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A Quantitative Approach to the Identification and Prediction of Supply Chain Agility

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of Supply Chain Agility

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ABSTRACT

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of Supply Chain Agility

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As the product-release cycle in the tech industry speeds up, there is more pressure on manufacturers to bring new products to market faster than ever. This puts a great deal of pressure on the suppliers of capital equipment used to manufacture these tech products. The supply chain agility of these suppliers is increasingly important. The purpose of this study is three-fold (1) to develop a methodology that can be used by any firm for measuring and ranking the agility of suppliers and finding the root causes of supplier agility, (2) to develop the first-ever fully quantitative measure of supply chain agility, and (3) to test if the supply chain management practices that are associated with agility in the academic literature are truly correlated with supply chain agility.

Using the outlined methodology in this paper, the data suggest that the customer's current system and processes adequately met the need for short-notice, expedited build times. However, many processes and communications between the suppliers and customer have a lot of room for improvement that may positively impact the supply chain agility of suppliers. Since most every firm captures this same data, such as PO create dates and supplier ship dates, any firm can and should replicate this analysis to discover their suppliers' unique drivers of supply chain agility.

Each supplier's historical agility was measured and ranked using historical order performance data. This agility score is the first of its kind to measure agility without the use of qualitative factors or self-reported measures of agility.

Only three of the supply chain survey questions developed from or borrowed from the academic literature were correlated with supply chain agility in this study. Survey responses regarding the frequency of communication and information sharing are two examples of variables that were not associated with supplier supply chain agility. The only survey question response that was found to be positively correlated with supply chain agility involves the agile practice of delayed product differentiation. Contrary to the literature, two questions involving supplier-customer communication and the linking of order management system were found to be negatively correlated with supply chain agility. In regards to the non-survey, historical data, the independent variables that were correlated with agility highlighted the need for improved systems and processes between the suppliers and customer. Two examples of processes and systems that need improvement are expedited build time requests and PO swaps.

Keywords: agility, supply chain, agile manufacturing, supply chain management, agility assessment, build time

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1 INTRODUCTION

1.1 Background

In the technology manufacturing industry, the product release cycle is speeding up. The fastest technology firms take as little as two quarters to get from idea to market because consumers want to buy the latest phones, tablets, and other tech devices on a faster and faster cadence and because there is an exponential deterioration in forecast accuracy beyond two quarters (Kempf, 2012). Those companies that cannot satisfy the market with quick product release cycles are finding it harder and harder to compete. For this reason, there is mounting pressure on the capital equipment suppliers of these technology firms to be agile in order to build the capital equipment that goes into the factories of their customers to make tech products in ever-shorter lead times and to meet a large number of short-notice, expedited build times.

If we assume that the build times of a capital equipment supplier for any one product falls into a normal distribution with contracted lead time at approximately the 96 percent confidence level (which aligns with the data), we see that these suppliers are now expected to ignore the contracted build time and deliver product all along the bell curve distribution of build times (see Figure 1-1).

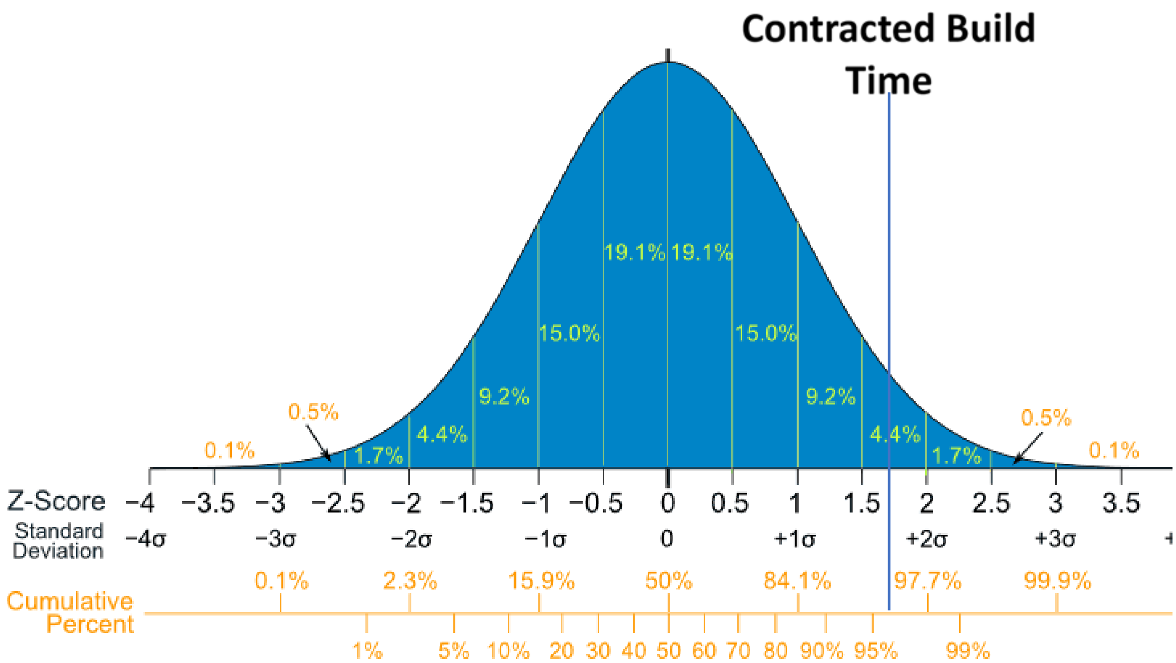


Figure 1-1: Supplier Build Time Distribution

Prior to this study, the customer assumed that when no formal notice was given to the supplier through the customer's ordering system, this would cause the orders to take longer to build. However, it was found that purchase orders (POs) with no formal forecast notice (i.e., late POs) and the shortest requested build times had by far the shortest actual build times (See Figure 1-2). This is the result of an effort across all suppliers to be agile and to build to the requested build time and not to the contracted build time. For example, in the figure below it is clear that the unforecasted POs (in blue) are built in much shorter build times than forecasted POs (i.e., POs with prior forecast notice (in red)).

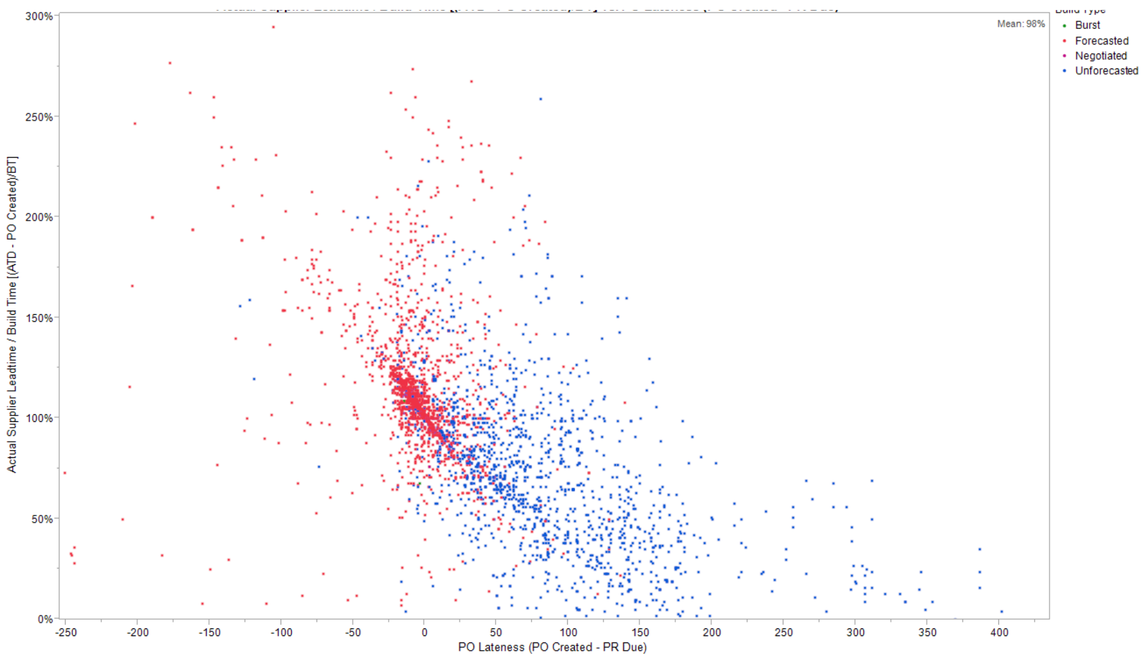


Figure 1-2: PO Lateness vs Actual Build Time / CBT

It was found that some of these suppliers have developed the agility to build to their customer's unanticipated, expedited build times, while other suppliers have less agility. In the figures below, we can see the performance of a more agile supplier vs. the performance of a less agile supplier. The actual build times of an agile supplier, more frequently than not, match the requested build times of the customer, no matter how short the requested build time. In the figure below, the fewer deviations from a straight, 45 degree, diagonal line indicate agility. Whereas, the non-agile supplier, who is unable to meet requested build times has a great number of deviations from requested build time. The line representing a non-agile supplier does not appear as a straight diagonal line.

