AN ANALYSIS OF THE MODELING USED TO DETERMINE CUSTOMER SATISFACTION

by

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ABSTRACT

Many companies use surveys to establish customer satisfaction metrics. This OEM has been using surveys to analyze customer satisfaction with their products, services, and distribution channel for several decades. Satisfaction metrics are established for the brand, product, and channel partners. The product metric is derived from a question on the survey asking customers how satisfied they are with the product. There are subsequent questions thereafter inquiring about satisfaction with specific functional areas of the product. It is common practice to use Partial Least Squares (PLS) regression analysis to evaluate what impacts the functional area questions have on the overall satisfaction question. The model results are used to understand what areas of the machine should be focused on to improve customers' experiences with the machine. These results are compared to other data sources such as warranty, field reports, customer focus groups, etc.

The results from these models are sometimes questioned based on what common intuition would suggest. Typically the top three drivers to the product metric are understandable, but there are often one or two key areas that do not make logical sense. The objective of this thesis was to understand whether PLS modeling is appropriate given the nature of customer survey data. Models were estimated using existing survey data on a specific model in the tractor product line.

PLS models assume data are linear with no bounds. This in itself likely makes this type of model inappropriate for analyzing customer survey data. Responses are bounded on an 11 point scale from 0-10, however, the PLS model being non-bounded assumes there can be a score under 0 or over 10. The model also assumes a linear slope that would

indicate each covariate answer 0-10 has the same level of effect on the response variable. This research has found that each covariate answer is in fact non-linear. For example, a customer answering a 2 to quality of manufacturing workmanship has a different impact on the overall satisfaction score than a customer who answers 8. Finally, this research discovered that the PLS models produce negative coefficients of significant value that are not reported to the enterprise.

Binary and ordered logistic (logit) models were estimated as an alternative to PLS. Logistic models are non-linear and are commonly used to evaluate bounded data. Response data were separated into two groups based on Net Promoter Score (NPS) Methodology (Reicheld 2006). Using the NPS methodology, 0-6 scores are considered detractors, 7-8 scores are considered passives, and 9-10 scores are considered promoters. The logistic models demonstrate that the top two drivers to customer satisfaction scores are still quality of manufacturing workmanship and reliability/operational availability (similar to results of the PLS model). The unresolved problems question on the survey was included in the models and demonstrated that the predicted probability of a customer being a promoter is much higher in both binary and ordered logit models if no unresolved problems exist. Finally, the model found engine oil consumption remained negative and is statistically significant suggesting that even with the alternative modeling approach there still may be data issues related to the survey.

It is recommended that the OEM implement logistic modeling for analyzing customer survey data. It is also recommended that a new survey design be constructed to eliminate issues with correlated data that can lead to spurious and unexplainable results.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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CHAPTER I: INTRODUCTION

The OEM has been using surveys to analyze customer satisfaction with their products, services, and distribution channel for several decades. Today the survey process is primarily used to help explain the overall customer experience with their brand. It consists of two primary measures: NPS (Net Promoter Score) and CSI (Customer Satisfaction Index). CSI has been the traditional way for industries to measure customer feedback. Only in the last decade has the NPS measure become more commonly used. The CSI is used to measure product performance and NPS is used to measure the brand and channel partner performance.

Each product line has its own CSI score that is a weighted average based on the most current 12 months of production (i.e., the last 12 build months). The CSI is derived from one question on each product's survey – "Overall, how satisfied are you with this product?" The customer is asked to answer the question on a 0-10 point scale with 10 being completely satisfied and 0 being completely dissatisfied. NPS methodology is measured on the same 0-10 point scale, however, questions are structured starting with the phrase "How likely are you to recommend…" said brand or channel partner. NPS scores are calculated by subtracting the percentage of promoters (9-10 scores) from the percentage of detractors (0-6 scores).

Product lines have surveys tailored to their specific products. In addition to the overall satisfaction question, there are other product-specific questions. For tractors this includes questions addressing the following areas: manufacturing quality, operational availability, performance, engine, chassis, transmission, and comfort and convenience (mostly operator's station). These functional areas are further broken down into individual questions that are used as independent variables within a partial least squares regression (PLS) model to understand their impact to the overall satisfaction. The PLS models have demonstrated over time that quality of manufacturing workmanship, reliability/operational availability, and machine productivity and capacity have the highest impact to the overall CSI score. In fact, the impact to the overall CSI score falls off drastically after these three. While these three factors may be the most important drivers of the CSI score, they do not necessarily receive the lowest scores on the survey. For example, noise level during operation has traditionally been one of the lowest scoring questions on the survey for tractors, but it has never appeared as a top driver to the overall CSI. Additionally, noise is one of the top negative comments received. Thus, many employees and managers struggle to understand the top driver methodology, or whether the results are significant. The objective of this thesis is to further understand the model being used by our analysts to determine if it is appropriate given the nature of the data being used.

As the OEM's competitors pressure them at home they must expand and be profitable abroad. It is crucial that the customer health metric is clearly understood and communicated. This thesis will attempt to fully understand the modeling characteristics used today. Existing models and processes will be evaluated, documented, and discussed. The background of the existing model and reasons for its use will be discussed. Finally, it will evaluate the appropriateness of logistic modeling as a comparison to the existing process. Data used in this thesis will be existing customer survey data responses from a specific model in the tractor product line.

