The second way that there can be problems based on different perceived values is when a project will most likely have a small loss, but has a small chance of providing a huge payback. Because management will over emphasize the small loss and undervalue the huge return, they will not take on enough of these positive NPV projects. These projects are like lottery tickets with a positive NPV. For example, we could set up a contract with a supplier where we pay an extra 1 cent per part for the guarantee that in the case of a shortage our parts will have priority over other customers. Because nobody expects a shortage this contract will most likely result in a small loss, but if there is a shortage the damage to the firm could be enormous unless the contract contains the priority clause.

3.4 **Chapter Summary**

This chapter described the methodology used to develop the model, and the requirements mandated by ABB. A significant portion of the chapter focused on incentive issues, and how managers might be incentivized to take projects that are not in the best interest of the firm. Asking managers to explicitly quantify risks might help to reduce inappropriate risk taking behavior. The next chapter discusses the issues with actually measuring and quantifying different types of costs.
Chapter 4: How to measure costs

Accounting was designed for financial reporting, and not for forecasting. This chapter describes how to avoid some of the problems typically associated with using accounting numbers for forecasting. Section 4.1 describes how using marginal cost instead of absolute cost reduces the amount of calculation required without reducing accuracy. Section 4.2 explains why focusing on cash flow instead of accrual based accounting will give more accurate results. The subsections under 4.2 go through specific examples where accrual and cash measurements vary, such as capital equipment, overhead allocation, changes in net working capital, and taxes.

The rest of the chapter describes other difficulties in measuring costs. Section 4.3 Error! Reference source not found. discusses the difficulties in determining which costs are sunk costs and which are not. Section 4.4 discusses the difficulty in modeling global optimums and the trade offs made when we ignore interdependence of different costs.

4.1 Advantages of Marginal vs Absolute Measurements

Measuring the full cost can be an informative exercise, but it is not well suited for making sourcing decisions in most cases. Normally, when sourcing a part one must choose between multiple suppliers. Assuming that you must purchase the part, the total cost of purchasing from any given supplier is irrelevant, and we should instead focus the difference in total cost between the different suppliers. It is not terribly useful, for example, to know that the total cost of sourcing from supplier ABC would be $2,000,000/year. However, it is quite useful to know that $250,000 could be saved by switching to supplier ABC. Of course, if in addition to knowing that it would cost $2,000,000/year to source from supplier ABC, we also knew that the cost of sourcing from our current supplier was $2,250,000, we could simply subtract the two numbers to come to the same conclusion. However estimating the full costs for both suppliers would take substantially more effort than only considering the differences in cost.
Some might argue that knowing only the difference in total cost is not enough because one needs to take into account the percentage savings and the risk of the change. However, the model presented in this thesis takes risk into account by charging a risk cost for different types of risks. Therefore if the total cost is calculated correctly, risk should already be taken into account, so this argument becomes invalid. Also, using scenario analysis will further help to understand the risk involved.

4.2 Advantages of Measuring Cash Flows vs Costs

There are two main reasons for using cash flows instead of costs. First it is more accurate, and second it helps to predict liquidity. Accrual based accounting distorts the timing of cash inflows and outflows, which is ultimately what investors and debt holders care about. The main problems occur for purchases of capital equipment, overhead allocation, changes in net working capital, and taxes payments.

4.2.1 Purchase of capital equipment

In reality, when a firm purchases capital equipment there is a large cash outflow up front, and then no other cash flows in the future related to the purchase of that equipment. However accounting principles require the firm to spread out the purchase cost of the equipment over a number of years. It is important to note that accounting treatment does lead to a real cash flow effect because depreciation affects EBIT, which affects tax paid. Therefore we can not totally ignore the accounting treatment of capital purchases.

4.2.2 Overhead and other allocation problems

When changes are made at a local level, different overhead allocation methods can lead to false conclusions about how much overhead costs will change. There is no perfect way to allocate overhead costs. The most common method is to use an allocation base, and scale overhead charges linearly with the allocation base\(^6\). Typical allocation bases include machine hours, labor hours, head count or PPE value. For financial reporting on

\(^6\) Other methods, such as Activity Based Costing, will have less problems than using allocation bases.
an aggregate level, the allocation of overhead is not critical because it simply shifts paper profits from one division to another, but does not change the aggregate profits.

While allocation bases might be sufficient for financial reporting, they are inappropriate for decision making. Certain expenses such as the cost of the CEO's car lease, or the salary paid to the internal legal staff, are not easily attributed to any specific division. The problems start when one assumes that if the allocation base is increased that overhead costs will actually increase proportionally. For example if overhead costs are allocated based on COGS and the supplier raises prices, actual overhead costs would not rise even though the cost allocation system would predict they would. When we consider changes in cash flows instead of changes in the amount of allocation base that we use, we can get more accurate results.

4.2.3 Change in Net Working Capital

The cash flow effects of changes in Net Working Capital are easy to forget because they don't show up anywhere on the income statement.

\[
\begin{align*}
\text{NWC} &= \text{Current Assets} - \text{Current Liabilities} \\
\Delta \text{NWC} &= \Delta \text{Current Assets} - \Delta \text{Current Liabilities}
\end{align*}
\]

The income statement ignores the up front cash needed to increase short term assets such as inventory or accounts receivable. It also ignores the cash generated from increasing short term liabilities such as accounts payable.

Instead of considering the up front cash required for increasing inventory, it is more common to consider an annual holding cost which includes both physical holding costs and the cost of capital. This method is convenient when analyzing inventory systems, but it is not consistent with cash flow methods. To be consistent, we would have to treat all cash flows in a similar manner. Considering the cash flow required to invest in inventory analyzes the cash flow generated for the owners of the business, the debt and equity holders. Considering the cost of capital as an annual charge on inventory ignores
actual cash flows, but instead looks at how much return the business is earning in excess of expected returns. Neither method is incorrect, but mixing methods can cause confusion.

In most cases, analyzing the change in cash flows and calculating an inventory holding cost will lead to similar conclusions. However in some cases, the two different methods will lead to significantly different conclusions. The first scenario is when the company is in risk of bankruptcy. ABB was in this situation in 2002, and correctly focused very heavily on liquidity and cash flows. Management often makes investments that do not necessarily pay out now, but are best in the long run. However when there is risk of bankruptcy, short term liquidity must also be considered. By considering only the inventory holding cost and not the cash required to purchase the inventory, we ignore the increased risk of bankruptcy from purchasing the inventory. We implicitly assume that the company will be in existence long enough to sell the inventory, which may not be true. By looking at cash flows instead of accrual based costs, the user will be able to see how cash flows are distributed over time instead of how fictitious accounting numbers are spread over time.

The second scenario is that the company is capital constrained and has trouble raising new money. In general we assume that capital markets are efficient, and that if a company has a NPV positive project it will be able to raise the capital for the upfront investment. When we make this assumption, companies should take any investment that is NPV positive. However, if capital markets are not efficient and companies can not raise capital then they need to be much more careful about which projects they select. They need to choose the projects that maximize value within their capital constraints, instead of simply picking all positive NPV projects. Because capital constraints work on the basis of real cash flows instead of accruals, it is more appropriate to consider the up front cash required to increase inventory than it is to amortize this investment with a fictitious holding cost.
The third scenario is relevant when inventory is not the only short term asset or liability that changes significantly from year to year. For example, if a plant starts to sell to its customers on credit, then accounts receivable will suddenly increase. There will be a one time impact on cash flows in that year as all cash flows from customers are pushed back in time.

4.2.4 Tax Considerations

Taxes are often ignored in analysis because they are complex, but ignoring taxes is simply an assumption that the marginal tax rate is equal to zero. Although assuming a marginal tax rate of 35% in the USA is a gross simplification, it is more correct than assuming a marginal tax rate of 0%. This becomes especially relevant when different countries or divisions have different marginal tax rates.

At ABB, for example, certain countries have not been profitable for over ten years and have a very large deferred tax asset. This means that in the short term their marginal tax rate is essentially zero. Technically, if we consider the marginal tax rate to be zero, then we should also consider the loss of real option value of keeping a deferred tax assets on the books. However that is beyond the scope of this thesis and would be unlikely to play a large role in decision making.