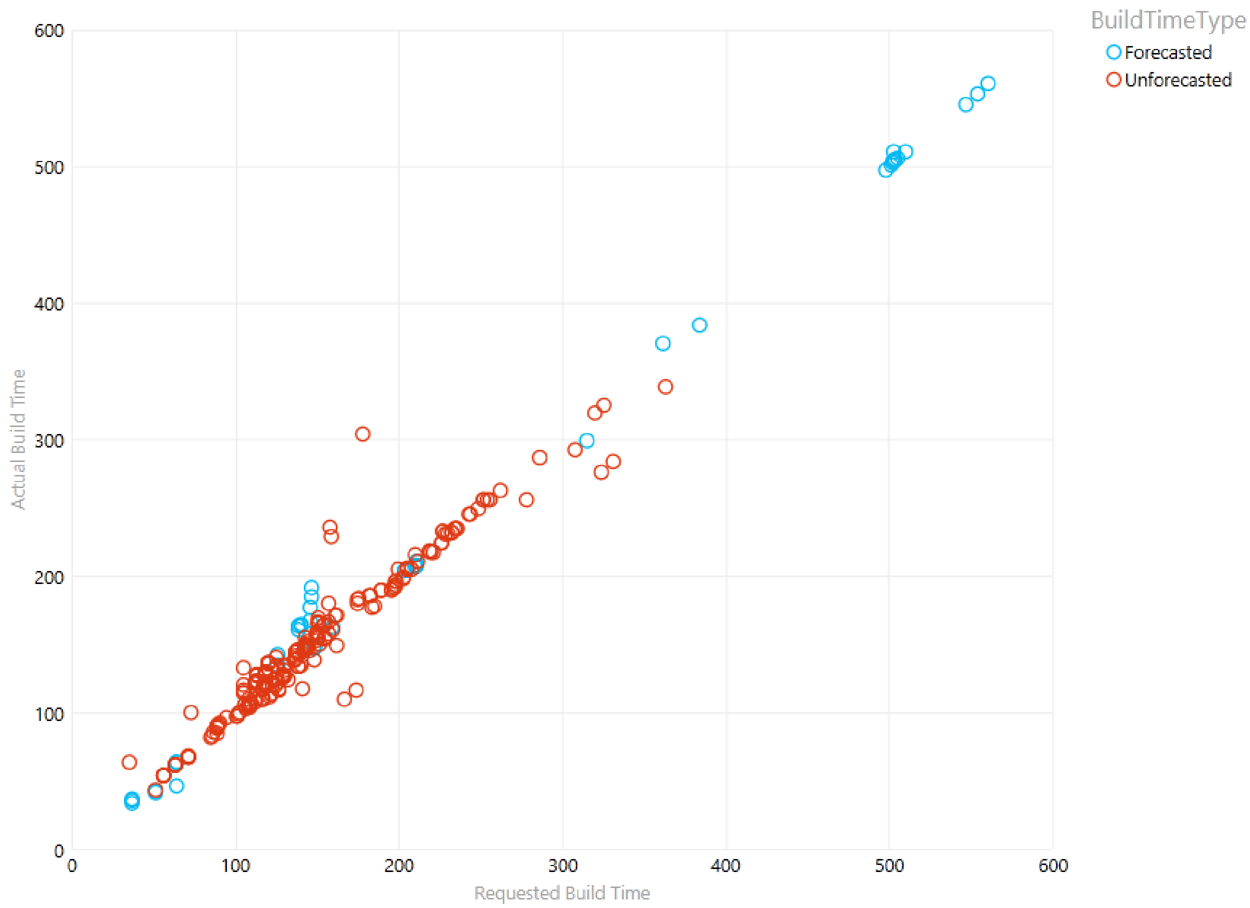


Figure 1-3: Very Agile Supplier

1.2 Problem Statement

As we can see in Figure 1-3 and Figure 1-4, the supply chain agility of a supplier is well represented in an x, y graph. However, suppliers cannot be ranked or compared using x, y graphs. For this reason, a mathematical equation was developed to score agility and determine the average deviation from perfect agility for each supplier.

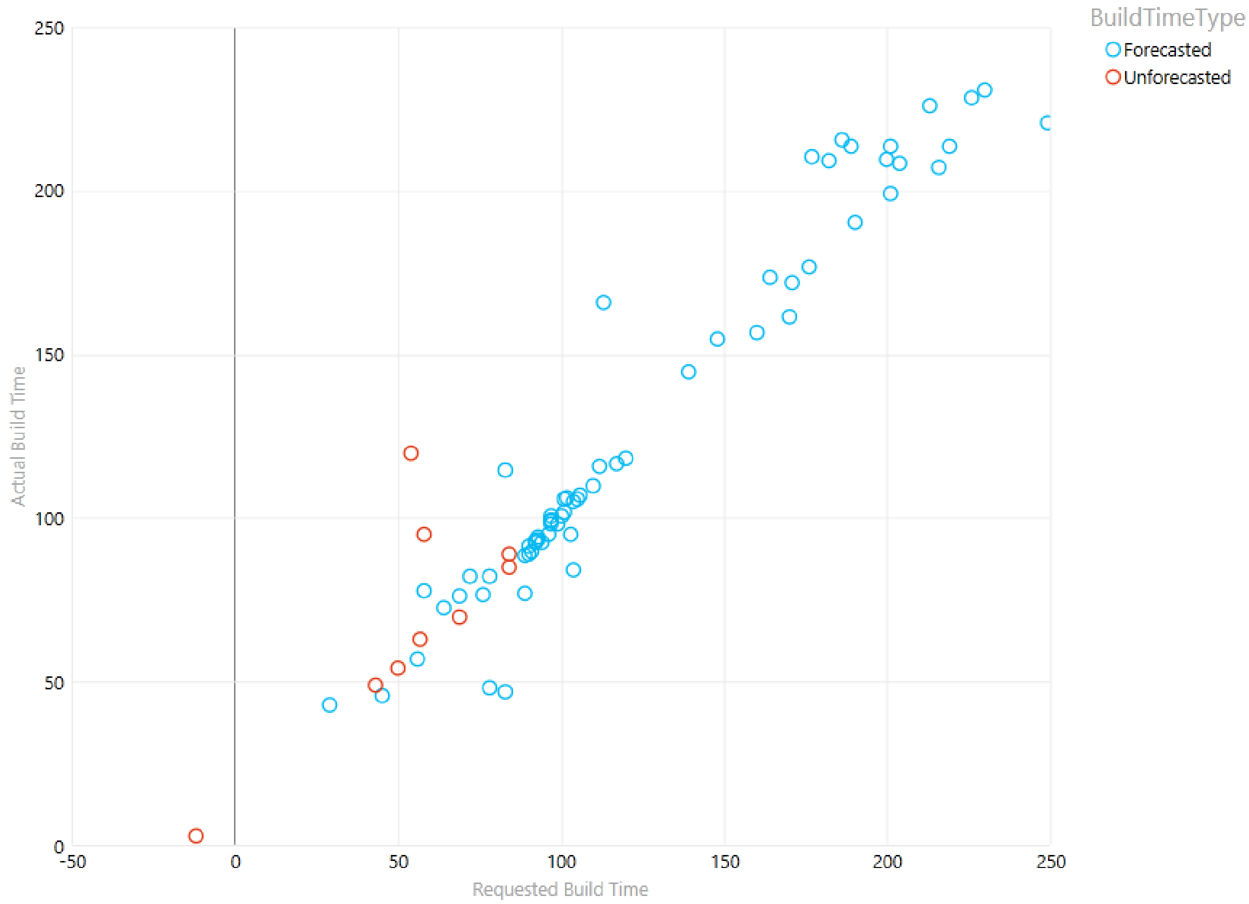


Figure 1-4: Less Agile Supplier

Next, a number of mostly customer-driven variables were evaluated for their impact on supplier agility. These variables are found in the data collected for over 2,000 recently shipped orders of new capital equipment. The purpose of this portion of the analysis is to test Hypothesis 1 and to understand what share of supplier agility is driven by the customer and what share is driven by the supplier. Understanding those processes and communications that are statistically correlated with supply chain agility and which are driven by the supplier versus the customer is valuable for interpreting the agility score of each supplier. In the next portion of the study, suppliers will be surveyed to discover supplier-driven supply chain management practices that are unable to be found in the internal data. Finally, the agility scores of nine suppliers will be evaluated against the customer-driven variables found to have an impact on supplier agility and against the supply chain management practices of the suppliers from the survey responses. This final analysis will give deeper insight into the potential root causes of agility scores, will support recommendations for managers and academics on the supply chain practices that may lead to supply chain agility, and will serve as a template and methodology for other firms to gain the same insights with their own suppliers.

1.3 Hypothesis

Supplier agility scores and actual build times are statistically correlated with the responses to each of following supply chain agility survey questions and with each of the following historical performance element:

- We receive the type of information from our customer that enables our sales forecasts to anticipate demand.
- Our sales forecasts are enabled by the timely receipt of information from our customer.
- We attempt to anticipate our customer's demand even before the release of a customer's forecast or PO.
- How often do you and your customer have formal meetings about capital orders?
- How often do you and your customer communicate by phone about capital orders?
- How often do you and your customer communicate through email about capital orders?
- Do you and your customer currently share operations planning information?
- Do you and your customer currently share forecast demand and sales information?
- Are your order management systems currently linked to that of your customer?

- When a late PO is released to your firm by your customer, what percentage of the time does your firm begin building the tool before you receive the PO?
- When a PO is released with no forecast notice to your firm, what percent of the time is the PO a complete surprise?
- At what percent of the way through the build does the tool become unique to your customer?
- Forecast notice before PO
- Requested build time (RBT)
- RBT change after the PO is created
- Contracted build time (CBT)
- Order expedite request
- PO Value change; number of days after PO created
- PO Swap; number of days after PO created
- Complexity of configuration

1.4 Contribution of This Study

Currently, there is no fully quantitative mathematical score of supply chain agility for measuring the agility of a firm's suppliers. Some studies have calculated firm agility scores from qualitative survey data measuring things like flexibility, collaboration, integration and market sensitivity using methods like "fuzzy logic" and IF-THEN rules (Vinodh, 2011; Calvo, 2008; Vinodh, 2012). However, this research paper is the first attempt to create a fully quantitative measure of agility using historical order data.

A second contribution of this study is a statistical analysis of the customer-driven variables that impact a supplier's actual build times. The analysis controls for the CBT, RBT, changes to RBT, and then identifies many other customer-driven processes and communications that are correlated with supplier ABT. The existing supply chain agility literature focuses primarily on the supplier's processes and communication, while this research also looks into the impact of the customer's processes and communications on a supplier's agility.

A third contribution of this study is that it is the first to conduct a correlation analysis between (1) agility scores, (2) survey results concerning supplier supply chain practices, and (3) the data collected for over 400 fulfilled orders of new capital technology equipment to determine statistical correlation between supplier supply chain management practices, customer impacts, and supply chain agility.

1.5 Assumptions

- Historical performance is an indication of present supplier supply chain agility.
- The existence or non-existence of supply chain practices can be determined by surveying the main contacts involved in the purchase of every capital product purchased by the customer.
- The supplier's agility for this one customer is a representation of the supplier's supply chain agility across all its customers.
- Contracted build time is a representation of a supplier's confidence level to meet a specific percentage of on-time delivery. If suppliers are padding or overcommitting contracted build times then agility is impacted.

1.6 Definitions

- % Expedite Requested = the percent of orders where the customer requests that the builder expedite the build time because it is critical to the customer
- Actual Build Time (ABT) = Actual Ship Date minus PO Created Date for an order
- Avg of RBT at Time of PO / CBT = the average RBT/CBT at the time the PO was created; this metric does not account for the changes to RBT/CBT after the PO is created
- Build Time* = contracted build time
- Capacity Process = the process generation of manufacturing
- Complexity of configuration (TPOC) = a measurement of configuration complexity measured by the number of gas and electrical connections of a capital tool purchased from a supplier
- Contracted build time (CBT) = the build time agreed upon during contract negotiations as the "never later than" date. Products with longer than contracted build time are often charged a penalty by the customer for lateness
- Critical A = a label given to an order where the customer requests the supplier expedite the build time
- Forecast Visibility/CBT = the number of days of formal notice of a PO before it is created, divided by contracted build time
- PO $ Change Lateness/BT = the number of days after a PO is created that a configuration change occurs that resulted in a price increase, divided by the contracted build time

- PO swap = a deleted and replaced PO with another PO or a PO with a delivery address change to accommodate the change in purchasing group to another segment of the customer's business
- PO Swap after O.PO %CBT = the number of days a PO is swapped after the release of the original PO, divided by contracted build time.
- RBT at Time of PO/Build Time = requested build time divided by contracted build time at the time the PO was created (This metric ignores changes to RBT that occur after the PO is created.)
- Requested Build Time (RBT) = Requested Ship Date minus PO Created Date for an order
- Requested Tender Date (RTD); i.e., Requested Ship Date = the date that the customer requested the supplier to hand the shipment over to the carrier
- RTD Push Out after PO/Build Time = changes to the RBT after the PO is created (A positive number means the RTD is moved farther into the future.)
- Supplier Committed Build Time (SBT) = the committed build time for an order given by the supplier in response to the customer's requested build time

1.7 Delimitations

The data selected for the computation of supplier supply chain agility scores includes only those purchases of capital equipment where the requested build time was less than 70 percent of the contracted build time and more than 30 percent of the contracted build time.