CHAPTER II: LITERATURE REVIEW

There is an abundant amount of research completed that links a positive correlation between customer satisfaction and revenue. As Reichheld explains in *The Ultimate Question*, customer health metrics are required for long-term sustainability and profitability (Reicheld 2006). Firms such as Southwest Airlines, Enterprise Rent-A-Car, EBay, HomeBanc, Dell, and Harley Davidson have built their entire business model, promotions, and bonus structures around it. Dell's Net Promoter Score and total shipments were more than double HP, IBM, and Gateway from 1999-2002. From 1999-2002 Southwest Airlines was one of only two firms in the industry with positive growth. During this time, their NPS was around 50% while the bulk of their competition hovered around 10%. The same held true for ASDA supermarket in the U.K. who had a 25% growth rate from 1999-2003 coinciding with NPS of 40%. During this same time, some of their competition had negative NPS values that were accompanied by negative growth. Reichheld's firm, Bain, discovered that on average a 12 point increase in NPS doubled these firms' rate of growth. Though the focus is on implementing a NPS style measurement system, there are cautions about mismanagement of even the simplest metric. Firms need to have a firm grasp on ensuring their metrics are able to drive quick, structured, and appropriate actions. Through a properly defined and estimated model, leadership can easily make decisions that make sense for the business and for the customer.

Chris Baumann, Greg Elliott, and Suzan Burton analyzed the impact of existing data known within the banking industry to data gathered via a newly established customer survey (Baumann, Elliott and Burton 1987). Their challenge was leveraging qualitative and quantitative data together to understand customer behavioral intentions. They discovered the strongest relationship with customer retention is their affective attitude towards the bank. Several different modeling approaches were required to obtain their conclusions. This research supports the need for more than one model, and/or different models to explain customer satisfaction. It is the sheer nature of customer data that induces qualitative information into models requiring non-traditional approaches.

Niranjan Baradi used an ordered logit model in his study analyzing factors affecting the adoption of various tillage systems for crop production in Kansas (Baradi 2005). The data analyzed in this study look very similar to customers' "perception" of the evaluated OEM's products. The different surveys utilized a 5 point scale encompassing responses of strongly disagree, disagree, neutral, agree, and strongly agree. Results suggested that current implementation of BMP (Best Management Practices – essentially a form of reduced or no tillage in this case) did not vary for different producer sizes or geographically. The study showed that respondents' perceptions about ground and surface water pollution varied. Current tillage practices utilized, level of involvement with production agriculture, and level of education were significant predictors of the types of tillage systems adopted. Finally, the model was able to determine that potential adoption varied amongst size and profitability of respondents. The findings of this thesis suggest that logit modeling is an appropriate method for analyzing customer survey data.

Travis Heiman utilized logit modeling in his thesis "Analysis of a Cooperative Dairy Producer Risk Management Program" (Heiman 2003). He utilized data collected by the DFA (Dairy Farmers of America) through its members. The DFA provides mostly services to its members, primarily of which are a variety of marketing channels for milk.

The data collected were similar in nature to that of the CSI data in this research. Customers' answers were typically limited to a pre-selected response whether they were binary or ordered. Heiman's research identified the impact producer age, operation size, facilities utilized, internet access, and regional location had on the utilization of DFA's forward contracting program.

Shonda Anderson used ordinary least squares (OLS) and ordered logit models in her thesis "Preferences of US, EU, Honduran, and Chinese Undergraduates for Cloning" (Anderson 2006). In her research, Anderson conducted surveys in several countries with pre-defined answers that were both binary and ordered in nature. All questions were either yes/no or categorical variables with upper and lower bounds from 1-5. Anderson ran several different OLS models on the likeliness to consume cloned meat using 12 independent variables. Results throughout her different models found consistently that "morally wrong" had the highest impact for not consuming cloned meat. Next, Anderson used an ordered logit model to "predict probabilities that a dependent variable will fall in one of the several ordered categories based on a set of independent variables" (2006, 7-79). New variables were created in this scenario to understand if respondents' opinions were outside of the 1-5 bounded responses after hearing new information about cloning. She found issues trying to separate students by major, but encountered issues with sample size. CSI analysis may encounter the same issue when separating by geographical region. It is interesting to note that Anderson found significance across all models that the morality of consuming cloned meat was negative for all regions accept China. However, due to technical issues with distribution of the survey, the China data may not have been valid. This data issue is comparable to the mulitcollinearity issues in CSI data.

These results are promising for CSI data in that consistency from global datasets with differences in explanatory variables can be found. The OEM is looking for consistency across product lines such that regional drivers can be attained. Anderson's data likely presents fewer issues with multicollinearity than CSI data, but still provides a good reference for the utilization of logit modeling.

In her thesis "Review and Analysis of the 2008 National Stocker Survey" Janell Roe utilized ordered and binary logit models to estimate several different dependent variables (Roe 2010). Survey data used in this research were gathered by BEEF Magazine and Kansas State University in 2008. This was a lengthy survey structured to profile stocker/backgrounders in the cattle industry (backgrounding is a temporary feeding period between weaning and full-feed). Roe used logit models to estimate producer decisions, health management, marketing practices utilized, and nutrition, as dependent variables. Through this modeling process she was able to obtain variables with and without significance in each of the models investigated.

CHAPTER III: DATA OVERVIEW

The OEM utilizes a supplier to manage the distribution and return of the different surveys. See Appendix 1 for an example of the tractor product line survey. The supplier translates survey comments and then sends the data to the OEM data warehouse where it can be mined by key stakeholders around the enterprise (enterprise is defined as the global product lines). There is some data-analysis executed by the supplier to produce individual product line metrics. However, it is each product line's responsibility to execute analysis of the data to understand what the top drivers of the metrics are for their particular product(s).