4.3 Is it a sunk cost?

The concept of fixed costs and variable costs can often become ambiguous because it depends on time horizon, level of aggregation and opportunity costs. To illustrate these concepts, we will consider the cost of an accountant spending an extra 10 hours per week with customs paperwork. Some people interviewed argued that there was no incremental cost because the accountant already works for us. If we look specifically at this accountant over a very short time horizon, and ignore opportunity costs then this statement is true. However if we considered the effect of having every accountant across the firm needing to spend 10 hours a month on additional paperwork, it would be clear that we would need to hire more accountants. At the plant level, the chunkiness and time delay of hiring people makes the variable nature of this cost difficult to see.
There is more than one way to think about the paradox of something being both a fixed cost and a variable cost. One way would be to consider that you can give a person an incremental amount of work without hiring someone else. Then you could give the same person another incremental amount of work without hiring someone else, but eventually the work load would become too much and you would have to hire someone. Clearly we can not allocate the new hire’s entire salary to the last small incremental amount of work that finally caused us to hire that person. Each incremental amount of work assigned contributed to the new hire, therefore we should instead allocate costs to each incremental amount of work assigned.

Another way to think about this would be to consider a probabilistic view. Each incremental amount of work that you assign someone today, will have a certain probability of requiring you to hire someone in the next period. If we assume that on average a person works 2000 hours/year, then on average every time we add 2000 hours/year worth of work we will have to hire a new person, then we can write

\[
\text{Prob}_{\text{HIRE}} = \frac{A}{2000}
\]

\[
\text{Cost of } A = (\text{Prob}_{\text{HIRE}}) \cdot (\text{Cost}_{\text{HIRE}}) = \left(\frac{A}{2000}\right) \cdot (\text{Cost}_{\text{HIRE}})
\]

\(A = \text{Additional \# of hours/year assigned}
\)

\(\text{Cost}_{\text{HIRE}} = \text{The annual cost of employing another person}\)

\[\text{Equation 1: Cost of using existing manpower}\]

We should also consider the opportunity costs of people’s time. If we did not assign them extra work, they would probably not have spent their time doing nothing. Instead when you assign them extra work, they would have to spend less time on other activities.

\[\text{Net Value}_{\text{NEW ACTIVITY}} = \text{Total Value Created}_{\text{NEW ACTIVITY}} - \text{Value Missed}_{\text{OLD ACTIVITY}}\]

\[\text{Equation 2: Opportunity Cost of People’s Time}\]
4.4 Local costs vs Firm wide costs
In principle, the best way to make decisions would be to look at the marginal cash flow implications to the entire firm as a whole. However, in practice this approach would be too onerous to undertake in large companies. Therefore we try to look at smaller parts of the system independently. ABB, for example, has over 100,000 employees, which are split among 5 separate divisions and operating in about 100 countries. Trying to model the entire system without drawing boundaries to contain the problem would be nearly impossible.

If a specific plant were to install energy efficient windows to save on heating costs, they could safely ignore the impact to all other plants in the ABB network. However, if they changed their inbound supply chain network, it would be likely to affect other plants that use shared resources such as truck capacity and warehouse space. If we only consider the costs and benefit to one plant we would be focusing on a local optimum instead of the global optimum. Unfortunately, analyzing the effect of a change on large supply chain networks can be extremely complicated. However, this is not a reason to ignore the effects on the larger network. When analytical methods are too difficult, simpler heuristic or experience based measures can be used.

In other cases it is less clear whether drawing boundaries around the problem is appropriate. For example, if a particular plant changes suppliers for a specific part we would not expect this to affect any other plant. However, if multiple plants used the same supplier then the remaining plants still using the original supplier have less bargaining power and ability to get volume discounts. Alternatively, we could consider the scenario where some ABB plants switch to the same supplier as other ABB plants in order to get a volume discount. In this case there would be a savings from volume discounts at not only the switching plant, but also the original ABB plants which used the supplier.
Because modeling the entire system is not feasible, whenever there are spillover effects beyond the boundaries of our model, we should try to estimate these effects and include it in our model as an additional expense or benefit. Estimating spillover effects as separate expenses may not capture all of the complexities of the various interactions, but it is the best option given the limited amount of time and resources available to analyze business decisions.

Not only do we need to consider the effect of one plant's actions on the other plants in the network, but we also need to consider the affect of each plant's actions on corporate costs. Certain activities such as marketing or legal often occur at a corporate level. For example, the utilities which buy ABB's products consider reliability to be of paramount importance. If a plant changes supplier, then marketing must spend a lot of time with the customer to get them to approve the change. The plant does not see the marketing costs, but they should still consider it when they make their supplier change decision.

**4.5 Chapter Summary**

There are many different ways to measure costs. This chapter describes the general method used in this model. There is a focus on cash flows instead of accounting accruals, and marginal costs instead of total costs. The next chapter explains the specific details of the model, and how to interpret the input variables used.
Chapter 5: Description of Model

This chapter explains how the model works. Section 5.1 describes the user interface and the basic structure of the model. It describes the part of the model that the user sees. Section 5.2 describes how data flows through the model. It describes the parts of the model that the user does not see. Sections 5.3 through 5.10 describe the various input variables, and the difficulties with estimating them properly.

5.1 User interface

The model is loosely modeled after financial statements because people have the most familiarity with that framework. See Appendix A for a screenshot. Inputs are divided into five categories (1) Up front investments, (2) Change in revenue, (3) Change in annual expenses, (4) Change in assets and liabilities, (5) Global Variables. Each category has multiple variables underneath it.

In the inputs section we can see a column labeled “Local Input” and a column labeled “Remote”. The local input is to be used in simple scenarios where the user can make a good estimate. If the situation is more complicated and the user is willing to spend a little more time, she can use the remote input. For example the local inputs for up front investments assume that all capital investments happen immediately and have the same depreciation life. If there are multiple investments that are depreciated over different time periods, or investments that will need to be made at a later date, the user will not be able to enter this in the local input. Instead, the user could use the remote input (Appendix B).

The example shown in appendix B represents a scenario where a piece of equipment is purchased up front at a cost of $25k. It will be depreciated over 5 years, and require an additional investment in the third year. It will be fully depreciated over five years, but we estimate that in the 5th year it will have a salvage value of $10,000. It will cost about $1,000 to find a buyer and administer the sale.
The general structure of this model has many advantages. Because financial statements are inclusive, it allows users to enter costs that the original creator of the model never considered. Also, because almost all of the inputs are measured in dollars, it is easy to scan over other people's work to do quick sanity checks. For example, it would take less than one minute to recognize if a user had ignored risk costs in a situation where risk is clearly a major factor. With a traditional cost savings calculation, one would need to spend a lot of time manually reviewing calculations to understand the assumptions made. The ability to quickly review the calculation of others can help to add transparency and reduce managers' ability to distort information based on their own personal incentives.
5.2 Flow of Data

The model works by converting inputs into future financial statement projections. The user can enter data into either the local inputs (1a) or the remote inputs (1b). The financial statements (2) will draw information from the local and remote inputs in accordance with the radio buttons selected. Finally, the model uses data in the financial statements to calculate the net present value of the free cash flows, which is presented in the output section (3).

Figure 5: Data Flow through the model

The user can enter data into either the local inputs (1a) or the remote inputs (1b). The financial statements (2) will draw information from the local and remote inputs in accordance with the radio buttons selected. Finally, the model uses data in the financial statements to calculate the net present value of the free cash flows, which is presented in the output section (3).

---

7 Financial statement projections include non-GAAP items such as risk costs. This way more accurate estimates of future cash flows can be made.
8 Radio buttons are the small circular buttons in the model. The user can use them to switch between local inputs and remote inputs.
For example, when the user enters an investment into the model, the financial statements sheet will automatically increase CAPEX and PPE in that year. In subsequent years a depreciation expense will be charged and PPE will be reduced until the item is fully depreciated. Free cash flow can be calculated using Equation 3.

\[
FCF = (1 \cdot t) \cdot EBIT + Dep - CAPEX - \Delta NWC
\]

**Equation 3: Free Cash Flow**

\( FCF \) = Free Cash Flow, \( t \) = marginal tax rate, \( EBIT \) = Earnings Before Interest and Taxes, \( Dep \) = Depreciation Expense, \( CAPEX \) = New capital Investment in a given year, \( NWC \) = Current Assets - Current Liabilities

The model also breaks down the NPV into components. This is done to help the users see what the biggest cost drivers are. One of the problems with NPV analysis is that the end result is just a single number, and it is difficult to tell what is driving that number.