Those purchases where the RBT is greater than 70 percent of the CBT were excluded because they do not examine situations where the agility of a supplier is stress tested. If the CBT is 100 days and the customer's RBT is 100 days, the agility of the supplier is not under stress because 96 percent of all shipments from capital suppliers arrive within CBT. The purpose of the analysis is to examine those times when the supplier's supply chain is put under the most stress and pushed to its limits.

All RBTs less than 30 percent of CBT were also excluded from this study because the majority of these capital purchases are for first-of-a-kind equipment that was co-developed between the supplier and the customer beginning months before the PO was created. This means that the PO create date is not a true indication of when the supplier began building the product. Subsequently, the RBTs for these orders (calculated as [Requested Ship Date] – [PO Create Date]) are incorrect and excluded on this basis.

After the dataset was narrowed to those RBTs between 30 and 70 percent of CBT, it was time to choose which suppliers would be included in the study and which suppliers would not. It was determined that those suppliers who most frequently are asked to build at shorter than CBT would be chosen. For this reason, the nine suppliers who had more than 10 RBTs between 70 and 30 percent of CBT were chosen to be in the study

2 LITERATURE REVIEW

2.1 Overview

There were three goals for reviewing the academic literature on agility: (1) develop a definition of supply chain agility and distinguish this definition from others in the academic literature, (2) identify the supply chain management practices that are associated with supply chain agility, and (3) assess the existing body of research in supply chain agility to learn what has already been done in the area of agility scoring and to learn how this research can uniquely contribute to that existing body of research.

A definition of supply chain agility was created by reviewing the literature. To create this definition, the concept of agility and the methodology for achieving agile supply chains was well researched (Sharifi, 2000; Naylor, 1999; Christopher, 2001; Sharifi, 2000; van Hoek, 2001; Mason-Jones, 2000; Yang, 2002; Lin, 2006; Swafford, 2006). It was found that agility in its most general terms is the ability to handle the unpredictability of business and still deliver to the customer's requested specifications (Myerson, 2014). Furthermore, agile manufacturing is a response to complexity brought about by constant change in a volatile market place. (Sanchez, 2001). The need for this type of agility arises in supply chains that provide and manufacture innovative products for high-tech industries with a high degree of market volatility and uncertainty in demand (Cheng, 2000, Calvo, 2007). For the purpose of this study, agility was narrowly defined to measure the agile performance of ABT to RBT. Therefore, supply chain agility is defined in this study as the ability of a firm to handle the unpredictability and stress of market demand and still deliver to the customer's requested build times in a market where customization, volatility, price, and/or other market force(s) require(s) that products be built to order.

A review of the literature revealed a large number of supply chain practices that contribute to supply chain agility. For example, Lin classified the drivers of agile supply chain into four categories: collaborative relationship, process integration, information integration and customer or marketing sensitivity (Lin, 2006). Moreover, He and Kusiak used "delayed product differentiation" to drive agility in the supply chain (He and Kusiak, 1995). Delayed product differentiation refers to delaying the time when a product assumes its identity. Increasing the level of part commonality at early stages of the manufacturing process can delay the differentiation of products. Drivers of agility in the literature were used to identify potential drivers of agility in the customer order data.

A number of the survey questions were adopted from the academic literature. The three questions in Figure 2-1 were adopted from Brusset using a 7-point Likert scale (Brusset, 2015).

Three more questions were adopted from Yang using a five-point Likert scale (Yang, 2014) (see Figure 2-2) because of their correlation with supply chain agility in the referenced study.

Based upon your experience, please evaluate the following statements using the Likert scale below:

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
We receive the type of information from our customer that enables our sales forecasts to anticipate demand	○	○	○	○	○	○	○
Our sales forecasts are enabled by the timely receipt of information from our customer.	○	○	○	○	○	○	○
We attempt to anticipate our customer's demand even before the release of a customer's forecast or PO.	○	○	○	○	○	○	○

Figure 2-1: Information Sharing Survey Questions One

Rate your customer's supply chain communication using the Likert scale below:

	Definitely yes	Probably yes	Might or might not	Probably not	Definitely not
Do you and your customer currently share operations planning information?	○	○	○	○	○
Do you and your customer currently share forecast demand and sales information?	○	○	○	○	○
Are your order management systems linked to that of your customer?	○	○	○	○	○

Figure 2-2: Information Sharing Questions Two

The next two questions in the survey were inspired by He, Kusiak and Tarafdar identified postponement and delayed product differentiation in their research as strategies for agility (He and Kusiak, 1995; Tarafdar, 2013). To understand what impact postponement and delayed product differentiation might have on the supply chains of the customer's nine suppliers, the following two questions were created for the survey, "At what percent of the way through the build does the tool become unique to this customer?" and "When a late PO is released to your firm by your customer, what percentage of the time does your firm begin building the tool before you receive the PO?" The first question gives insight into the supply chain of the supplier to see if a generic product is first built, which at a later stage would be customized for each customer. The percent of the way through the build that this occurs might give insight as to whether the supplier is using the postponement technique. The second question helps to understand if semi-finished products are built by the supplier in advance of the actual customer demand. Then when the customer's orders come in and the uncertainty is reduced, the products might then be finished (Swaminathan, 1998).

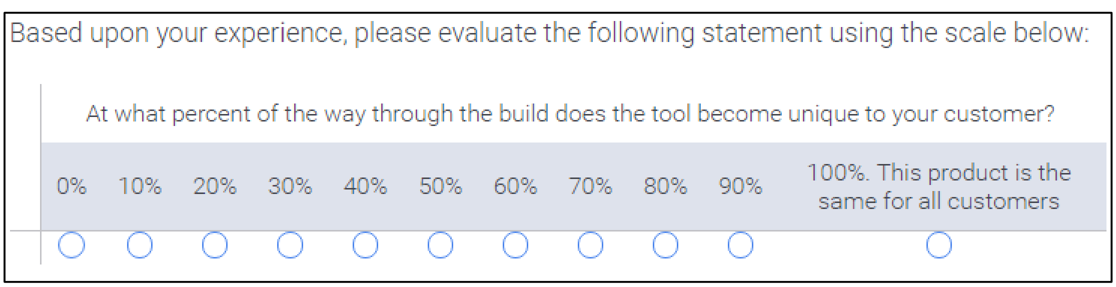


Figure 2-3: Postponement Survey Question One

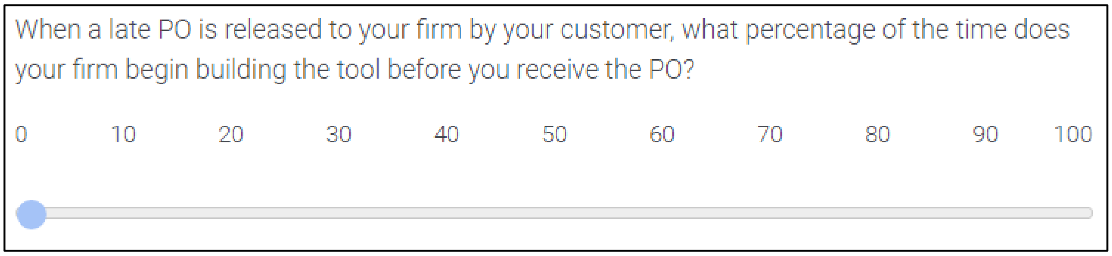


Figure 2-4: Postponement Survey Question Two

A great deal of research suggests that information sharing is crucial to an agile supply chain (Bottani, 2010; Liker, 2004; Brusset, 2016; Li, 2005; Li, 2006; Wong, 2005; Zhou, 2007; Singh, 2015; Kelle, 2005; Perry, 1999; Yang. 2013). In fact, approximately three-quarters of the research that was sampled about agility referred to information sharing as a strategy for agile manufacturing. For this reason, the following four survey questions were created to understand the potential impact of information sharing on the supply chain agility of a supplier, “When a PO is released with no forecast notice to your firm, what percent of the time is the PO a complete surprise?”, “How often do you and your customer have formal meetings about capital orders?”, “How often do you and your customer communicate by phone about capital orders?”, and “How often do you and your customer communicate through email about capital orders?”

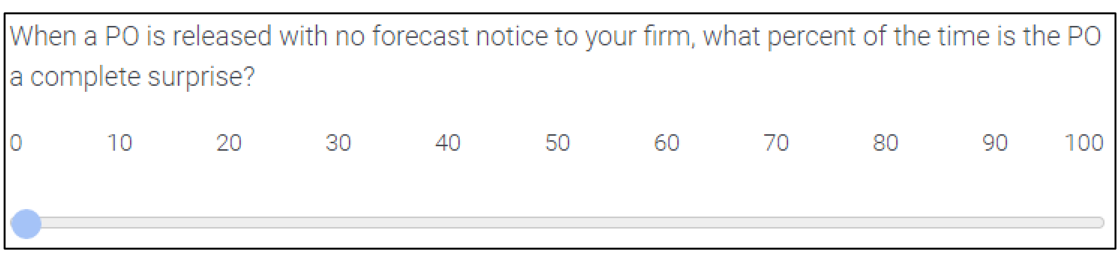
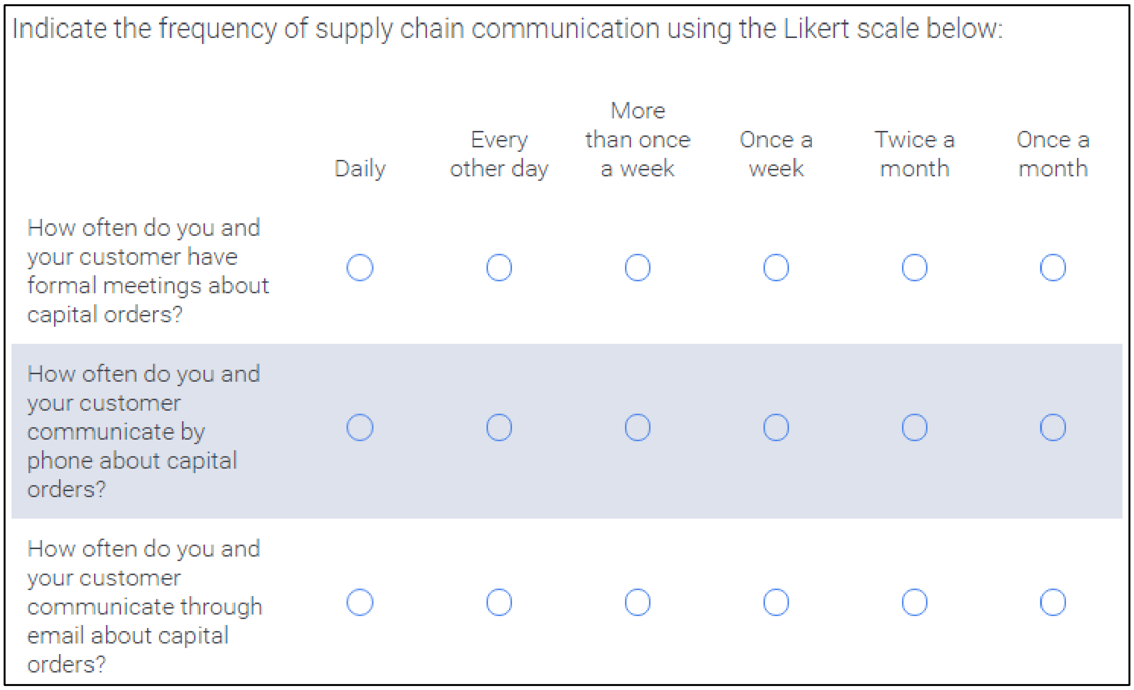