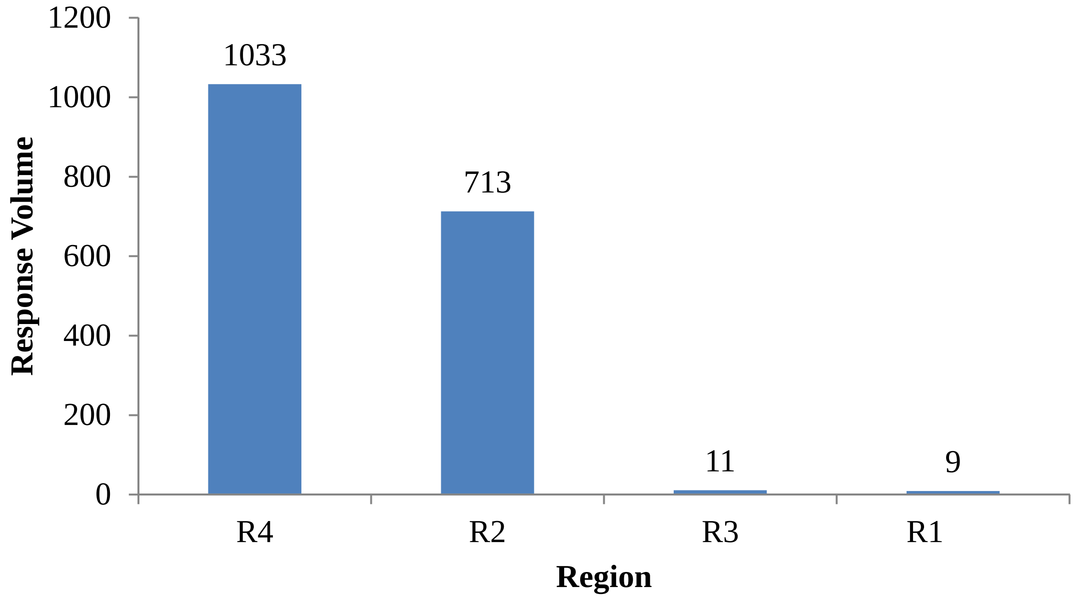
The two primary survey types are channel and product. The channel surveys are essentially similar across the enterprise, but the product surveys are tailored to each respective product line. Most all product lines ask three similar questions about quality, operational availability (machine uptime), and productivity. With each group there are specific product questions such as engine, drivetrain, ground engaging, cutting, etc. Also included on each survey are several warranty and financing questions. Finally, there is a place for open ended comments at the end of each product and financing question groups. The process for distribution of the survey varies globally. Customers in some regions receive paper surveys mailed to them and some receive phone calls. Customers receiving mailed paper surveys have the option to respond online. Additionally, the dealer and product surveys are combined in some regions and mailed separately or called separately in others.

Appendix 2 shows the correlations of the survey response data. The Overall CSI is highly correlated with quality of manufacturing workmanship, reliability/operational availability, and productivity and capacity. The responses for these three factors are also highly correlated with each other. Other high correlations include productivity and capacity and power level, productivity and capacity and engine lug down and recovery, power level and engine lug down and recovery, transmission speed selection and transmission shifting, transmission speed selection and clutch, transmission shifting and clutch, usefulness of OM and instructional material and ease of adjustment to various conditions, serviceability and ease of adjustment to various conditions, ease of adjustment to various conditions and control placement and operation, and ride comfort and seat comfort. The majority of the correlations fall between 0.40 and 0.60.

On the product surveys there is one question that asks customers, on a scale of 0-10 with 0 being completely dissatisfied and 10 being completely satisfied. “Overall, how satisfied are you with this product”? It is from this question that the customer satisfaction index (CSI) metrics for the various products are driven. The other product-specific questions on the survey are utilized in in the regression model to determine the drivers to the overall CSI score.

For this report the data have been narrowed to a specific model in the tractor product line and encompasses global responses. Figure 3.1 displays the survey response distributions by geographical region. This shows that 58% of the responses come from region 4, 40% from region 2, 1% from region 3, and 1% from region 1. It is commonly thought that there are distinctly different drivers to the overall satisfaction score within each region. Therefore, it makes sense to introduce this regional information into the analysis process.

Figure 3.1 Survey response distributions by region



*R4: North America, Australia, New Zealand; R2: Europe, CIS, North Africa, Near and Middle East; R3: South America, Mexico; R1: South Africa, Asia

Though the survey is on an 11 point scale (0-10) the data are multiplied by a factor of 10 giving a 0-100 point scale. For the purposes of this research the data were converted back to its original state (i.e., 0-10 scale). Table 3.1 is a sample of the raw data. The overall satisfaction score and product-specific functional area scores are on the same 11 point scale. *Brakes*, *cab air quality*, *clutch*, and *fuel consumption* are 4 of the 32 independent variables used in the PLS model.

Table 3.1 Sample raw data

Observation	*Overall Satisfaction*	*Brakes*	*Cab Air Quality*	*Clutch*	*Fuel Consumption*
1	10	10	10	10	10
2	10	10	10	10	10
3	9	9	9	9	9
4	9	9	9	7	10
5	9	9	9		8
6	10	10	10	10	10
7	10	10	10	10	8
8	10	10	10	10	10
9	8	10	10	8	9
10	6	10	10	10	10
11	8	9	9	9	10
12	0	4	2	0	5