### 5.3 Up Front Investment

Up front investments represent anything that is spent or forgone upfront to allow the project to happen. New Capital Investments will be depreciated, while Other Restructuring Costs represent costs that can not be depreciated.

<table>
<thead>
<tr>
<th>Examples of New Capital Investments</th>
<th>Examples of Other Restructuring Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Purchase of mold or tooling</td>
<td>• Vendor Qualification</td>
</tr>
<tr>
<td>• Purchase of machinery or equipment</td>
<td>• Sample approval</td>
</tr>
<tr>
<td>• Building new warehouse</td>
<td>• Other time or resources spent to make the new deal happen</td>
</tr>
<tr>
<td>• No longer need to buy equipment (a negative capital investment)</td>
<td>• Cost of quality problems during transition</td>
</tr>
</tbody>
</table>

**Table 2: Examples of New Capital Investment and Other Restructuring Costs**

New Capital Investments will be depreciated over the number of years specified, while Other Restructuring Costs will be expensed up front. If there are investments that happen at later dates, the user can click the remote radio button, and enter in a more detailed schedule of investments. The model will make sure that the CAPEX, depreciation, and PPE will flow through the financial statements properly.
5.4 **Change in Revenue**

In general, changes in suppliers will not cause any change in revenue, but it could happen in some cases. For example, if we are purchasing an upgraded controller from a new supplier, that will allow us to sell the product at a higher price. Alternatively, certain sourcing decisions open up new markets and allow for increased sales volume. For example, Mexico has local content laws which prevent the sale of ABB products unless a certain percentage of the products comes from Mexico.

5.5 **Change in Annual Expenses: Materials**

Change in Annual Expenses outlines all of the major expense categories on the income statement. It is important to explicitly split these expenses into different categories for two reasons. First, interviews with users demonstrated how easy it was for users to anchor onto a certain type of cost and ignore all other types of costs. By separating costs into different categories it helps users to ensure that they don't miss any major costs categories. Second, this allows the costs to be split appropriately into the projected financial statements, which allows users to focus on other metrics if they choose.

---

9 Non-operational items such as Minority Interest, dividend income, and effects from accounting changes, are not listed. If any of these items are important, they can be included under “Change in Other Expense”.
5.5.1 Change in Cost of Raw Materials

Change in material cost is kept separate from changes in transportation costs and duties costs to ensure proper comparisons. Otherwise it would be easy to mistakenly compare two quotes where one quote included shipping and the other did not. When users are asked separately to state the change in transportation costs and the change in duties costs, they are forced to consider whether or not the prices quoted to them include transportation and duties. Interviews with users showed that people were often aware of the new price, but were not sure if that price included transportation and duties.

\[ \Delta \text{Raw Material Cost} = (\text{New Annual Materials Cost}) - (\text{Old Annual Materials Cost}) \]

Equation 4: Raw Material Cost

Note that a reduction in material costs will show up as a negative number. Some users found this confusing, and wanted to show a positive number to represent savings.
5.5.2 Change in Transportation Cost

As mentioned earlier, the user must check to see whether the Change In Cost of Raw Materials included changes in transportation costs. If transportation costs are included in the raw material price, then transportation costs will be zero.

\[
\Delta \text{Transportation Cost} = (\text{New Transportation Cost}) - (\text{Old Transportation Cost})
\]

Equation 5: Transportation Cost

It is important to remember to include all components of transportation costs. When thinking about the transportation costs for an overseas supplier, it was common for the users interviewed to only think about the ocean freight, and not the cost of getting from the supplier’s plant to the Chinese port, and the cost of getting from the US port to the specific ABB plant.

In order to estimate the new transportation costs, the user will have to make assumptions about order size and order frequency. There will be a balance between transportation costs and inventory holding costs. Inventory models are provided in the remote inputs based on economic order quantity and lot size-reorder point systems, but during interviews supply chain managers were more comfortable with estimating the order quantities and frequencies themselves. The lot size-reorder point system is explained further in section 5.5.4 and Appendix C.

5.5.3 Change in Duties Costs

In principle calculating the duties is simple; simply multiply the part cost by the HTS\(^{10}\) rate. However in practice it is quite difficult to determine the proper HTS rates because products that seem very similar can have different HTS codes, and hence different HTS rates.

\(^{10}\) Harmonized Tariff Schedule
The variation between similar items can be seen clearly with screws. One might expect all screws to be within the same HTS category, but this is not true. The descriptions listed in the official HTS schedule\textsuperscript{11} can be compared with examples from a common industrial goods supplier\textsuperscript{12} to visually show that small differences in type of product can lead to large differences in HTS rate (Figure 6).

The pictures shown in Figure 6 are just a sample of the types of screws that fit the description. To the untrained eye, some screws between HTS categories may look more similar than screws within an HTS category. For example a self tapping screw with a Phillips head and a sheet metal point will look very similar to a fully threaded wood screw with a Philips head, but look quite different from a self tapping screw with a hex washer head and a self drilling head.

In general, one can not blindly base HTS categories on past orders unless the exact same part number is being ordered. However, in some cases even this rule does not hold. No duties are paid on lock washers and spring washers if they are shipped with bolts, but charged at 5.8\% otherwise.

Although the HTS rate is the main component of the duties, there are some other charges. There is a 0.21\% merchandising processing fee\textsuperscript{13}. When shipping via sea, there is a 0.125\% Harbor Maintenance fee\textsuperscript{14} as well. There is also a Clearance fee of about $75 to $100 per entry, and a $20 Messenger fee per entry.

\begin{footnotesize}
\begin{enumerate}
\item The full HTS Schedule can be found at \url{http://www.usitc.gov/tata/hts/bychapter/index.htm}
\item The data for screws came from CHAPTER 73, ARTICLES OF IRON OR STEEL
\item Pictures are taken from McMaster Catalog. The catalog can be found online at \url{http://www.mcmaster.com/}
\item Often abbreviated as MPF
\item Often abbreviated as HMF
\end{enumerate}
\end{footnotesize}
<table>
<thead>
<tr>
<th>HTS Code</th>
<th>Description</th>
<th>Examples</th>
<th>HTS Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>7318.11.00</td>
<td>Coach screws&lt;sup&gt;15&lt;/sup&gt;</td>
<td><img src="image" alt="Coach screw" /></td>
<td>12.5%</td>
</tr>
<tr>
<td>7318.12.00</td>
<td>Other Wood Screws</td>
<td><img src="image" alt="Other Wood Screw" /></td>
<td></td>
</tr>
<tr>
<td>7318.14.10</td>
<td>Self-tapping screws</td>
<td><img src="image" alt="Self-tapping screw" /></td>
<td>6.2%</td>
</tr>
<tr>
<td>7318.14.50</td>
<td>Self-tapping screws:</td>
<td><img src="image" alt="Self-tapping screw" /></td>
<td>8.6%</td>
</tr>
<tr>
<td></td>
<td>Having shanks or threads with a diameter of less than 6 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Having shanks or threads with a diameter of 6 mm or more</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7318.15.20</td>
<td>Bolts</td>
<td><img src="image" alt="Bolt" /></td>
<td>Free</td>
</tr>
<tr>
<td>7318.15.40</td>
<td>Machine screws</td>
<td><img src="image" alt="Machine screw" /></td>
<td>Free</td>
</tr>
<tr>
<td></td>
<td>9.5 mm or more in length and 3.2 mm or more in diameter (not including cap screws)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7318.15.80</td>
<td>Socket screws</td>
<td><img src="image" alt="Socket screw" /></td>
<td>8.5%</td>
</tr>
</tbody>
</table>

Figure 6: HTS rates for screws

<sup>15</sup> A coach screw is a heavy-duty screw that can be turned by a spanner. They are used mainly to connect metal plates to timber. A coach screw looks like a bolt except that the threaded portion is the deep flutes of a wood screw rather than the fine machine thread that screws into a bolt. Coach screws have hex heads.
5.5.4 Change in Inventory Carrying Costs

Users can choose to either enter the costs of increased inventory directly or they can use the remote input. The remote input is a standard inventory model based on economic order quantity (Appendix C). When piloting with users, most preferred to make their own estimates instead of using inventory model provided in the remote input section.