Figure 2-5: Information Sharing Question Three


Indicate the frequency of supply chain communication using the Likert scale below:

	Daily	Every other day	More than once a week	Once a week	Twice a month	Once a month
How often do you and your customer have formal meetings about capital orders?	○	○	○	○	○	○
How often do you and your customer communicate by phone about capital orders?	○	○	○	○	○	○
How often do you and your customer communicate through email about capital orders?	○	○	○	○	○	○

Figure 2-6: Infomation Sharing Question Four

2.2 Implications

The academic literature review enabled an assessment of the landscape of other agility studies to learn what has already been done in the area of agility scoring and to determine how this research might be differentiated. It was found that attempts have been made to calculate firm agility scores from qualitative data and survey data on the subjects of flexibility, collaboration, integration and market sensitivity using surveys (Brusset, 2016; Yang, 2014; Vinodh, 2011). In these two studies, hundreds of surveys were collected from firms to determine agility. Similarly, other studies use methods like “fuzzy logic” and IF-THEN rules to determine agility internally (Vinodh, 2011; Calvo, 2008; Vinodh, 2012). The main problem with these methods is that they rely heavily on the self-reporting of suppliers to measure agility. Also, since the data for agility scores is collected together with data for agility drivers, there is room for bias in the results. In contrast, just as with a double-blind study, the agility scores of this research were calculated and collected separately from the supplier survey data. Likewise, the supplier scores were not revealed until after the supplier survey data was collected and evaluated. Furthermore, each supplier's agility score was calculated from historical performance data, in order to reduce self-reporting bias. Once the agility score is calculated, survey data is used to find correlations between the agility score and supply chain management practices that are correlated with the supply chain agility score.

3 METHODOLOGY

3.1 Design of Analysis

The first step of the process was to evaluate the customer order data using multi-directional, stepwise, multilinear regression to identify as many customer-driven independent variables as possible that are correlated with ABT. The dataset includes over 2,000 new capital equipment purchases. By initially using a large dataset in addition to the narrow subset of nine suppliers that was involved in the final analysis, those independent variables that were identified as drivers of ABT in this initial analysis were then used in the next portion of the study to evaluate the customer and supplier impacts on the agility of specific suppliers.

For this portion of the study, ABT was chosen as the dependent variable instead of the ABT-RBT used in the agility score calculation. In place of using ABT-RBT, ABT is the dependent variable and the RBT is controlled for in this analysis. Using ABT-RBT created a correlation that was nonlinear (see Figure 3-1) and the variable was unable to be transformed to create a linear trend that was as predictive as using ABT as the dependent variable and controlling for RBT. This is likely the case because there is a confounding effect on the analysis when two variables that have different drivers are combined into one variable.

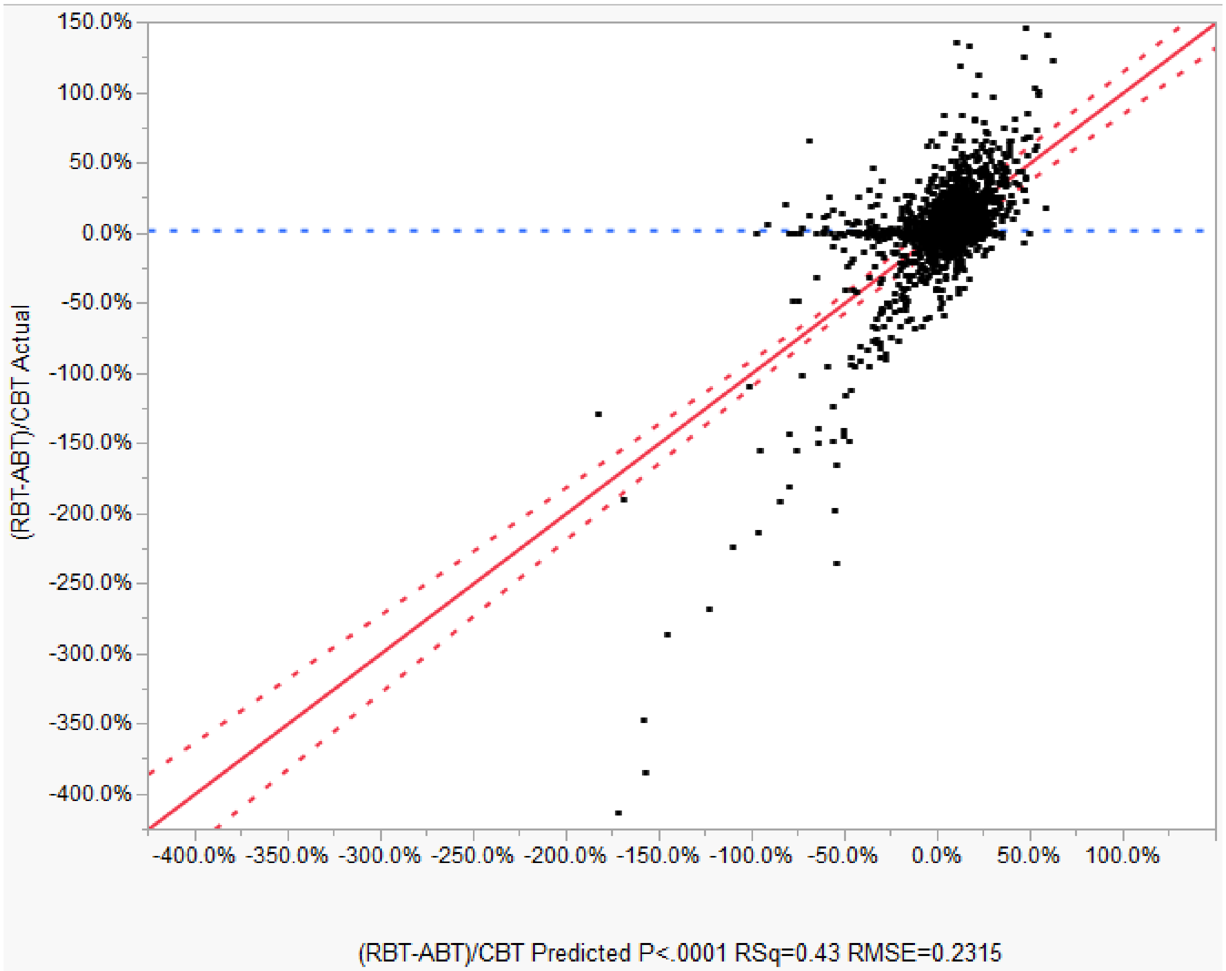


Figure 3-1: (RBT-ABT)/CBT Actual by Predicted Multilinear Regression Analysis

Table 3-1: Variables Tested for Correlation with ABT/CBT

Independent Variables
Requested Build Time (RBT)
RBT Changes after PO Create
Order Expedite Request
Configuration Change
Contracted Build Time
PO Swap
Complexity of Configuration
Price
Order Sequence
Forecast Notice Before PO

The initial step was to test all the variables in Table 3-1 for correlation with ABT. The next step taken was to calculate the supplier averages of all of the independent variables that impact ABT for the nine suppliers selected for the study. The data from 440 orders was averaged across the nine suppliers. Two examples of the averaged independent variables calculated for each supplier are RBT as a percent of CBT and order expedite requests as a percent of all orders. The purpose of calculating averages of all the known drivers of supply chain agility was to see if there are any supplier-specific variables that are impacting supply chain agility and to control for RBT and other variables in a multi-linear regression analysis.

The final step to determine the drivers of supplier supply chain agility was to run a multi-directional, stepwise, multilinear regression. The supply chain agility score was the dependent variable and the supplier averages of the variables that impact supply chain agility as well as the nine supplier survey responses served as the independent variables. The r-squared, coefficients, and the p-values will tell us the impact and significance of the correlations between agility scores and independent variables.

3.2 Quantifying Supply Chain Agility

The mathematical equation developed to represent supply chain agility is based upon the definition of supply chain agility provided by this paper: The ability of a firm to handle the unpredictability and stress of market demand and still deliver to the customer's requested build times in a market where customization, volatility, price, and/or other market force(s) require(s) that products be built to order.

A supply chain agility calculation must considers change, uncertainty and unpredictability within the business environment and the supplier's responds to changes (Vinodh, 2011). Agility is a high-level strategy focused on success in an unpredictable business environment (Sanchez, 2001). Focusing on the individual customer, agile competition has evolved from the unilateral producer-centered, customer-responsive companies inspired by lean manufacturing to the interactive producer-customer relationships of agile manufacturing (Goldman, 1994). Flexibility is the main factor of agility (Calvo, 2008). Since agility means meeting customer specifications and requirements despite unpredictability, the perfectly agile supplier would ship all shipments on the day requested by the customer. Any shipment late to the requested ship date is an indication of a deficiency in agility. Therefore, a mathematical expression of agility should be able to measure the deviation from perfect agility.

The mathematical equation that has been chosen for quantifying supply chain agility is represented below as equation 3-1.

$$\text{Avg. \% Late} = \sqrt{\frac{\sum_{i=1}^{n}\left(\frac{ABT_i - RBT_i}{CBT_i}\right)^2}{n-1}} \quad (3\text{-}1)$$

In this equation, “ABT_i” represents the actual build time. “RBT_i” represents the requested build time. “n” is equal to the sample size. “CBT_i” represents the contracted build time negotiated between the supplier and the customer when the procurement contract was signed. Finally, Avg. % Late is our inverse measure of agility, which is equal to the average percentage of CBT that the ABT was late to the RBT. See Appendix A for implementation of the equation in Microsoft Excel DAX formulae.

3.2.1 Considerations of the Agility Equation

$ASD_i - RSD_i$ is divided by contracted build time (CBT) because the average contracted build times of some suppliers are more than double the average contracted build time of other suppliers. In order to normalize the lateness of a shipment, the contracted build time was used to create a measurement of lateness as a percentage of the contracted build time. Furthermore, normalization with CBT was applied due to the success of this normalizing technique when used to increase r-squared and lower the p-value for linear regression models with ABT/CBT.

Another consideration or practical use application of the equation is that all early shipments are considered on time. To calculate this, $\mathrm{ABT}_i - RBT_i$ is equal to zero for all early shipments. It is assumed that if the supplier shipped early, the supplier proves that it was capable of meeting the delivery specifications of the customer and the supplier shipped early for other considerations. For example, the customer may allow early shipments in order to take advantage of a time-sensitive discounts. Counting early shipments as on-time assumes that if the customer allowed the shipment to be received at its receiving dock early, then the early shipment is equally as desirable as an on-time shipment.