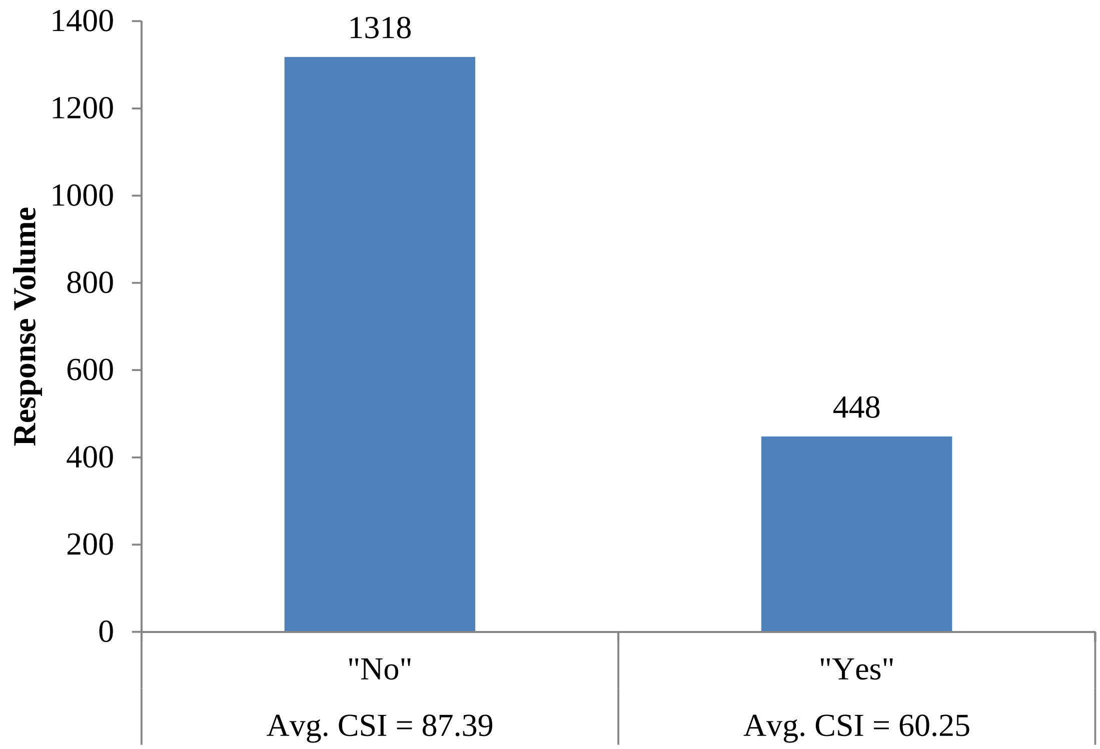
Figure 3.2 shows the distribution of survey responses in each 0-10 category for the overall satisfaction question on the survey, i.e., the response variable used in both PLS and logit regression models. The distributions are relatively similar for the continuous independent variables. As previously mentioned, customers responding with 9-10 are classified as promoters, 7-8 are passive, and 0-6 are classified as detractors. It can be seen that 1000 (57%) of the respondents are promoters, 464 (26%) are passive, and 295 (17%) are detractors. It is a general rule that the more evenly distributed the response data are within each category the more accurate the ordered logit model is. Some product lines may not have enough data in each NPS category to accurately estimate a model. Therefore, it may be necessary to combine the detractors and passives into one category and compare them against the likelihood of being a promoter versus not being a promoter. To determine if this is important, both binary and ordered logit models are estimated.

Figure 3.2 Survey response distributions of Overall Satisfaction scores

Figure 3.3 shows the response distributions of customers answering “No” and “Yes” to the unresolved problems question on the survey. After answering the product-specific functional area questions, customers are asked “Do you have unresolved product problems?” with the option to choose “Yes” or “No”. There is then a space provided for customers to comment on their unresolved problems. As seen in figure 3.1.3, 448 (25%) customers answered yes to this question. An unresolved problem could be company, product, dealer, or financing related. There may not be any unresolved issues remaining, but the previous product issues could have been significant enough that the customer is concerned about the resale of the product. Figure 3.3 also shows that customers with unresolved problems have an average CSI 27.2 points lower than those without unresolved problems. The fact that 25% of customers have unresolved problems combined with the

large CSI gap indicate that the presence or lack thereof of unresolved problems should be accounted for in the modeling process.

Figure 3.3 Survey response distributions of customers answering "No" and "Yes" to the unresolved problems question on the survey



For each product related question on the survey, Table 3.2 shows the summary statistics of the survey responses. The responses to the scores have relatively high averages (i.e., none are less than 8). *Overall satisfaction* had the lowest average score of 8.05 and *lighting* had the highest average score of 9.30. Variability exists in that all questions received a min score of 0 and a max score of 10. *Noise level during operation* had the most variability with a coefficient of variation of 0.32. The *unresolved problems* variable is binary (i.e., customers responses were either yes or no).

Table 3.2 Total survey responses (n), mean, standard deviation, and coefficient of variation (CV)

Variable	n	Mean	Std. Dev.	CV
Overall Satisfaction	1759	8.05	2.44	0.30
Quality of manufacturing workmanship	1754	8.29	2.20	0.27
Reliability/Operational availability	1754	8.14	2.51	0.31
Machine productivity and capacity	1737	8.74	1.88	0.22
Power Level	1763	8.93	1.66	0.19
Engine lug down and recovery	1756	8.79	1.77	0.20
Engine oil consumption	1751	9.22	1.24	0.13
Fuel Consumption	1758	8.17	2.14	0.26
Engine cooling system	1753	8.41	2.28	0.27
Transmission shifting	1734	8.49	2.28	0.27
Transmission speed selection	1750	8.75	2.01	0.23
Clutch	1709	8.83	1.85	0.21
Power take-off (PTO)	1693	8.84	1.80	0.20
Ease of attaching/detaching implement	1751	8.73	1.72	0.20
Implement hydraulics	1755	8.82	1.80	0.20
Lighting	1760	9.30	1.25	0.13
Brakes	1756	8.84	1.91	0.22
Steering system	1759	8.88	1.90	0.21
Wheels and tires or Tracks and undercarriage	1753	8.93	1.72	0.19
Fuel tank capacity	1761	9.15	1.40	0.15
Hitch	1744	8.82	1.96	0.22
Fuel System	1750	9.00	1.55	0.17
Usefulness of operator's manual and instructional material	1752	8.60	1.76	0.20
Serviceability	1751	8.39	1.90	0.23
Ease of adjustment to various conditions	1743	8.66	1.68	0.19
Control placement and operation	1753	8.89	1.58	0.18
Noise level during operation	1760	8.15	2.63	0.32
Visibility	1758	9.22	1.27	0.14
Cab air quality (a/c, heater, filter)	1760	8.89	1.79	0.20
Ride comfort	1763	8.90	1.70	0.19
Monitors/Displays	1757	8.85	1.72	0.19
Seat comfort	1764	8.96	1.69	0.19
Sound system	1737	8.93	1.70	0.19
Unresolved Problems	1680	NA	NA	NA