The remote input section uses a lot size reorder point system model (LSRP model). The LSRP model assumes that demand and lead time are normally distributed. The equations for this model are shown in Appendix C. It also assumes that the system is continuously reviewed, and an order is placed whenever the inventory falls below a certain level. Every order placed is for the same quantity. This quantity is determined by the economic order quantity equation. In order to calculate the reorder point, we must know the service level, which is the percentage of orders which arrive before we run out of inventory. Because we know the distribution of demand and the distribution of lead time, we can choose a reorder point which will have the same probability of stock out as we desire in the service level. Setting the reorder point represents a tradeoff between inventory holding costs and risk of stock out.

A convenient way to think about inventory in the LSRP model is to think about safety stock and cycle stock (Equation 6). The cycle stock is the average amount of inventory used between deliveries divided by two. Based on an assumed demand and delivery frequency, the cycle stock can be calculated exactly. The cycle stock concept really helps to anchor estimates made by managers. The average inventory must always be at least equal to the cycle stock. The safety stock is the average amount of inventory on hand when a new shipment arrives. For a precise definition of safety stock and cycle stock see the equations in Appendix C.

\[
\text{Avg Inv} = \text{Avg Cycle Stock} + \text{Avg Safety Stock}
\]

Equation 6: Average Inventory
Once the amount of extra inventory is determined, we must determine how to convert units of inventory into an annual cost. In this section, the user should only consider the physical cost of inventory. Traditionally inventory calculations consider both the cost of capital tied up in inventory and the physical cost of holding that inventory. In this model, the cost of capital will be considered in the “Change in Assets & Liabilities” part of the model (section 5.9.1).

The change in the physical cost of inventory is related to the extra space it takes up and the amount of extra labor used to move the extra inventory around (Equation 7). The method presented in Equation 7 is not the only way to calculate the change in physical holding cost, but it is a good method for the generic case. The user should feel free to use whatever method he feels appropriate.

\[
\Delta \text{Physical cost of Inv} = (\Delta \text{sq ft}) \cdot \left( \frac{\$}{\text{sq ft}} \right) + (\Delta \text{hr of labor}) \cdot \left( \frac{\$}{\text{hr of labor}} \right)
\]

Equation 7: Inventory Holding Cost (Physical Holding Cost)

5.5.5 Change in SCM Costs

When switching suppliers there is some administrative work that needs to be done, especially with an overseas supplier. The change in Supply Chain Management costs takes into account the extra time spent on travel, relationship building, legal issues, accounting issues, etc.

5.6 Change in Annual Expenses: Production

Sourcing will generally not have any effect on production costs. However it was included for completeness. Although it is not discussed in this thesis, this basic model structure is also used for other projects such as deciding were to locate manufacturing plants. For plant location decisions, the production cost in different locations is one of the most important factors.
5.7 Change in Annual Expenses: Risk

In section 3.3.1 inappropriate risk behavior was discussed. By explicitly asking users to estimate the cost of risks, we can reduce this inappropriate behavior. We can never eliminate this behavior because management will have incentives to underestimate risk in some cases and overestimate in other cases; however we can make it more difficult for managers to totally ignore risk or claim that something is too risky without even attempting to quantify the cost of the risk. Because risk costs are listed in a simple format right beside all of the other costs, one can quickly scan the inputs and should be able to see if the risk costs are being grossly exaggerated or understated.

Technically the correct way to calculate the expected value would be to integrate over all possibilities. If we assume that there are three variables (x,y,z) that can affect the outcome, and that we can measure the outcome as an explicit function, \( F(x,y,z) \), and that we know the probability distributions of x,y,z, then we can write

\[
E(F) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} F(x,y,z) \cdot PDF(x,y,z) \cdot dx \cdot dy \cdot dz
\]

where

\[
PDF(x,y,z) = \text{Probability Density Function}
\]

Equation 8: Average Outcome using Integrals

While the Equation 8 is mathematically precise and unambiguous, it is also totally impractical. Instead we must instead use an approximate equation

\[
E(F) \approx F_{\text{No Risk}} - P_1C_1 - P_2C_2 - P_3C_3 \cdots - P_nC_n
\]

where

\[
P_n = \text{Probability of risky event "n" happening}
\]

\[
C_n = \text{Incremental Cost of risky event } P_n = F_{\text{No Risk}} - F_{P(n)}
\]

Equation 9: Average Outcome using an approximate method

For the model presented in this thesis the risky events identified are 1) slowdown, 2)shutdown, 3)currency fluctuation, and 4) Warranty Costs.
The $F_{\text{No Risk}}$ scenario does not represent the best case scenario, but instead the expected outcome when everything goes as planned. In this case $F_{\text{No Risk}}$ would represent a new supplier who had the same warranty costs, slowdowns and shutdowns as the current supplier, and the exchange rate would stay constant. The best case, on the other hand, would be when the new supplier suddenly had quality and delivery of 100%, and currency fluctuated in a very favorable direction. While the best case outcome may be an interesting number to calculate, it is not helpful for calculating the expected outcome in this model.
5.7.1 Additional Slowdown Risk Cost

Slowdown costs (section 5.7.1) and Shutdown costs (section 5.7.2) both measure the same thing in principle, the cost of disruptions to operations. Shutdown occurs when the supplier causes the plant, line, cell, etc to totally shut down. The resources sit idle. Shutdown might be caused by late deliveries or poor quality parts. With slowdown resources don’t sit idle. Instead, rescheduling or rework can make sure that productive work is done. Frequent unplanned schedule changes are inherently less efficient than following the original production plan.

Earlier versions of the model had both of these in one category, but piloting showed that users would tend to either think of the shutdown risk and ignore the slowdown risk, or they would think of the slowdown risk and ignore the shutdown risk. Shutdowns happen infrequently, but when they do happen they are quite costly. Slowdowns on the other hand happen much more frequently, but are less costly per incident. It is difficult to say which cost is more important on a probabilistic basis without checking some rough numbers.

The user may choose to estimate slowdown costs in many different ways depending on the situation. If a plant is running at or close to capacity, the user could approximate the slowdown cost as the cost to make up the lost production capacity with overtime shifts.

\[
\text{Slowdown Cost} \approx (\text{expected days of slowdown}) \times (\% \text{ efficiency loss}) \times \left( \frac{\text{Cost}}{\text{day of overtime}} \right)
\]

Equation 10: A method for calculating slowdown costs

The expected number of slowdown days is not an exact number. It is based on the chance of a slowdown, and the likely length of that slowdown. It is treated as a risk cost because we are uncertain about whether there will be any slowdown at all. Even for a plant that is not running at capacity, this might be a reasonable approach because it might come close to approximating the option value of having excess capacity. If the slowdown will cause future deliveries to customers to be late, one should also consider
the cost of the damaged relationship. The user should consider how much lost profit per year is caused by the damaged relationships. Estimating this is quite difficult and could easily merit an entirely separate research paper.

### 5.7.2 Additional Shutdown Risk Cost

Shutdown is much more serious than slowdown because more production capacity is lost and damaged customer relations are more likely. The user should consider whether or not idle employees can be sent home. For example when Ford temporarily shuts down a plant in Detroit, they are required to pay idle workers 95% of their take-home pay plus full benefits. In other cases employees can be sent home without pay. However in this case there is some cost associated with damaging employee relations and the ability to retain good people.

When long shutdowns lead to lost sales, the user needs to be careful about what figure is used to represent the lost sales. Considering lost revenue would overstate the loss because some of the variable costs such as raw material costs were not incurred. Considering lost profit would likely understate the loss because the firm still incurs all costs that are fixed in the short term, making historical profit margins irrelevant. Proper consideration of the cost of lost sales would include both lost revenues and reduced variable expenses.

When lost capacity can be made up with overtime, the user can use a method similar to the one used in calculating slowdown costs.