An "n-1" denominator was chosen, instead of "n" because the observations in this study represent a sample of the whole population of shipments for a supplier and not the entire population. The entire population that would measure the supply chain agility of a supplier would include all shipments to all suppliers. The observations in the dataset represent the shipments for only one customer. For this reason, the denominator contains n-1 and not n.

3.3 Supplier Survey

Twenty-seven surveys were filled out by the customer’s main points of contact at each of the nine suppliers. All who were given the survey responded to the questions. Many follow up emails and phone calls were made to ensure that every account manager of every current capital product purchased by the customer responded to the survey. Larger suppliers with more account managers filled out a larger number of surveys, to ensure that all of the products purchased by the customer were considered in the survey responses. See the numbers of responses per supplier in Table 3-2.

Table 3-2: Count of Supplier Responses by Supplier

Supplier	*Count of Responses*
1	2
2	4
3	4
4	2
5	4
6	3
7	5
8	1
9	1

Despite all efforts to receive 100 percent survey responses, there were six questions for which all respondents of supplier G did not provide responses. Supplier G did not feel comfortable providing this information to the customer.

The responses of all the surveys of each firm were then averaged by supplier so that the average supplier agility score could be compared to the average supplier response in the regression analysis.

4 RESULTS AND DISCUSSIONS

4.1 Final Analysis Results

4.1.1 Discussions of the ABT/CBT Analysis

The ABT/CBT analysis of over 2,000 capital orders shows that the supplier's ABT is correlated with RBT, RBT changes, order expedite requests, configurations changes, CBT, PO swaps, and the complexity of configuration. This analysis offers clear evidence that there are many customer-driven variables that may impact a supplier's supply chain agility. It is unclear the exact percentage of variation in agility that is explained by these customer-driven variables because some of the variables (e.g., CBT) are jointly (supplier and customer) driven variables. However, this analysis makes it clear that beyond RBT, a supplier's supply chain agility is directly correlated with many actions taken by customers.

After controlling for RBT and CBT, the most highly correlated customer-driven variables are the number of days a PO swap is performed after the original PO is created, and the number of days a PO's value changes after a PO is created. One explanation as to why PO swaps may impact ABT is that changing the customer's PO number or changing the PO destination causes rework, which may slow down the supplier's build process. This means that if all else is held constant and we assume a 100 day CBT, every 10 days that a PO swap occurs after the PO is created is correlated with an increases in the ABT of 3.7 days (see Figure 4-1). This is a substantial increase in ABT considering that a PO swap is a managerial consideration and has no direct impact on the manufacturing process. This example illustrates one way that a customer's processes and communications can impact a supplier's agility.

Prediction Expression

$$
\begin{aligned}
&0.55119754110094 \\
&+ 0.66636169468501 * \text{RBT at Time of PO/CBT} \\
&+ 0.56877978518708 * \text{RBT Increase After PO/CBT} \\
&+ -0.0009019921437 * \text{CBT} \\
&+ 0.03738836130564 * \text{Process} \\
&+ \text{Match}\left(\text{Critical A}\right)\begin{pmatrix} 0 & \Rightarrow -0.1132218686459 \\ 1 & \Rightarrow 0.11322186864593 \\ \text{else} & \Rightarrow . \end{pmatrix} \\
&+ 0.08011157415005 * \text{PO \$ Change Lateness/CBT} \\
&+ \text{Match}\left(\text{PO Swap}\right)\begin{pmatrix} 0 & \Rightarrow 0.05342715386115 \\ 1 & \Rightarrow -0.0534271538611 \\ \text{else} & \Rightarrow . \end{pmatrix} \\
&+ 0.36526332535528 * \text{Swap After O.PO/CBT} \\
&+ -0.0009094440237 * \text{TPOCs}
\end{aligned}
$$

Figure 4-1: ABT/CBT PO Analysis Linear Equation

It was also found that requesting expedited build had a negative correlation with ABT. This is especially concerning and unexpected because when the customer asks that a build time be expedited (i.e., marks the order "Critical A"), the customer expects that the supplier will reduce the build time. However, this is not the case. One explanation for this is that a Critical A tool is usually set apart from the other orders by the customer because the ABT is already longer than is desirable. For this reason, we should already expect the build time to be longer than average. The concerning aspect if this find is that the ABT remains above average, even after the supplier and the customer use many resources to attempt to change this. On the other hand, it would be poor judgement to say that the order expedite program between the customer and suppliers is a failure because we do not know the ABT starting point when the expedited shipping was requested. Also, we do not know how close to the ship date, the expedite request was made. This issue is very important issue that deserves more root-cause analysis.

One explanation for the PO value change correlation with ABT is that a PO value change often indicates a change in the bill of materials (BOM). A BOM change is rework that can directly affect the manufacturing process and can extend the ABT. One interesting thing to note is that the number of times a PO's value is changed had no significant correlation with ABT, only the number of days the value change occurred after the PO was created. If all else is held constant and we assume a CBT of 100 days, every 25 days that a PO's value is changed after the PO is created correlates with a 2 day increase in ABT. While statistically significant, this ABT increase is surprisingly low. One explanation for the low impact is that the portion of PO value increases that actually impact the manufacturing process is uncertain. Also, it may be a tribute to the supplier's processes that can quickly adjust to BOM changes.

Table 4-1: Analysis of ABT/CBT Summary of Fit

Summary of Fit	
RSquare	0.664647
RSquare Adj	0.663507
Root Mean Square Error	0.253527
Mean of Response	1.029266
Observations (or Sum Wgts)	2658

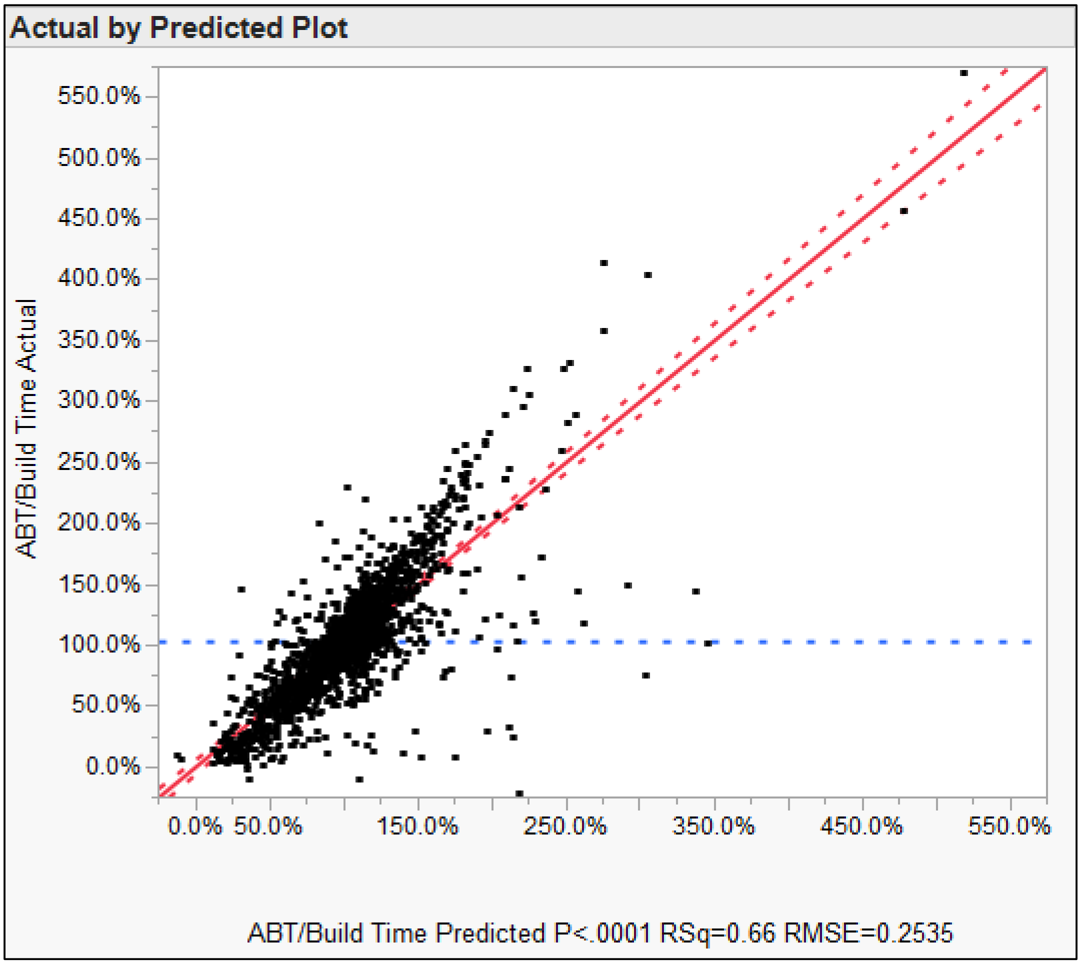


Figure 4-2: Analysis of ABT/CBT Actual by Predicted Plot

Table 4-2: Variable Correlated and Not Correlated with ABT/CBT

Variables not Correlated with Actual Build Time	*P-Value*	*Variables Correlated with Actual Build Time*	*P-Value*
Price	0.2357	Requested Build Time (RBT)	<0.001
Order Sequence	0.4960	RBT Changes after PO Create	<0.001
Forecast Notice Before PO	0.5844	Contracted Build Time (CBT)	<0.001
		Manufacturing Process Changes	<0.001
		Order Expedite Request	<0.001
		PO Value Change, # of Days after PO Create	<0.001
		PO Swap	0.0052
		PO Swap, # of Days After PO Create	<0.001
		Complexity of Configuration	0.0011

Table 4-3: Analysis of ABT/CBT Scaled Estimates

Scaled Estimates

Nominal factors expanded to all levels
Continuous factors centered by mean, scaled by range/2

Term	Scaled Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.0884224	0.027146	40.10	<.0001*
RBT at Time of PO/Build Time	2.1690073	0.044227	49.04	<.0001*
RTD Push Out After PO/Build Time	2.1755827	0.049368	44.07	<.0001*
Build Time*	-0.151986	0.016712	-9.09	<.0001*
CapacityProcess	0.0373884	0.005219	7.16	<.0001*
Critical A[0]	-0.113222	0.020467	-5.53	<.0001*
Critical A[1]	0.1132219	0.020467	5.53	<.0001*
PO $ Change Lateness/BT	0.218304	0.031263	6.98	<.0001*
PO Swap[0]	0.0534272	0.019083	2.80	0.0052*
PO Swap[1]	-0.053427	0.019083	-2.80	0.0052*
PO Swap After O.PO %CBT	0.3451738	0.072828	4.74	<.0001*
TPOCs	-0.043199	0.013238	-3.26	0.0011*

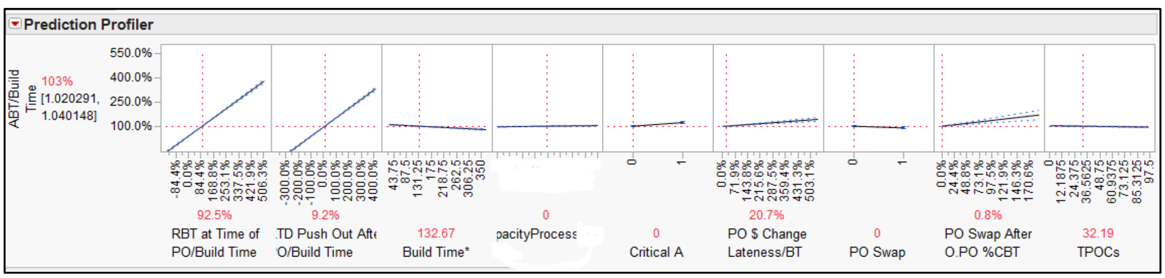


Figure 4-3: Analysis of ABT/CBT Prediction Profiler

4.1.2 Discussions of Agility Score Analysis Best Fit Model 1

In the correlation analysis of supplier agility scores using multi-directional, stepwise, multilinear regression with 12 averaged supplier survey responses and 16 averaged customer order variables, 96 percent of the variation in supplier supply chain agility was explained by the variation in four independent variables: (1) surprise orders, (2) expedited order requests (see Figure 4-4 and Figure 4-5), (3) average of RBT/CBT, and (4) product customization.