*All questions had at least one response of 0 and one response of 10 (i.e., min and max values for all questions were 0 and 10)

CHAPTER IV: METHODS

The objective of this study is to understand the existing regression modeling methods used to analyze customer satisfaction data. More specifically, the objective is to understand whether the coefficients and their values make sense and whether an alternative modeling approach should be considered. This was accomplished by first estimating the existing partial least squares (PLS) model, then estimating alternative logistic (logit) models. Excel Minitab and Stata/MP 13.1 software were utilized to estimate these models.

4.1 Partial Least Squares Model

The OEM's corporate data analyst group completes the analysis of CSI data for most of the enterprise. Due to the large quantity of questions on current product surveys, the model used needs to have the capability to handle large data sets with highly correlated explanatory (independent) variables (Tobias 1995). For these reasons partial least squares (PLS) regression has been chosen. The specific software used to estimate models is Excel Minitab. The model groups like coefficients together into components for separate analysis. It then chooses the best quantity of groups to analyze against each other to produce the final output. This chapter will present the steps taken to develop the PLS models and the challenges associated with the process.

The response variable used in the PLS model is the overall satisfaction question from the survey. Of the 1766 customer surveys used in these analyses 1759 customers answered the overall satisfaction question. However, due to various other survey questions also having missing values, the model was estimated with 1421 observations. The model is estimated to understand the impact each product-specific functional area question on the survey (independent variables) has on the overall satisfaction score.

There are a total of 32 independent variables used in the PLS model. They include all product related questions on the survey with categorical responses ranging from 0-10. The individual product area questions are the following: *quality of manufacturing (MFG) workmanship*, *reliability/operational availability, machine productivity and capacity, power level, engine lug down and recovery, engine oil consumption, fuel consumption, engine cooling system, transmission speed selection, transmission shifting, clutch, power take off (PTO), ease of attaching/detaching implement, implement hydraulics, lighting, brakes, steering system, wheels/tires or tracks/undercarriage, fuel tank capacity, hitch, fuel system, usefulness of OM and instructional material, serviceability, ease of adjustment to various conditions, control placement and operation, noise level during operation, visibility, cab air quality (a/c, heater, filter), ride comfort, monitors and displays, seat comfort,* and *sound system*.

The expected sign of each independent variable is listed in table 4.1. It is hypothesized that all variables in both PLS and logit models will have a positive sign, i.e., as each independent variable question score increases this will result in an increase to the response variable o*verall satisfaction*. The variable *unresolved problems* was not utilized in the PLS model, but will be used in the logit models. This variable is further discussed in sections 4.2.1 Ordered Logistic Model and 4.2.2 Binary Logistic Model.

Table 4.1 Expected signs of independent variables

Variable	Expected Sign
Quality of MFG Workmanship	Positive
Reliability/operational avail.	Positive
Productivity and capacity	Positive
Power level	Positive
Engine lug down and recovery	Positive
Engine oil consumption	Positive
Fuel consumption	Positive
Engine cooling system	Positive
Transmission speed selection	Positive
Transmission shifting	Positive
Clutch	Positive
Power take off (PTO)	Positive
Ease of attach/detach imp.	Positive
Implement hydraulics	Positive
Lighting	Positive
Brakes	Positive
Steering system	Positive
Wheels/tires or tracks/undercar	Positive
Fuel tank capacity	Positive
Hitch	Positive
Fuel system	Positive
Usefulness of OM and instructional material	Positive
Serviceability	Positive
Ease of adj. conditions	Positive
Control placement and operation	Positive
Noise level during operation	Positive
Visibility	Positive
Cab air quality (a/c, heater, filter)	Positive
Ride comfort	Positive
Monitors/displays	Positive
Seat comfort	Positive
Sound system	Positive
Unresolved problems	Negative

4.2 Logistic Models

Ordered and binary logit regression models were evaluated as an alternative to PLS. The survey has a pre-defined survey response of 0-10 therefore not allowing a negative CSI score or a score over 10, i.e., the data are bounded. Logit models were chosen because they assume the data have upper and lower bounds, whereas PSL models do not. Another reason logit models were chosen over PLS is because PLS estimations are linear, whereas logit models are non-linear. Essentially a PLS model assumes the impact of a customer's response moving from a 1-2, 3-4, 8-9, etc. are constant, but it is hypothesized that this is not the case with the actual survey data.