### 5.7.3 Additional Currency Risk Cost

Unlike slowdown risk and shutdown risk, currency risk does not fit perfectly into the form of Equation 9. Plant shutdowns and slowdowns are always negative, but currency fluctuations can be good or bad, but on average have a neutral effect. It would be incorrect to simply consider stable exchange rates as the no risk case, and an unfavorable currency shift as one of the scenarios. If one were to do this, they would have to consider favorable currency fluctuations as well.
Fortunately there is a market based price for currency risk. The cost to set up efficient currency risk hedges should be a good proxy for the cost of that risk. Efficient markets keep this price fairly accurate because those who feel the price is too high will sell the hedge, and those who feel the price is too low will buy the hedge. Even if the firm does not hedge, the cost of hedging is a good proxy for the cost of risk exposure.

There are many different ways to hedge, and it is important that we consider the most efficient way to hedge in our calculations. Considering inefficient hedging strategies will lead to erroneous results. This can be illustrated with an example. ABB plans to purchase goods in one year for 32 CNY from a Chinese supplier, and the current exchange rate is 8 CNY = 1 USD. This simplest, but not most efficient, way to hedge against currency risk would be to immediately exchange 4 USD for 32 CNY, and then keep the 32 Chinese Yuan for one year. Because the cost of capital for ABB is much higher than the interest they could earn in a risk-free account, they will effectively lose money while the 32 CYN is held for a year.

A much more efficient way to hedge would be with financial derivatives. A forward contract can be set up with an investment bank where the bank will pay ABB if the exchange rate moves unfavorably, and ABB will pay the bank if the exchange rate moves favorably. The contract can be set up such that ABB will have to pay exactly 4 USD in one year regardless of what happens with the exchange rate.

\[
\text{Payout(USD)} = \frac{32}{E_2} - 4 
\]

\(E_2 = \text{exchange rate in one year (CYN/USD)}\)

Note that if we assume that exchange rates are inherently unpredictable, and are just as likely to go up as they are to go down, the expected exchange rate one year from now will be the same as it is today, 8 CYN/USD. If this happens the payout will be equal to zero, and ABB will only pay 4 USD. If the exchange rate moves, then ABB will still only pay 4 USD, which can be shown in the equation below.
Before transaction fees, the cost of setting up this contract should be zero. The bank acts as a consolidator and eliminates its own risk by taking the opposition for other firms. In this case, it would be a combination of people, Chinese firms who have future obligations in USD and people who are speculating that the Chinese currency will become weaker relative to the USD. However, in practice there is a transaction cost that covers the bank's administrative costs, and ensures that the bank makes a profit. This transaction cost of setting up the hedge can be estimated as half of the bid-ask spread in the financial derivatives used, plus the brokerage fees paid.

\[
\text{Net Paymet(USD)} = (\text{Payment to supplier}) - (\text{Payment from bank})
\]

\[
= \left( \frac{32}{E_2} \right) - \left( \frac{32}{E_2} - 4 \right)
\]

\[
= 4
\]

5.7.4 Change in Annual Warranty Cost

ABB policy states that switching suppliers for cost cutting purposes must not come at the expense of quality. Therefore when users are asked what the quality cost of switching suppliers will be, they immediately reply that there will be no quality cost. However, when they are asked if it is more likely that there will be a quality problem tomorrow or the first day that we start using parts from the new supplier, they all have the same answer. It is more likely that there will be quality problems the day we start using parts from a new supplier.

Because of the explicit company policy, employees are encouraged to either reject new suppliers, or ignore the chance of quality problems during the transfer. One way to solve this problem in the model is to treat quality problems as a one time up front cost. The

\[\text{In the general case, the expected value of future exchange rates is not necessarily the same as the current exchange rate. For example, if one currency has systematically higher inflation on average then there will be a systematic trend in the exchange rate. One can observe the implied future exchange rate from currency derivatives that are traded on the open market. The cost of the hedge in this case will be the amount paid up front, plus the present value of the expected future payment to the bank.}\]

\[\text{The bid-ask spread represents the difference between the current lowest price that a seller has posted and the current highest price that a willing buyer has posted. Practically speaking, the bid-ask spread is never zero because as soon as that happens a sale is made, and then the remaining buyers and sellers define the new bid-ask spread.}\]
costs of poor quality can be entered in the up front investment section as a restructuring cost.

It should be noted that while warranty costs are the most obvious consequence of poor quality, there can also be a cost associated with poor quality, such as the cost of damaged customer relations.

5.8 Change in Annual Expenses: Other

There are often certain costs that don't fit clearly into any of the other expense categories. All of those costs should be entered here. This gives the user flexibility to analyze a much wider range of scenarios.

5.9 Change in Assets and Liabilities

Changes in assets and liabilities do not affect income, so they are often ignored in cost models. Changes in assets and liabilities do however affect cash flows and other performance ratios.

5.9.1 Change in Inventory Value

Accounting for changes in inventory value is more difficult than changes in other current assets because of the different conventions used in inventory theory which can cause confusion. In this model, changes in inventory will be treated the same as changes in any other short term asset or liability. We will consider the cash required/returned to increase/decrease inventory levels, and will not charge an annual holding cost based on the cost of capital. In the annual expense section the user should consider only the physical inventory holding costs, and in this section the user should enter the change in inventory value. The model will ensure that both the cost of capital and the physical holding cost will be considered.

5.9.2 Change in Accounts Receivable

Supplier changes are unlikely to change accounts receivable. If accounts receivable increases there is a one time cash decrease because this is similar to giving a loan to our
customers. If accounts receivable decreases, there is a one time cash increase because this is similar to customers paying back part of the loan we made to them in the past.

In practice, accounts payable can change when the volume of sales changes, or the payment terms given to customers change. The firm will require some customers to pay immediately, and will give other customers very long payment windows.

**5.9.3 Change in Accounts Payable**

Changes in accounts payable have no effect on the income statement, but will have cash flow implications. If accounts payable increases, there is a one time cash increase because this is similar to our suppliers giving us a loan. If accounts payable decreases there is a one time decrease in cash because this is similar to the firm paying back some of the loans that suppliers have previously extended.

In practice, accounts payable can change when the volume of purchase changes, or the payment terms from our suppliers change. Some suppliers require immediate payment, while others will accept payment up to 90 days after the goods are received.

**5.10 Tax Rate**

The tax rate refers to the marginal tax rate, and not the average tax rate. Business units that have a large tax loss carry forward will not have to pay any taxes in the short term, so a marginal tax rate of zero can be used. The method of calculating taxes is a simplification of the tax code, but it serves as a reasonable approximation.

---

18 Technically if a marginal tax rate of zero is used, the loss of real option value caused by consuming the tax loss carry forward should also be considered.

19 We are ignoring differences between financial accounting and tax accounting that can defer tax. We are also assuming that in years with losses, negative taxes will be paid. If we assume that the business will make a profit in the near future, then this is a good approximation. If the business will not make a profit in the near future, then this assumption is not very strong.
5.11 Model Output

When all of the appropriate estimates are entered into the model, the model outputs the net cash flows in graphical form (Appendix A). The model also outputs the NPV of the cash flows, and the payback period. To help understand where the value is being created or destroyed, the model breaks down the contribution to NPV into various components.

5.12 Chapter Summary

This chapter described how the model works, and what the user interface looks like. The input variables are explained. Some potential frameworks to estimate input variables are presented. The next chapter uses these concepts in a real example.
Chapter 6: Case Study – Copper Pins

This chapter applies the concepts developed in the previous chapter to a real example. The numbers and type of part have been disguised for confidentiality reasons, but the general lessons from the model remain the same.

6.1 Description of Scenario

In this example we will look at changing the supplier of a copper pin from a local US supplier to a low cost supplier in China. Table 3 summarizes the price quotes of the current supplier and the new supplier. Because of hidden costs, this information should not be used to determine which supplier will be the best choice. Instead, this information should be put into the model along with other information in order to guide the decision.