One reason the adjusted r-squared is so high may be because the regression analysis was performed using averages across 9 suppliers. Averages, by their nature, remove a large amount of the variation that exists between the 440 individual purchases and the 27 survey responses in the analysis. Furthermore, when the sample size from the 440 POs was averaged across only 9 suppliers the small sample size of 9 suppliers may have impacted the adjusted r-squared. Regrettably, the small sample size of 8 suppliers (9 suppliers minus non-response of one supplier) was unavoidable, since only nine suppliers qualified for the study because they had a large enough sample size of RBTs between 70 and 30 percent of CBT. On the other hand, a multi-linear regression model should account for a low sample size in the reporting of statistical significance in the p-value, and the p-values are all statistically significant to the 0.1 level (see Table 4-5).

As you can see in the "Scaled Estimates" of Table 4-5, the majority of the predictive power comes from the percent of surprise orders and average "RBT at time of PO/CBT":

Table 4-4: Model 1 Summary of Fit

Summary of Fit	
RSquare	0.98124
RSquare Adj	0.956226
Root Mean Square Error	0.018357
Mean of Response	0.17125
Observations (or Sum Wgts)	8

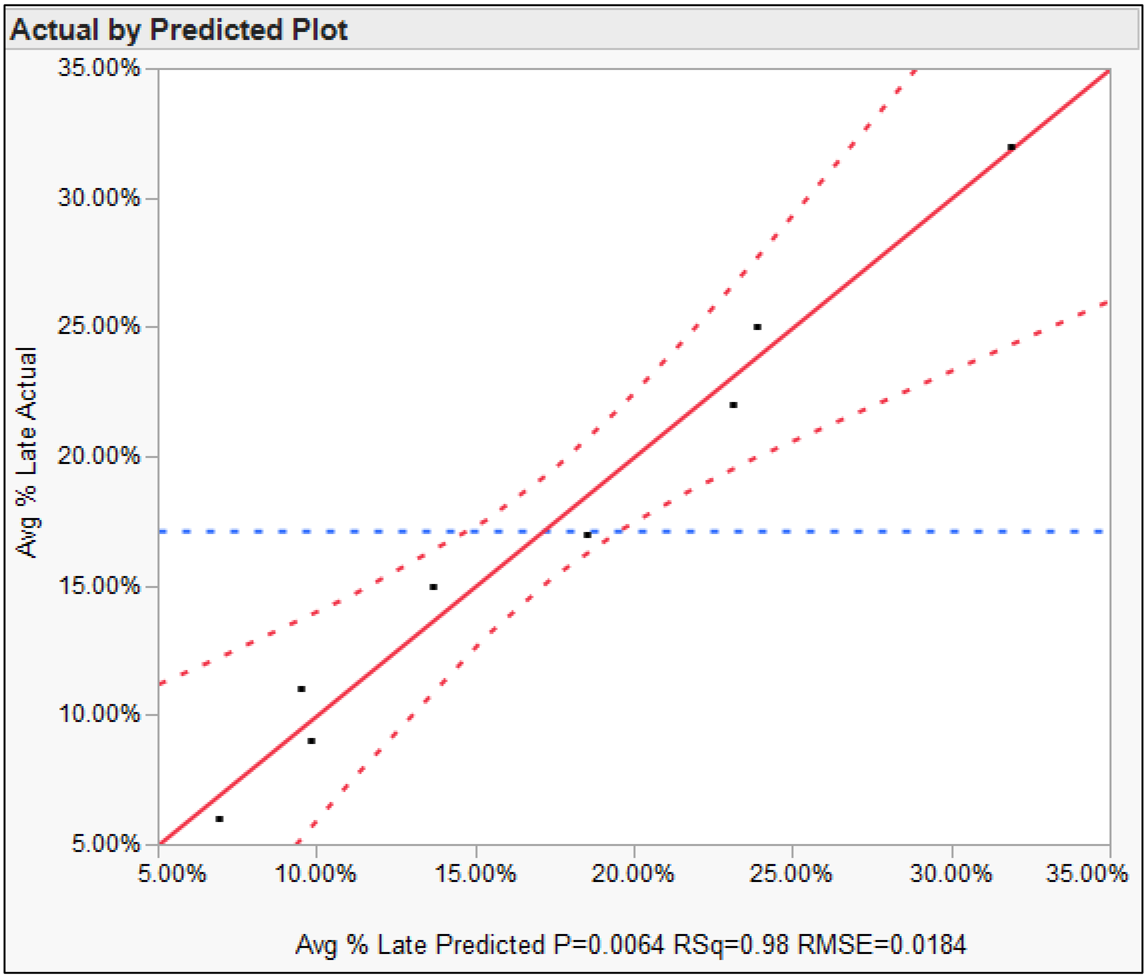


Figure 4-4: Actual by Predicted for Agility Score Best Fit Model

Table 4-5: Model 1 Scaled Estimates

Scaled Estimates

Continuous factors centered by mean, scaled by range/2

Term	Scaled Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.17125	0.00649	26.39	0.0001*
% Expedite Requested	-0.038426	0.010844	-3.54	0.0383*
Avg of RBT at Time of PO / CBT	0.062666	0.011259	5.57	0.0114*
When a PO is released with no forecast notice to your firm, what p...	-0.115032	0.011942	-9.63	0.0024*
Average of At what percent of the way through the build does the to...	-0.032335	0.013379	-2.42	0.0944

The most peculiar correlation exists between surprise POs and the supplier agility score. It was expected that if a supplier received a disproportionate amount of surprise POs, compared to other suppliers, this would correlate with decreased supplier agility; however, the opposite is true. The more often POs are a surprise to the supplier, the more likely a supplier is agile to meet short RBTs. As stated earlier, the small sample size of suppliers may still have skewed the results, even though the p-value indicates that there is only a 0.024% chance that this correlation is due to chance. If we assume that the correlation is not by chance, one explanation for this correlation is that a more agile supplier may define a surprise PO differently than a less agile supplier. A more agile supplier may be more acutely aware of surprise POs, as opposed to a less agile supplier that spends less time and resources to anticipate customer demand. Consequently, a more agile supplier might report a higher percentage of surprise POs than a less agile supplier.

The other correlations of this best-fit model are much more intuitive. As can be seen in Figure 4-5, an increase in expedite requests from the customer correlates with an improvement of the agility score. In other words, when the customer puts more emphasis on the order arriving to RBT, the supplier may be more likely to meet RBT. Next, an increase in RBT as a percent of CBT correlates with a decrease in a supplier's supply chain agility. One explanation for this correlation is that a supplier may begin to do a better job of expecting short RBTs if the customer continuously requests very short build times from the supplier. However, when the average RBT/CBT is high, a less common short RBT may be more difficult for a supplier to execute.

Another correlation was found between the percent of customization and supply chain agility. The most likely explanation for this correlation is that the agility of a supplier is improved when the products ordered by the customer are similar to those of other customers. The multi-linear regression analysis suggests that if all else is held constant and if a supplier's product is the same 80 percent of the way through the build, the agility of a supplier is 42 percent better than the agility of a supplier whose product becomes customized at 20 percent of the way through the build. This is further evidence supporting the theory that postponement and delayed product differentiation improve supply chain agility.

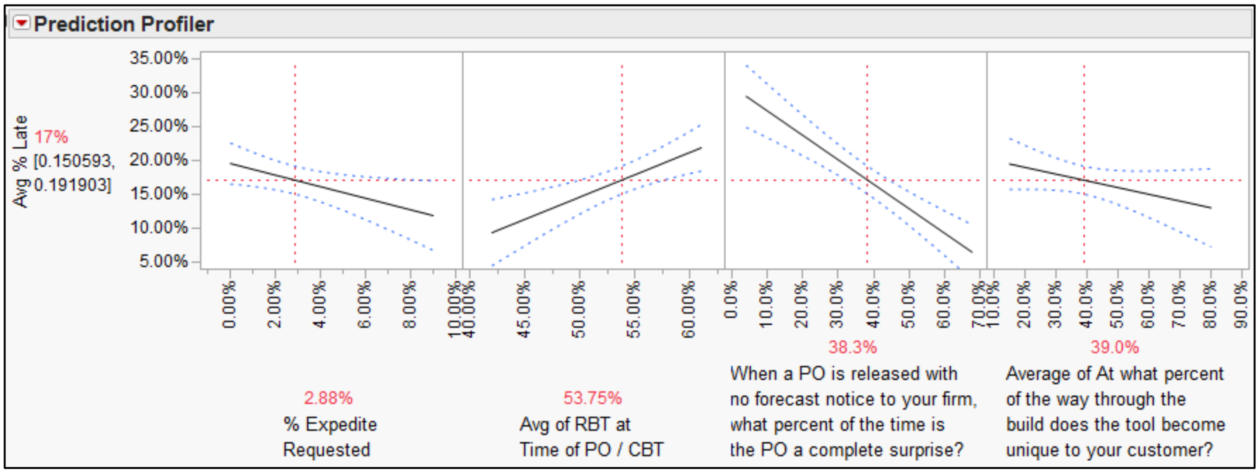


Figure 4-5: Model 1 Prediction Profiler

4.1.3 Discussions of Agility Score Analysis Model 2

Due to the counterintuitive nature of the Surprise PO variable's correlation with supply chain agility and in order to understand more thoroughly potential drivers of supply chain agility, a second multi-linear regression model was developed with the Surprise PO variable excluded. Surprisingly, the variation of these three independent variables in Model 2 still explains 87 percent of the variation in supply chain agility scores (see Table 4-6).