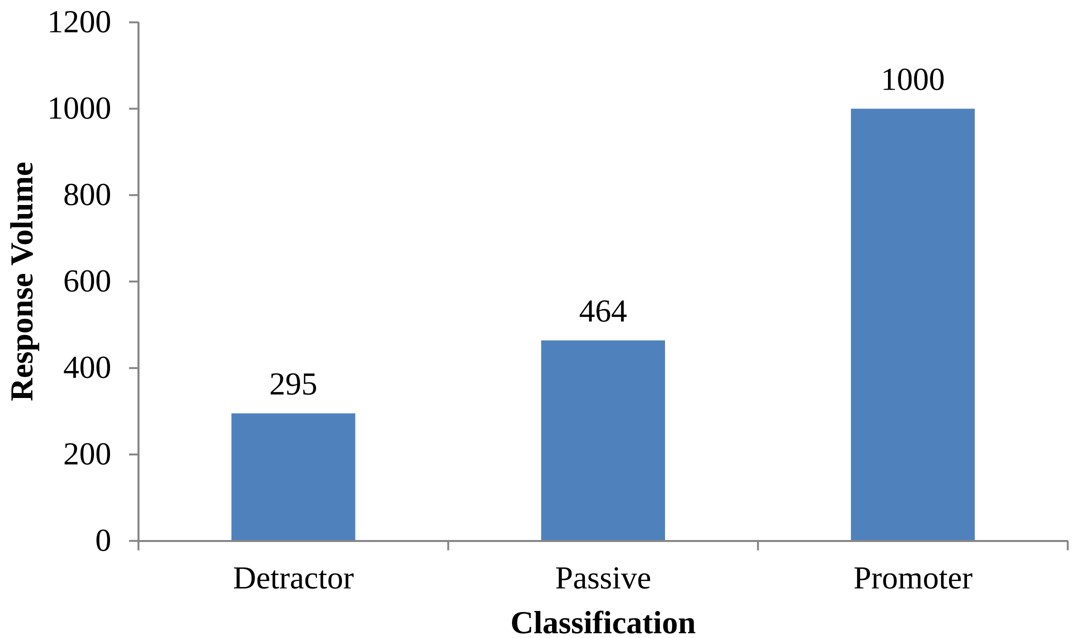
The same response data will be used to estimate both binary and ordered logit models. However, the data were structured differently to accommodate the model formats. Each structure will be further discussed in sections 4.2.1 and 4.2.2. The 32 continuous independent variables will remain the same for both binary and ordered models.

The unresolved problems question was included as a binary independent variable in both logit models. The data analyzed for this research shows the average overall satisfaction score is 27.2 points lower (on the 0-100 scale) for those customers answering "Yes" they have unresolved problems compared to those who answered "No" they do not have unresolved problems. It is not uncommon in other product lines to see a 20-30 point gap between those customers with and without unresolved problems. Thus, it makes sense to introduce this information into the model. The data were entered in the model as a binary variable with those answering "No" as 0 and those answering "Yes" as 1. It is hypothesized that unresolved problems will have a negative sign, i.e., customers with unresolved problems will have a lower overall satisfaction score than those without unresolved problems.

4.2.1 Ordered Logistic Model

An ordered logit model allows for various categorical responses that have natural ranking or order. Utilizing the net promoter score (NPS) methodology the response variable (overall satisfaction scores) can be grouped into three categories (Reicheld 2006). These categories are referred to as detractors (0-6 scores), passives (7-8 scores), and promoters (9-10 scores). Figure 4.1 shows the distribution of the response variable when grouping by NPS methodology. Thus, it makes most logical sense given the net promoter score methodology for categorizing responses to estimate an ordered logit model.

Figure 4.1 Ordered survey sample size and distribution by response classification



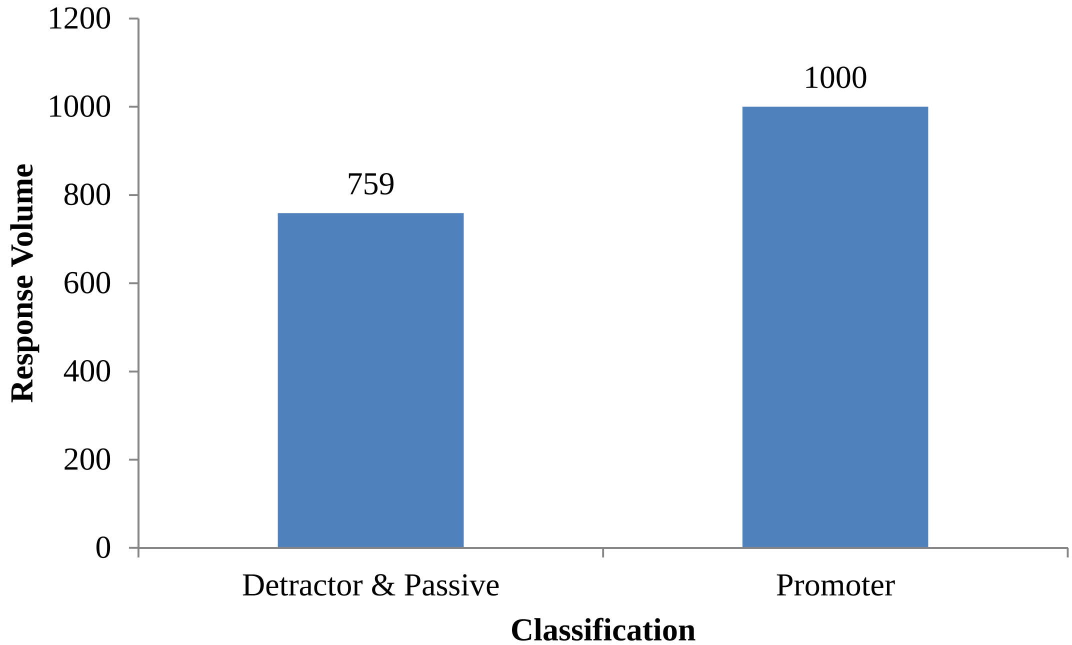
4.2.2 Binary Logistic Model

In cases with very few respondents in some categories data may be aggregated for analysis. For this research a binary model was also considered where the response variable (overall satisfaction score) were divided into two groups: detractors/passives (0-8 scores) and promoters (9-10 scores). Detractor/passive scores were given a value of 0 and promoter scores were given a value of 1. The model estimates the probability (marginal effect) of a customer being a promoter versus being a detractor or passive.

Figure 4.2. illustrates the survey sample size and distribution of responses between the two groups for the binary model. This method of aggregating and analyzing the data

with a binary logit model (as opposed to an ordered logit model) would be most appropriate for data sets where there are very few respondents in one of the three NPS categories. This is sometimes the case with low volume product lines, or products with very high CSI scores resulting in few respondents in the detractor or neutral categories.