<table>
<thead>
<tr>
<th></th>
<th>Current Supplier</th>
<th>New Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>USA</td>
<td>China</td>
</tr>
<tr>
<td>Price per unit</td>
<td>$0.83</td>
<td>$0.31</td>
</tr>
<tr>
<td>Transportation</td>
<td>FOB supplier’s plant</td>
<td>FOB supplier’s plant</td>
</tr>
<tr>
<td>Annual Volume</td>
<td>200,000</td>
<td>200,000</td>
</tr>
</tbody>
</table>

Table 3: Supplier Choices for Copper Pins

To simplify the analysis, we will assume that ABB’s blue collar workers make $200/day with benefits and its white collar workers make $400/day with benefits. This translates to $15/hr and $20k worth of benefits for blue collar workers, and $80k annual salary with $20k worth of benefits for white collar workers. Engineers will be assumed to make $300/day.
6.2 Up Front Investment

Up front investments represent anything that is spent or forgone up front that will allow us to outsource from China.

6.2.1 New Capital Investment

Capital investments are quite straightforward. The supplier required ABB to pay for a mold at a cost of $1,200. The standard depreciation life for a mold is 3 years.

<table>
<thead>
<tr>
<th>New Capital Investment/Sales</th>
<th>$1,200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation life (years)</td>
<td>3</td>
</tr>
</tbody>
</table>

6.2.2 Other Restructuring Costs

Even though the mold purchase is the only item that can be explicitly allocated to the change in supplier, it is not the only cost associated with changing suppliers. We must consider all relevant switching costs. In this case, the hidden switching costs are much larger than the non-hidden cost of purchasing the mold.

Before ABB can use the new supplier, ABB must complete a supplier qualification, get parts through sample approval, and update their engineering drawings. Unlike the mold, we can not easily determine the cost of these activities, but a reasonable estimate will be better than an assumption of zero.

The supplier qualification will likely involve two trips to China. We can assume that two people will go on each trip, and that they will visit 5 suppliers over two weeks. A two week trip will cost about $7,500/person including flight, hotel, meals, and other expenses. In addition to the items that show up on the expense report, we also need to consider the time people spend on the vendor qualification both in China and in the US. It will take about 20 person days to complete the vendor qualification.
Supplier Qualification Costs

\[ \text{Supplier Qualification Costs} = \frac{7,500 \cdot (2 \text{ trips}) \cdot (2 \text{ people})}{5 \text{ suppliers}} + (20 \text{ days}) \left( \frac{400}{\text{days}} \right) = \$14,000 \]

Sample approval will probably take four person days of engineering time, and updating engineer drawings will take 1 day.

\[ \text{Sample Approval Costs} = (5 \text{ days}) \left( \frac{300}{\text{day}} \right) = \$1,500 \]

In this case, other restructuring costs equal approximately, $15,500. However, it is important to note that supplier qualification, sample approval, and engineering updates are not the only types of costs that should be considered. Depending on the situation, there may be other types of costs to consider.

Other Restructuring Costs | $15,500

6.3 Change in Revenue

In this case there will be no change in revenue.

Change in annual revenue | $0

6.4 Change in Annual Expenses: Material

6.4.1 Change in Cost of Raw Materials

Change in raw material cost is straight forward. It is the main driver for switching to a low cost supplier.

\[ \Delta \text{Raw Material Cost} = (\text{New Annual Materials Cost}) - (\text{Old Annual Materials Cost}) \]
\[ = (2000\text{parts}) \cdot (\$0.31) - (2000\text{parts}) \cdot (\$0.83) = -\$104,000 \]

Change in Cost of Raw Material | -$104,000
6.4.2 Change in Transportation Cost

With the old supplier, a truck delivered 4000 parts about once a week at a cost of $150 per delivery. In this case, the supply chain manager estimated that we would require four shipments a year. Each shipment would come close to filling a sea container at a cost of $4,000 per sea container. When the sea container arrived at the port in the US, it would cost $1,000 to ship the goods to the warehouse via truck.

\[
\text{Old Shipping Cost} = \left( \frac{150}{\text{shipment}} \right) \cdot \left( \frac{50 \text{ shipments}}{\text{year}} \right) = 7,500
\]

\[
\text{New Shipping Cost} = \left( \frac{4000 + 1000}{\text{shipment}} \right) \cdot \left( \frac{4 \text{ shipments}}{\text{year}} \right) = 20,000
\]

\[
\Delta \text{Shipping Cost} = 20,000 - 7,500 = 12,500
\]

Shipping more than four times a year would allow for lower inventories, but if we received shipments more than four times a year, we would still have to pay the full cost of the sea container. Transportation costs could become too high. It would be possible to coordinate with other ABB plants and consolidate two partial shipments into one sea container. However this seemed difficult and unlikely to happen in the short term. It was felt that we should not depend on this future consolidation to justify the change of suppliers.

| Change in Transportation Costs | $12,500 |
6.4.3 Change in Duties Costs

No duties are paid to the current US supplier. The duties charged on this part would be 2.7\%^{20}, plus a $120 clearance fee on each shipment.

\[
\Delta \text{Duties Cost} = \left( \frac{\$0.31}{\text{part}} \times 200,000 \text{ parts} \times 2.7\% \right) + \left( \frac{\$120}{\text{entry}} \times 4 \text{ entries} \right) - 0 = 2,154
\]

| Change in Duties Costs | $2,154 |

6.4.4 Change in Inventory Carrying Costs

Initially the supply chain manager estimated that inventory would need to increase from two weeks to four weeks. After introducing the Cycle Stock and Safety Stock framework as discussed in section 5.5.4, the estimates become more realistic. Because the delivery period increased from 1 week to 13 weeks, the cycle stock mechanically increased from 0.5 weeks to 6.5 weeks. Note that cycle stock alone is greater than the initial estimate for total inventory. This shows the power of using the cycle stock / safety stock framework.

Currently 1.5 weeks of safety stock is being held. When the lead times become 13 times as long, it is estimated that safety stock will go up to about 7 weeks. Therefore total inventory would increase from 2 weeks to 13.5 weeks.

The physical cost of holding inventory can be estimated by the amount of space it takes up. With the new supplier, ABB will need to hold an additional 11.5 weeks of inventory which equates to 46,000 parts. Each rack space can hold 1,000 parts, therefore the plant will need an additional 46 rack spaces. Based on the costs of the building, the amount of space a rack occupies and the amount of labor dedicated per rack space, we estimate that each rack space costs $110/year.

\[
\Delta \text{Physical Holding Cost} = (46 \text{ rack spaces}) \times \left( \frac{\$110}{\text{rack space}} \right) = $5,060
\]

---

^{20} This includes the MPF and the HMF (Merchandise Processing Fee and Harbor Maintenance Fee)
Normally inventory calculations include the cost of capital tied up in inventory. This will be accounted for in the “Change in Assets & Liabilities section”.

| Change in Inventory Carrying Cost | $5,060 |

### 6.4.5 Change in SCM Costs

When dealing with a Chinese supplier there will be cultural differences, language barriers, time zone problems, and increased paperwork required. This will cause ABB supply chain employees to spend more time managing the relationship with the supplier and dealing with daily problems. On average, a supply chain person will need to spend an extra two days a month dealing with issues caused by the problems mentioned above.

**Personnel Cost**

\[
\text{Personnel Cost} = (\frac{2 \text{ days}}{\text{month}} \times 12 \text{ months}) \times \left( \frac{\$400}{\text{day}} \right) = \$8,400
\]

In addition to the daily issues, four supplier visits per year will likely be made. Two ABB employees will go on each trip, and they will visit a total of 5 suppliers on each visit.

**Travel Cost**

\[
\text{Travel Cost} = \frac{\$7,500}{\text{person \cdot trip}} \times 2 \text{people} \times 4 \text{trips} \times \frac{1}{5} = \$12,000
\]

| Change in SCM Cost | $20,400 |
6.5 **Change in Annual Expenses: Production**

Normally supplier changes do not affect production costs in any way, however in this case there was a change. The old supplier was not able to make the copper pin long enough, and had to make two pins that were manually screwed together at the ABB plant. The new supplier had better production capabilities, and is able to make the pin in one piece. It takes about 20 seconds to screw together the two pieces which means that for 200,000 parts a year we save a total of 139 working days, where a working day is defined as 8 hours. It should be noted, that extra care needs to be taken when the new supplier is supplying a part that is different in some way. Supply chain personnel may not have the technical or operational knowledge to realize that the cheaper part is somehow inferior or incompatible.

\[
\Delta \text{direct labor cost} = (-139 \text{ days}) \times \frac{200\text{ }}{\text{day}} = -27,800
\]

There are no changes to energy costs, rent, or other production expenses.