Table 4-6: Model 2 Summary of Fit

Summary of Fit	
RSquare	0.921331
RSquare Adj	0.874129
Root Mean Square Error	0.030232
Mean of Response	0.178889
Observations (or Sum Wgts)	9

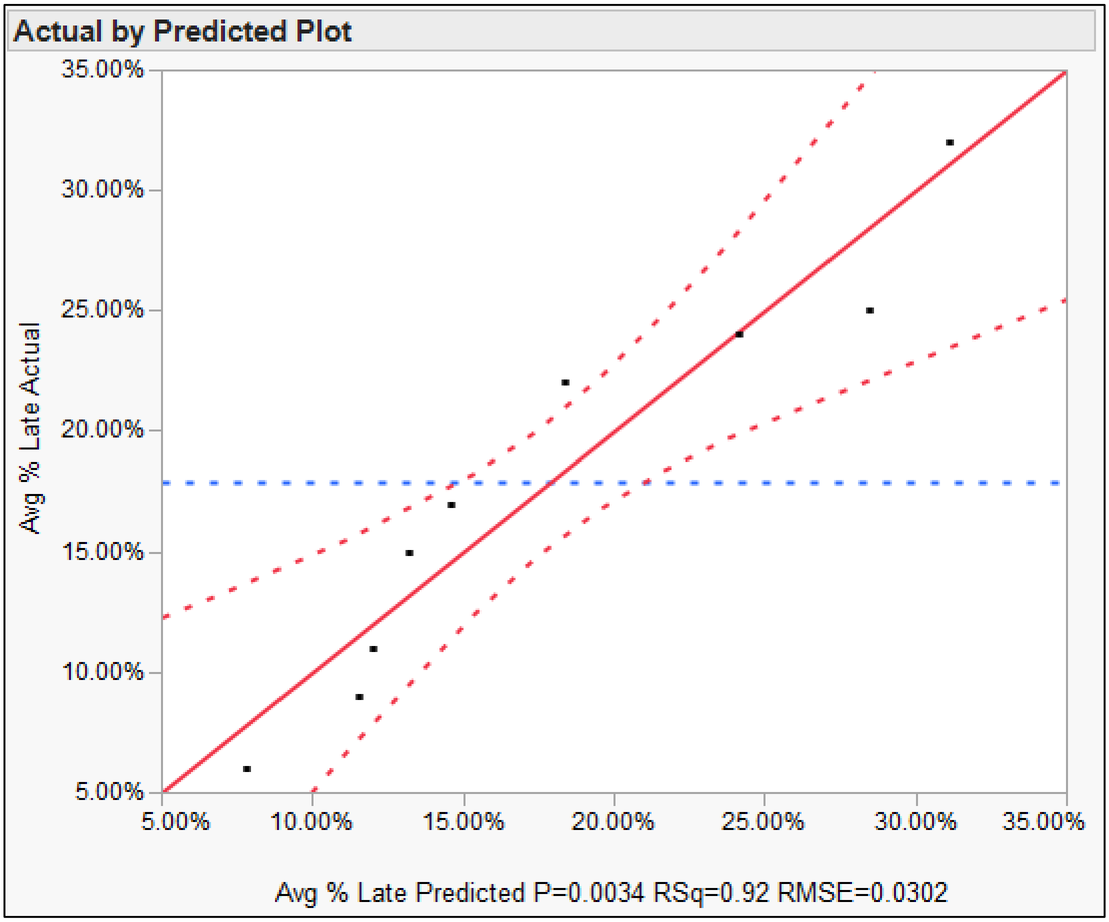


Figure 4-6: Model 2 Average % Late Best Fit

As can be seen in Table 4-7, supply chain agility is correlated with the changes in RBT/CBT that occur after the PO is created, the average supplier CBT, and the linking of order management systems between customer and supplier. In the case of RBT reductions, the analysis shows that when RBT is reduced by the customer after the PO is already created, this action is correlated with a reduced ability of the supplier to be agile to meet RBTs. In fact, the impact is quite large. For example, if all else is held constant and if the average reduction in RBT after PO create is 15 percent for one supplier, the agility of the supplier is likely to be 54 percent less than the agility of a supplier with an average reduction in RBT of only five percent. This shows that late build time requests by the customer may have an impact in the agility of a supplier.

The second independent variable in this model that is correlated with supply chain agility is the average CBT. The longer the average CBT, the more likely a supplier is to be agile. One potential explanation for this correlation is that the capital equipment with the longest build times is the most likely capital equipment to slow the ramping up of a customer's factory. For this reason, the customer should be expected to put more scrutiny on ABTs for long CBTs. Furthermore, a tool that takes a longer time to build is generally more expensive and the supplier is likely to provide a higher level of customer service to customers that pay a high price.

The last independent variable correlated with supply chain agility is the linking of customer and supplier order management systems. One explanation offered by capital buyers at the customer firm is that these automated order management systems are often inflexible. For example, three suppliers are known to have created an automated order management system that automatically commits the supplier to the RBT, irrespective of the supplier's actual ability to meet or not meet an RBT. Additionally, suppliers with automated order-processing systems miss their supplier committed build time (SBT) three times as often for capital supporting item orders than all other suppliers, when SBT is equal to RBT. In Figure 4-7, the three bars on the left represent the three suppliers with automated order-processing systems.

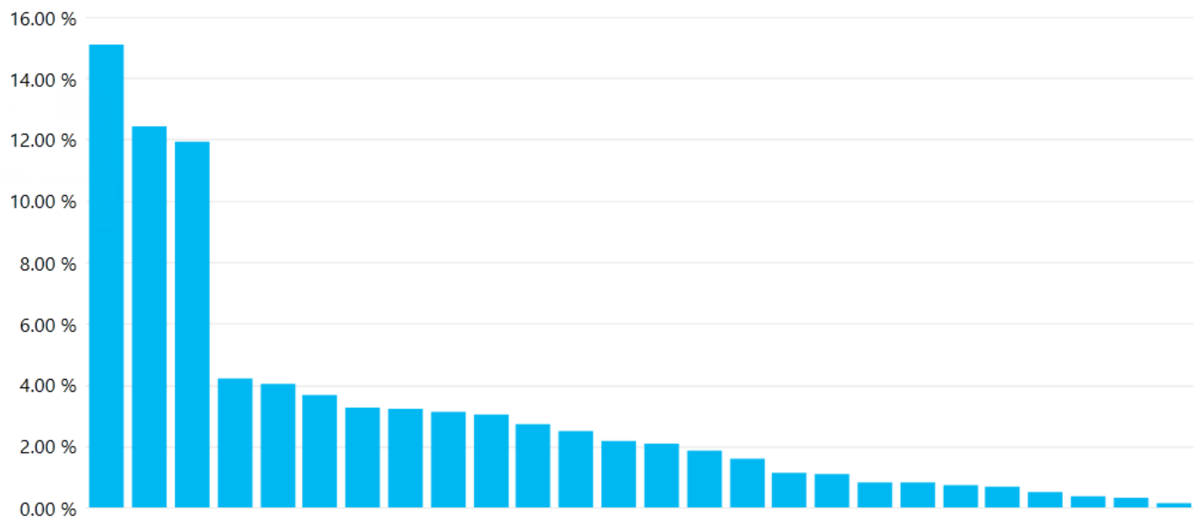


Figure 4-7: Percent of Late Shipments, Where SBT=RBT

Instead of adding value, the automation increases rework and potential oversights. Current automated order processing systems do not appear to be suited to take into consideration the actual capacity and constraints of a supplier's supply chain while simultaneously considering the RBTs of a customer. Manual and active vigilance and negotiation between a supplier's account managers and a customer's buyers is still best suited for this task.

Table 4-7: Model 2 Scaled Estimates

Scaled Estimates

Continuous factors centered by mean, scaled by range/2

Term	Scaled Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.1788889	0.010077	17.75	<.0001*
Avg of RBT Reductions After PO / CBT	0.0927156	0.018458	5.02	0.0040*
Avg CBT	-0.120896	0.018939	-6.38	0.0014*
Are your order management systems currently linked to that of your customer?	0.0553636	0.018663	2.97	0.0313*

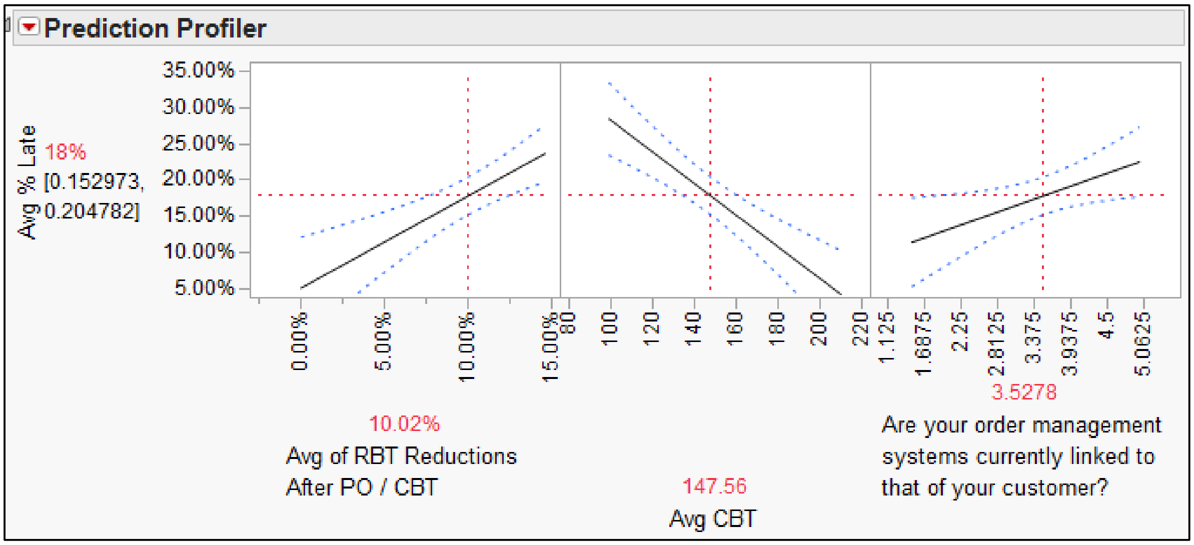


Figure 4-8: Model 2 Prediction Profiler

4.2 Conclusions and Recommendations

Nine of the twenty variables tested by the hypothesis of the paper were found to be correlated with supply chain agility. However, two of those correlations were found to be opposite of what was expected and what was suggested in the academic literature (i.e., order management systems linkage and surprise POs). The table below shows the hypothesis variables found to be correlated with supply chain agility:

Table 4-8: Hypothesis Results

Independent Variable	**Agility Correlation?**
We receive the type of information from our customer that enables our sales forecasts to anticipate demand.	No

Table 4-8, Cont'd.

Our sales forecasts are enabled by the timely receipt of information from our customer.	No
We attempt to anticipate our customer's demand even before the release of a customer's forecast or PO.	No
How often do you and your customer have formal meetings about capital orders?	No
How often do you and your customer communicate by phone about capital orders?	No
How often do you and your customer communicate through email about capital orders?	No
Do you and your customer currently share operations planning information?	No
Do you and your customer currently share forecast demand and sales information?	No
Are your order management systems currently linked to that of your customer?	Negatively Correlated
When a late PO is released to your firm by your customer, what percentage of the time does your firm begin building the tool before you receive the PO?	No
When a PO is released with no forecast notice to your firm, what percent of the time is the PO a complete surprise?	Negatively Correlated
At what percent of the way through the build does the tool become unique to your customer?	Positively Correlated
Forecast notice before PO	No

Table 4-8, Cont'd.