Figure 4.2 Binary survey sample size and distribution by response classification



CHAPTER V: MODEL RESULTS

5.1 Partial Least Squares Model Results

Table 5.1 shows the results from the PLS model. The model evaluated 10 components and selected three as the optimal model to estimate. The optimal model is defined as the model with the highest predicted R-squared. This model has a predicted R-squared of 0.75 meaning 75% of the variability in *overall satisfaction* is explained by the 32 independent variables. The p-value for the model is 0.000, which is less than 0.05, providing sufficient evidence that the three-component model is significant.

The coefficients from the model reflect the impact that the independent variables have on the *overall satisfaction* (i.e., the dependent variable). Because the units are the same on all of the independent variables, the magnitude of the coefficients can be directly compared. As seen in Table 5.1 *reliability/operational availability* has a coefficient value of 0.329 and an average CSI score of 81.41. Thus, for a one-unit increase in *reliability/operational availability* the o*verall satisfaction* score will increase by 0.329 holding all other variables constant.

Of the 32 variables, the estimated coefficients for 23 variables are positive as predicted: *quality of MFG workmanship, reliability/operational availability, productivity and capacity, engine cooling system, ride comfort, transmission shifting, serviceability, noise level during operation, fuel consumption, steering system, brakes, monitors and displays, implement hydraulics, power level, ease of adjustment to various conditions, engine lug down and recovery, cab air quality (a/c, heater, filter), transmission speed selection, wheels and tires or tracks and undercarriage, power take off (PTO), clutch, fuel system,* and *sound system.*

The estimated coefficients on the remaining nine variables were negative, which was not consistent with expectations. The variables that were negative are *visibility*, *control placement and operation, seat comfort, hitch, ease of attaching/detaching implement*, *usefulness of operator's manual and instructional material, lighting, fuel tank capacity,* and *engine oil consumption.* It is not fully understood and there is no intuitive explanation of a factor with a negative coefficient which points to the possible issue with the modeling approach or problems with the data itself. Using *engine oil consumption* as an example, a one-point increase would cause the *overall satisfaction* score to decrease by 0.086 points. Additionally, variables such as *engine oil consumption, lighting,* and *visibility* have the highest average functional area scores. Thus, it is unknown what is causing them to be negative. It is hypothesized that the negative variables are being affected by other variables of higher significance within their PLS components causing them to be negative. Another possibility is that there is not enough variability within the scores of the negative variables that would cause them to stand alone within the component set thus leading to potentially spurious results.

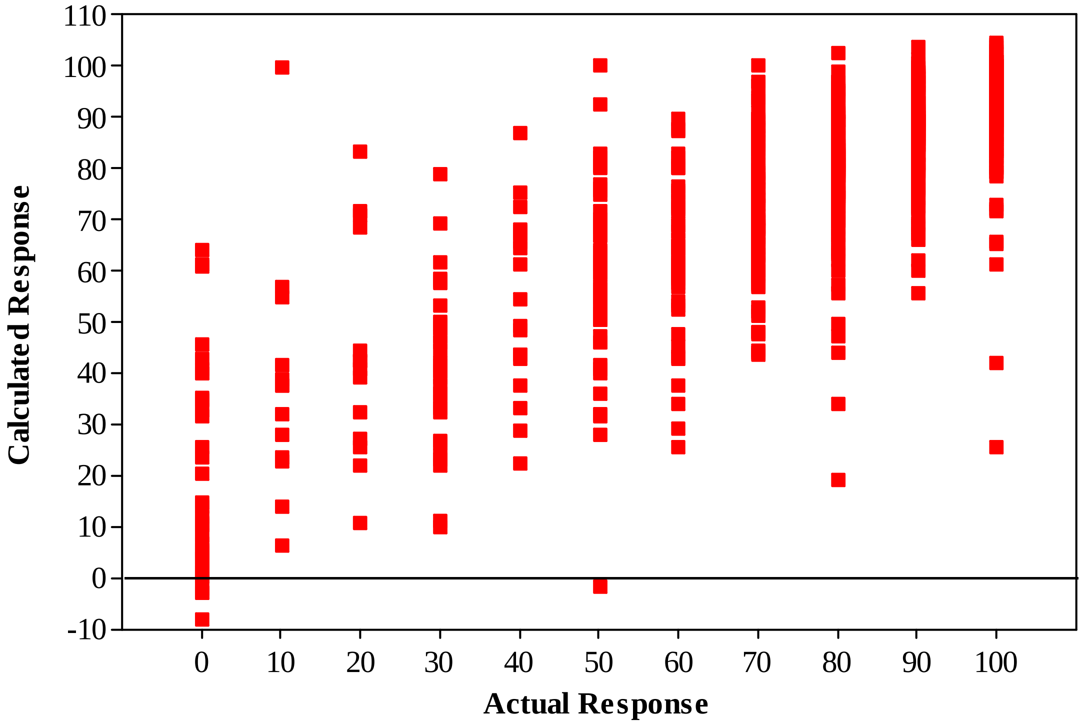
Table 5.1 PLS model Coefficient, Reported Coefficient, and Average CSI score; sorted descending by Coefficient absolute value