<table>
<thead>
<tr>
<th>Change in Energy Cost</th>
<th>$0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Rent for Production</td>
<td>$0</td>
</tr>
<tr>
<td>Change in Manufacturing Labor</td>
<td>-27,800</td>
</tr>
<tr>
<td>Change in Other expenses</td>
<td>$0</td>
</tr>
</tbody>
</table>
6.6 Change in Annual Expenses: Risk

6.6.1 Additional Slowdown Risk Cost

In this case we expect to have about one additional day of problems per month with the new supplier, and we expect that production efficiency will be decreased by 15% on slowdown days. The lost production will be made up by using overtime shifts costing $13,500.

\[
\text{Shutdown risk cost} = \left( 12 \frac{\text{slowdown days}}{\text{year}} \right) \times \left( 15\% \times \frac{\$13,500}{\text{day}} \right) = \$24,300
\]

| Additional Slowdown Risk Cost | $24,300 |

6.6.2 Additional Shutdown Risk Cost

Shut downs happen much less frequently than slow downs, but they can have large consequences. It was estimated that over ten years this particular supplier might shut down the plant once. This must be a shutdown that the previous supplier would not have caused. For example, if the new supplier is overseas and the current supplier is domestic, the sea container holding the pins falling off the ship would count as an additional risk that ABB is now exposed to. However, if the supplier could not ship pins due to a worldwide copper shortage, this would not represent an increase in risk. We must further assume that having no pins from this supplier would shut down the ABB plant because they would not be able to make any product.

One additional shutdown over ten years can be represented as a 10% chance of shutdown in any given year. In this case, the shut down could simply be made up with overtime labor. It was not felt that there would be any significant adverse effect on customer relations. This particular supplier could only shut down part of the plant, instead of a slowdown which was assumed to affect the whole plant. The cost of running an overtime shift in this case would be $4,500.
\[
\text{Shutdown Cost} = (10\% \text{ chance of shutdown}) \times \left( \frac{\$4,500}{\text{shutdown}} \right) = \$450
\]

| Additional Shutdown Risk Cost | $450 |

*In this case, the cost of shutdown was quite low, because we assumed that we could simply make up the production with overtime, and there would be no lost revenue or damaged customer relationships. It might have been useful to consider the scenario where the supplier shuts down the ABB plant for two weeks. At this point, it is not as simple as making up lost production with overtime. The users in this case felt that a two week shutdown would never occur.*

**6.6.3 Additional Currency Risk Cost**

During this pilot, the users felt strongly that the Chinese Yuan was so stable with the US dollar that there was no currency risk. They felt that because the Chinese government controlled the currency, that there was no risk involved.

| Additional Currency Risk Cost | $0 |

*Just because the government has been controlling currency in the past, it does not mean that they will continue to do it in the future, especially as Chinese markets become more open. To put things in perspective, before 1950 the Canadian dollar traded at a fixed exchange rate relative to the US dollar.*

In hindsight, we can now look at the exchange rate history and see that the Chinese government did in fact let the Chinese Yuan move. Ironically, the Yuan had already started to move when this analysis was conducted, but because of the belief that the Yuan was so stable, nobody actually looked it up.*
One could also consider operational hedging, where a local supplier could be used in the case of future unfavorable exchange rates. The cost of the operational hedge would include the premium on any parts purchased.

### 6.6.4 Change in Annual Warranty Cost

The users in this pilot felt that there would be no decrease in quality with the new supplier.

| Change in annual warranty cost | $0* |

*See section 5.7.4 for a discussion of why managers might be incentivized downplay the risk.
6.7 *Change in Annual Expenses: Other*

In this case, not only would there be extra work for supply chain personnel, but there would also be extra record keeping work for accounting. The international aspect of the new suppliers makes record keeping more difficult and time consuming. It was estimated that an extra two days a month would be required.

\[
\Delta \text{Other Exp} = \left( \frac{2 \text{ days}}{\text{month}} \times 12 \text{ months} \right) \times \frac{\$400}{\text{day}} = \$9,600
\]

<table>
<thead>
<tr>
<th>Change in Sales Expense</th>
<th>$0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in G&amp;A Expenses</td>
<td>$9,600</td>
</tr>
<tr>
<td>Change in Other Expense</td>
<td>$0</td>
</tr>
<tr>
<td>Change in Other Income</td>
<td>$0</td>
</tr>
</tbody>
</table>
6.8 Change in Assets and Liabilities

6.8.1 Change in Inventory Value

As we determined in section 6.4.4, inventory would increase from 2 weeks to 13.5 weeks (8,000 parts to 54,000 parts)

\[
\Delta \text{Inv Value} = (54,000 \text{ parts}) \left( \frac{$0.31}{\text{part}} \right) - (8,000 \text{ parts}) \left( \frac{$0.83}{\text{part}} \right) = $10,100
\]

Many users multiplied the change in units of inventory by $0.31 to calculate the change in inventory value, but they forgot to include the fact that although we have more units of inventory from the new supplier, each unit of inventory costs less. This is an easy mistake to make.

<table>
<thead>
<tr>
<th>Change in Inventory Value</th>
<th>$19,00</th>
</tr>
</thead>
</table>

6.8.2 Change in Accounts Receivable

There will be no change on how our customers pay us

<table>
<thead>
<tr>
<th>Change in Accounts Receivable</th>
<th>$0</th>
</tr>
</thead>
</table>
6.8.3 Change in Accounts Payable

Accounts Payable represents the average amount that the company owes its suppliers at any given time. In this case the change in accounts receivable reflects the changes for both the new supplier and the new transportation methods. The old parts supplier required payment in 60 days, but the new supplier requires payment in 30 days. Transportation payment period is constant at 21 days in both cases.

\[
\begin{align*}
\text{AP (old supplier)} &= \left( \frac{200,000 \text{ parts}}{\text{year}} \times \frac{0.83}{\text{part}} \right) \times \left( \frac{60 \text{ days}}{365 \text{ days}} \right) = \$27,288 \\
\text{AP (old transport)} &= \left( \frac{15,000}{\text{year}} \right) \times \left( \frac{21 \text{ days}}{365 \text{ days}} \right) = \$863 \\
\text{AP (new supplier)} &= \left( \frac{200,000 \text{ parts}}{\text{year}} \times \frac{0.31}{\text{part}} \right) \times \left( \frac{30 \text{ days}}{365 \text{ days}} \right) = \$5,096 \\
\text{AP (new transport)} &= \left( \frac{30,000}{\text{year}} \right) \times \left( \frac{21 \text{ days}}{365 \text{ days}} \right) = \$1,726 \\
\Delta \text{Accounts Payable} &= (\$5,096 + \$1,726) - (\$27,288 + \$863) = -\$21,329
\end{align*}
\]

| Change in Accounts Payable | $21,329 |

6.9 Global Variables

The marginal tax rate for this business is 35%, and the specified WACC is 15%.

| Tax Rate | 35% |
| WACC (Interest Rate) | 15% |
6.10 Analysis of Model Output

The model output is shown in Figure 8. Because the NPV is positive, and the project has a quick payback\(^1\), this is a good project and it should be accepted. Before investing, it would be a good idea to run scenario analysis, to make sure that the model is not overly sensitive to a few inputs.

\[\text{Figure 8: Model Output}\]

Normally we might expect to see a negative effect on cash flow up front due to investment, and then steady positive cash flows in all subsequent periods while the firm reaps the benefit of the supplier change. However, in this case we see two consecutive periods of diminished performance. The first period represents the up front investment,

\[^1\] In theory the payback is irrelevant to the investment decision. Only NPV should be considered. However because we did not account for the increased uncertainty as projections more farther into the future, short paybacks might be desirable. Also, requiring short paybacks also helps to mitigate the incentive of managers to make hockey stick projections, where the project shows little returns until some time in the future where it has a huge payout.
and the second period represents the first year of purchasing from the new supplier. There is a one time hit to cash flow in the first year caused by increased inventory and decreased accounts payable.