Requested build time (RBT)	Positively Correlated
RBT changes after the PO is created	Positively Correlated
Contracted build times (CBT)	Negatively Correlated
Order expedite request	Positively Correlated
PO Value change; number of days after PO created	Negatively Correlated
PO Swap; number of days after PO created	Positively Correlated
Complexity of configuration	Negatively Correlated

The greatest contribution of this research is found in the portion of the analysis conducted on the data collected of over 2,000 sales orders. The analysis demonstrated correlation between the dependent variable of ABTs and nine independent variables. This analysis showed clear evidence that a strong correlation exists between the agility of suppliers and the timing and content of communications to a supplier. When RBT, CBT, technology changes, and the complexity of configuration are controlled for, we see that a customer's processes and communications (represented by RBT changes after the PO, expedite requests, and PO swaps) have a significant impact on the ABT of a supplier. The biggest weakness of both correlation analyses is that they are observational in nature. In other words, we can only infer correlation and not causation. For this reason, more research and analysis are necessary to build a preponderance of evidence as to the SCM practices that cause supply chain agility.

4.2.1 Recommendations for Supply Chains

The most striking revelation of this research is that early notification of a future PO does not reduce ABT or increase supplier agility. There are four pieces of evidence from this study that support this conclusion: (1) Figure 1-2 offers the strongest evidence that the later a PO is created, the shorter the ABT, (2) even for the most challenging of RBTs (i.e., between 70 and 30 percent of CBT) the average supplier ABT miss was only about 20 percent of CBT, (3) the ABT/CBT analysis revealed that forecast notice before the PO is created was not correlated with ABT/CBT (see Table 4-2), (4) In the ABT/CBT analysis, late changes to the RBT of POs had a minimal impact on supplier performance. The coefficients of "RBT/CBT at the time the PO is created" and "RBT/CBT changes after the PO is created" are 0.66 and 0.57 respectively (see Figure 4-1). This suggests that if the RBT is 70 days when the PO is created, the ABT will be nearly the same is if the RBT is 100 days when the PO is created and then the RBT is changed to 70 days sometime after the PO is created, and (5) surprise POs were negatively correlated with agility in the agility score vs supplier survey analysis—meaning that surprising a supplier with a new PO correlated with an increase in supplier performance, not a decrease (see Figure 4-5).

One recommendation that stems from this insight that suppliers have met the customers need for short-notice, expedited build times is that fewer resources should be focused on forecasting future purchases to suppliers, and more resources should be focused on identifying the root causes of the independent variables correlated with supplier agility and making the changes that will likely impact supplier agility.

It may be tempting to recommend that the solution to getting shorter ABTs is to reduce more RBTs. Since this is an observational study, this conclusion cannot be supported. Theory and intuition suggest that if a greater proportion of RBTs were reduced, capacity constraints would disrupt the current ability of suppliers to provide expedited ABTs. The best solution, as will be suggested again later, is to conduct root-cause analysis to discover the drivers of the independent variables that are correlated with ABT. An example of how to do this is to ask, 'Why is the ABT greater for orders where the customer has requested expedited build times?', 'Are the current processes adequate?', 'Is the supplier's capacity to blame?', 'Do most requests for expedited build times occur too late?', or 'Would the problem be improved if the customer purchased/reserved capacity in advance from the suppliers?' Further analysis is required, including a variable to track how many days before the shipment, did the request of expedited build time occur. When the root cause is discovered, improvements can be made to this process that are much more likely to improve supplier agility than simply reducing a greater proportion of RBTs.

It may also be tempting for a customer to want to use the agility score as a target with which to manage suppliers. However, it would be unwise to measure a supplier's performance using this metric because, as shown in this research, the supplier's and customer's performance impact on the agility score of a supplier. Agility score improvement must, therefore, be a joint effort. Additionally, Goodhart's law would suggest that managing suppliers to their agility score would reduce the metric's value because "when a measure becomes a target, it ceases to be a good measure."

Instead of using the agility score as a target, customers should use the research methodologies presented in this paper to identify the root causes of supply chain agility for its own suppliers. This research should be duplicated by any firm interested in identifying the root causes of supply chain agility and making improvements that improve supply chain agility. The customer should calculate the supplier agility score for each of its suppliers and then perform a multilinear regression analysis to correlate agility with independent variables hypothesized to influence that agility. The independent variables selected in this analysis can serve as examples of variables to select for regression analysis. Other statistical tools, such as cluster analysis, could be useful to find commonalities between suppliers with high agility scores. Additionally, customers should survey potential suppliers and use this data to select suppliers that match the profile the most agile suppliers.

In this study, technology and communication interact with agility differently than expected. This study demonstrates that the frequency of meetings, emails, and phone conversations does not necessarily correlate with supplier agility performance. Additionally, this study suggests that technological solutions, such as linking order management systems, may actually be detrimental to order fulfilment (see Figure 4-8). This appears to be an example of how technology can be used to fix to a problem, but instead its implementation is detrimental to long-term interests. The key to profitable technology use is to first implement good processes and then support those processes with technology. Finally and counterintuitively, surprising a supplier with a new PO may not have a detrimental impact on supplier ABT. All of these insights act as small puzzle pieces to direct firms where to look for the root of problems that impede agility and to highlight solutions that improve agility.

4.2.2 Recommendations for Further Research

This may have been the first study of agility using historical data to score supplier agility. However, the sample size of nine suppliers in the agility score analysis reduced the reliability of the survey portion of the analysis. It is highly recommended that another study be performed with a larger number of suppliers that also compares survey results to a quantitative measure of agility. Another way to increase the number of suppliers in the study is to be less stringent for admitting data into the study. For example, All RBTs less than 90 percent of CBT could be included, and instead of removing all RBTs less than 30 percent, a more intensive process could be undertaken to selectively eliminate inaccurate RBTs from the dataset. An additional way to increase the sample size of suppliers is to collect the data from several customers. All of these methods combined may yield a more reliable analysis than the survey results analysis of this study.

Another recommendation is that the agility of suppliers should be tracked over time to assess changes to the customer, suppliers and the industry as a whole. For example, if a customer loses a leadership position in the market and bargaining power with suppliers is reduced, the agility score of all suppliers is likely to trend downward, since the bargaining power of the customer is reduced. Agility scores over time can be used as an indicator of bargaining power and other trends.

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APPENDICES

APPENDIX A. EXCEL DAX , SUPPLIER AGILITY CALCULATION

A.1 Average Percent Late DAX Calculation

$Avg\ (ABT - RBT)/CBT\ for\ RBT < 70\%BT$:

$$= ([Avg\ (ABT - RBT)/CBT\ for\ RBT\ 30 - 39\%] * [Count\ of\ ABT\ for\ RBT\ 30 - 39\%] + [Avg\ (ABT - RBT)/CBT\ for\ RBT\ 40 - 49\%] * [Count\ of\ ABT\ for\ RBT\ 40 - 49\%] + [Avg\ (ABT - RBT)/CBT\ for\ RBT\ 50 - 59\%] * [Count\ of\ ABT\ for\ RBT\ 50 - 59\%] + [Avg\ (ABT - RBT)/BT\ for\ RBT\ 60 - 69\%] * [Count\ of\ ABT\ for\ RBT\ 60 - 69\%])/([Count\ of\ ABT\ for\ RBT\ 30 - 39\%] + [Count\ of\ ABT\ for\ RBT\ 40 - 49\%] + [Count\ of\ ABT\ for\ RBT\ 50 - 59\%] + [Count\ of\ ABT\ for\ RBT\ 60 - 69\%] - 1)$$

A.2 Average (ABT-RBT) / BT for RBT 30 to 39 Percent

$Avg\ (ABT - RBT)/BT\ for\ RBT\ 30 - 39\%$:

$$= IF((AVERAGE([(ABT - RBT)/CBT\ for\ RBT\ 30 - 39\%]) * [Count\ of\ ABT\ for\ RBT\ 30 - 39\%])/([Count\ of\ ABT\ for\ RBT\ 30 - 39\%] - 1) > 1,1,(AVERAGE([(ABT - RBT)/CBT\ for\ RBT\ 30 - 39\%]) * [Count\ of\ ABT\ for\ RBT\ 30 - 39\%])/([Count\ of\ ABT\ for\ RBT\ 30 - 39\%] - 1))$$

A.3 Count of ABT for RBT 30 to 39 Percent

$$Count\ of\ ABT\ for\ RBT\ 30-39\%:=COUNTA([ABT\ for\ RBT\ 30-39\%])$$

A.4 (ABT-RBT) / CBT for RBT 30 to 39 Percent

$$=IF([Requested\ BT\ Groups]="E:30-39\%",IF(([ABT/CBT]-[RBT\ /CBT]) < 0,0,[ABT/CBT]-[RBT\ /CBT]),BLANK())$$

A.5 ABT for RBT 30 to 39 Percent

$$=IF([RBT\ Groups]="E:30-39\%",[ABT/CBT],BLANK())$$

A.6 RBT Groups

$$
\begin{aligned}
&= IF(AND([RBT\ /CBT] >= 2.3, [RBT\ /CBT] < 2.4), "Y: 230 - 239\%", IF([RBT\ /CBT] >= 0.0, IF([RBT\ /CBT] >= 0.1, IF([RBT\ /CBT] >= 0.2, IF([RBT\ /CBT] \\
&>= 0.3, IF([RBT\ /CBT] >= 0.4, IF([RBT\ /CBT] >= 0.5, IF([RBT\ /CBT] >= 0.6, IF([RBT\ /CBT] >= 0.7, IF([RBT\ /CBT] >= 0.8, IF([RBT\ /CBT] \\
&>= 0.9, IF([RBT\ /CBT] >= 1.0, IF([RBT\ /CBT] >= 1.1, IF([RBT\ /CBT] >= 1.2, IF([RBT\ /CBT] >= 1.3, IF([RBT\ /CBT] >= 1.4, IF([RBT\ /CBT] \\
&>= 1.5, IF([RBT\ /CBT] >= 1.6, IF([RBT\ /CBT] >= 1.7, IF([RBT\ /CBT] >= 1.8, IF([RBT\ /CBT] >= 1.9, IF([RBT\ /CBT] >= 2.0, IF([RBT\ /CBT] \\
&>= 2.1, IF([RBT\ /CBT] >= 2.2, IF([RBT\ /CBT] >= 2.3, IF([RBT\ /CBT] >= 2.4, "Z: >= 240\%"), "X: 220 - 229\%"), "W: 210 - 219\%"), "V: 200 - 209\%"), \\
&"U: 190 - 199\%"), "T: 180 - 189\%"), "S: 170 - 179\%"), "R: 160 - 169\%"), "Q: 150 - 159\%"), "P: 140 - 149\%"), "O: 130 - 139\%"), "N: 120 - 129\%"), \\
&"M: 110 - 119\%"), "L: 100 - 109\%"), "K: 90 - 99\%"), "J: 80 - 89\%"), "I: 70 - 79\%"), "H: 60 - 69\%"), "G: 50 - 59\%"), "F: 40 - 49\%"), \\
&"E: 30 - 39\%"), "D: 20 - 29\%"), "C: 10 - 19\%"), "B: 0 - 9\%"), "A: < 0\%"))
\end{aligned}
$$