The breakdown of NPV shows us what the major cost drivers are. For example we see that risk costs are much more important than up front investments. This is helpful because we know that on a percentage basis we can tolerate much more estimation error in investment costs than in risk costs. When running scenarios, we can probably leave investment cost constant.

These results can be compared to rules of thumb that ABB has used in the past, where hidden costs are estimated as 40% of part price, and only savings in the first year are considered.

\[
\begin{align*}
\text{Raw Savings}_{\text{OLD METHOD}} &= ($0.83 \times 200,000) - ($0.41 \times 200,000) = $104,000 \\
\text{Hidden costs}_{\text{OLD METHOD}} &= 0.83 \times 200,000 \times 40\% = 66,400 \\
\text{Total Project Value}_{\text{OLD METHOD}} &= $37,600
\end{align*}
\]

**Equation 11: Calculation of project value using rules of thumb**

In this case the 40% rule understated the value of the savings. This might explain why ABB has been underutilizing suppliers in low cost countries.

### 6.11 Chapter Summary

This chapter demonstrated how the model can be used with a real example. It showed how the user could make estimates without having extensive amounts of data. The output of the model showed that the proposed sourcing project is a good project.
Chapter 7: Conclusions

7.1 Benefits of the Model

The model allows users to make much better sourcing decision than the previous 40% rule of thumb. The model presented in this thesis and the 40% rule of thumb gave a roughly similar result for the copper pin case study. However this will not be true in all cases. For example when certain fixed costs do not scale with volume or part price, the percentage of hidden costs will vary with volumes. The gold bar example in section 1.2 showed how this rule can lead to extremely inconsistent results.

The model is excellent for communicating results because the inputs and outputs are clearly visible. Unlike most NPV calculations, there is not a single output, but instead a break down of cost and cost savings into easily recognizable categories. This makes it easier for others to focus on the largest cost drivers, or alternatively discuss cost drives that should be important but do not seem to play a large role in the model.

Full costs calculations are generally not simple, and all models will have some room for error. This model relies heavily on the opinion of the user. However, this model has some built in mechanisms to contain these errors. First, because almost all of the inputs are in dollars, if one cost stands out above the rest, it will be very apparent. In contrast, other models that ask for various inputs in different units can lead to errors that are difficult to spot. For example, if the annual volume is entered in units of thousands of parts instead of units of parts, large errors can occur. Second, because of the way the model is laid out, it serves as a check list. It ensures that even if users do not calculate all costs perfectly, at least they will consider all of the relevant cost categories.
7.2 Lessons learned

There is a tradeoff between a) amount of user knowledge required, b) accuracy, c) number of inputs, and d) variety of applicable audience. Most attempts to reduce the need for user knowledge by adding calculation capabilities to the model resulted in a greatly increased number of inputs, or a greatly reduced applicable audience. Given the number of factors that are simultaneously being balanced in model design, it is not surprising how many different models are available for supplier selection.

While technical accuracy is important, it is not the most important factor. The model must be accepted, and used properly. To gain acceptance, a significant amount of time was spent formatting the user interface and choosing variable names in a way that users found intuitive. Also the use of familiar accounting categories helped users to feel comfortable with the model. To ensure that the model will be used properly, the incentive issues for the users need to be considered. Asking managers to take actions based on one model, but then rewarding based on a different model can cause problems.

In order to deal with the complexity of supplier selection, it was common for users to create simple mental models that only considered one or two variables. In some scenarios these one or two variables might have been the most important factors, but the simple model can not be well generalized to all scenarios. Simple mental models can lead to large errors. The simple one page layout of the model presented in this thesis enabled users to see a comprehensive list of factors simultaneously.

Even when perfect data is not available, as with the copper pin example, estimates can give the user a feel for what factors are important. When one ignores certain costs, an assumption is still being made. The assumption is that the cost is zero instead of the actual best estimate. This model empowers users to make estimates even when they do not have perfect data.
7.3 Future Work

The model is currently in working condition. Future work should focus on spreading and improving the model. Because the model gives much better results than the 40% rule of thumb, wide spread use could allow ABB to make significantly better sourcing decisions. However, to spread the model effectively, the model needs a champion. Currently there are only limited resources committed to supporting the model.

The current owner of the model is a single person who has not been assigned any additional time to support the model. That person does not have an incentive to widely distribute the model because it will greatly increase their work load. This is unfortunate, because the more people that use the model throughout the organization, the easier it will be to compare projects and compare best practices.

User feedback and data could help to improve the model further. For example, a catalog of standard examples could be developed. This would give users a good starting point, which will reduce their work load and allow for more accurate and consistent results.

More research could be done about how to better estimate risk factors. The risk estimations in this model were very subjective. Data on labor disruptions, hurricanes, hedging fees, etc could help to quantify the cost of risks better.
### Appendix A  
**Main Input/Output Screenshot**

#### Inputs
- **WACC** (Weighted Average Cost of Capital) Interest Rate: 10%
- **Tax Rate**: 35%
- **Change in Accounts Payable**: $2,379
- **Change in Inventory**: $23,000
- **Change in Accounts Receivable**: $9,650
- **Change in Cost of Raw Material**: $24,300
- **Change in Transportation Cost**: $27,640
- **Change in Other Expenses**: $27,000
- **Change in Depreciation**
- **Change in Other Restructuring Costs**: $36,000

#### Outputs
- **Net Present Value (NPV)**: $89k
- **Payback Period**: 1.5 years
- **Cash Flows after Tax**:
  - Year 1: $30
  - Year 2: $10
  - Year 3: $30
  - Year 4: $30
  - Year 5: $30

#### Breakdown of NPV
- **Asset/Liability**: $37
- **Other Cost**: $24
- **Risk Cost**: $67
- **Production Cost**: $56
- **Revenue**: $23

#### Relevance
- **Relevance**: 1
- **Breakdown of NPV**

#### Remote Usage
- **Local Input**: $12,600
- **Remote Input**: $15,500
### Remote Input – Invest or Sell

<table>
<thead>
<tr>
<th>Sales of Equipment, Buildings, etc</th>
<th>Investments (Capitalized or Expensed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td>Depreciation Life Remaining</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

#### Cash Flows (After Tax)

<table>
<thead>
<tr>
<th>NPV (Investment)</th>
<th>$317,249</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$30,000</td>
</tr>
<tr>
<td></td>
<td>$8,000</td>
</tr>
<tr>
<td></td>
<td>$37,350</td>
</tr>
<tr>
<td></td>
<td>$10,000</td>
</tr>
</tbody>
</table>

#### Costs

<table>
<thead>
<tr>
<th>Extra tax paid</th>
<th>Loss on Sale</th>
<th>Cash invested</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8,000</td>
<td>$37,350</td>
<td>$30,000</td>
</tr>
</tbody>
</table>

### Appendix B
Appendix C  Inventory Equations

Note: All “time” measures are converted to days, and all “per time” measurement are converted to “per day” for consistency but these conversions are not shown here.

- \( \sigma_D = \text{Stdev of demand} \approx \frac{\pm \text{range}}{4} \)  
  
  assume that people typically quote +/-2stdev as the +/- range

- \( \sigma_{LT} = \text{Stdev of Lead Time} \approx \frac{\pm \text{range}}{4} \)

- \( z = \text{NORMIV}(\text{service level}, 0, 1) \)

- \( H = \text{Holding Cost} = (\text{Unit Cost}) \cdot (\text{Holding cost %}) \)

- \( Q = \text{Order Size} = \text{MIN} \left( \frac{\text{Min Order Size}}{2} \left( \frac{\text{Order Cost} \cdot (\text{Quantity Used})}{\text{Holding Cost}} \right) \right) \)

- \( \text{Safety Stock} = z \cdot \sqrt{LT \cdot \sigma_D^2 + D^2 \cdot \sigma_{LT}^2} \)

- \( \text{Pipeline Stock} = \frac{Q}{2} \)  
  (This depends on who own the inventory while in transit)

- \( \text{WIP} = \text{Unaffected by changes in sourcing} \)

- \( \text{FGI} = \text{Unaffected by changes in sourcing} \)
References


ix Alex Taylor III, "Behind Ford's scary $12.7 billion loss", *CNN Mone.comy*, January 26 2007

x Various, 'Canadian dollar", *Wikipedia*, March 27, 2007

xi http://finance.yahoo.com/