Variable	Coefficient	Reported Coefficient	CSI score
Reliability/Operational availability	0.329	0.249	81.40
Quality of manufacturing workmanship	0.298	0.225	82.90
Machine productivity and capacity	0.135	0.102	87.38
Engine cooling system	0.097	0.073	84.05
Engine oil consumption	-0.086	0.000	92.18
Fuel tank capacity	-0.058	0.000	91.49
Noise level during operation	0.055	0.041	81.48
Transmission shifting	0.054	0.041	84.87
Ride comfort	0.047	0.035	89.03
Lighting	-0.044	0.000	92.98
Serviceability	0.044	0.033	83.91
Usefulness of operator's manual and instructional material	-0.042	0.000	86.01
Fuel Consumption	0.042	0.031	81.65
Steering system	0.034	0.026	88.81
Brakes	0.033	0.025	88.36
Ease of attaching/detaching implement	-0.030	0.000	87.32
Hitch	-0.028	0.000	88.20
Monitors/Displays	0.026	0.020	88.47
Implement hydraulics	0.025	0.019	88.18
Seat comfort	-0.023	0.000	89.56
Power Level	0.021	0.016	89.29
Engine lug down and recovery	0.020	0.015	87.88
Cab air quality (a/c, heater, filter)	0.020	0.015	88.85
Ease of adjustment to various conditions	0.020	0.015	86.62
Control placement and operation	-0.015	0.000	88.91
Transmission speed selection	0.014	0.010	87.50
Wheels and tires or Tracks and undercarriage	0.010	0.007	89.25
Power take-off (PTO)	0.003	0.002	88.40
Visibility	-0.003	-0.002	92.20
Clutch	0.001	0.001	88.26
Fuel System	0.001	0.000	90.00
Sound system	0.000	0.000	89.26
Constant	1.118	NA	NA

Figure 5.1 displays a graph of the actual responses to the overall satisfaction question and the estimated responses of the PLS model. This graph provides evidence that the PLS model is estimating responses outside the bounded response criteria of 0-10. This

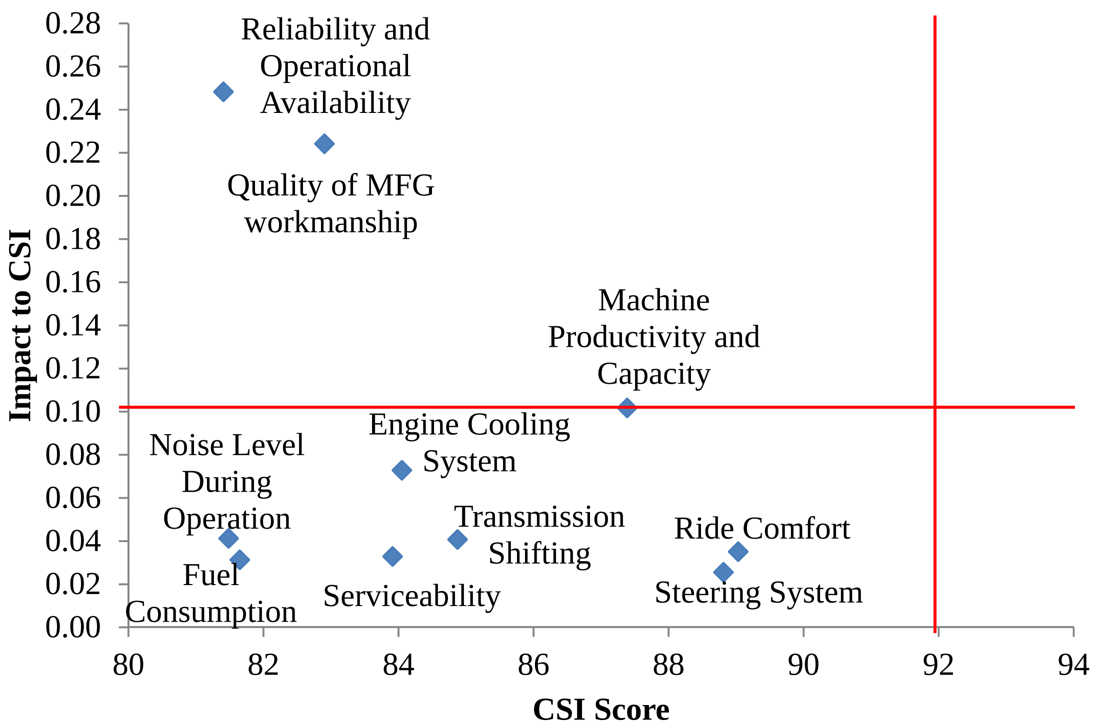
indicates that PLS modeling approach is probably not appropriate for analysis on customer survey data.

Figure 5.1 PLS model response plot



The top 10 coefficients, organized by highest absolute value, are graphed in an IP (Impact Performance) chart to share with the enterprise such that this information can be used to facilitate action and decision making. IP charts provide four quadrants of focus as shown in Figure 5.2. Variables in the upper left quadrant are areas of low CSI performance with high impact to the overall satisfaction score and should reflect areas of focus for improvement. Survey questions falling in the upper right are areas of high CSI performance and should be areas of focus to keep doing well. Anything in the lower quadrants are typically considered as low impact to the overall satisfaction score, are areas to monitor, but not essential areas of focus. The left and right quadrants are determined by each product line's CSI goal (92.0 for tractors on the 100 point scale). Top and bottom quadrants are typically determined by the average impact of the top 10 questions. However, this number can change drastically with different data sets and thus lacks consistency. The large tractor group (200+ engine HP) has recognized that coefficients consistently tend to cluster around zero between -0.10 to 0.10. Anything outside this range stands out individually as primary drivers to CSI and thus has chosen to be consistent in dividing the top and bottom quadrants at 0.10.

Figure 5.2 Top 10 Impact/Performance Chart



On the surface it appears that the data makes sense. The OEM would expect their customers to be most concerned about reliability and operational availability, quality of MFG workmanship, and machine productivity and capacity. This research has identified that the top 10 coefficients reported in IP charts do not match the estimated coefficients from the PLS regression model.

The top 10 variables identified in table 5.1 are (in order from largest to smallest absolute coefficient value): *reliability and operational availability, quality of MFG workmanship, machine productivity and capacity, engine cooling system, engine oil consumption, fuel tank capacity, noise level during operation, transmission shifting, ride comfort,* and *lighting.* The variables not reported on the IP chart are: *engine oil consumption, fuel tank capacity,* and *lighting,* which happen to have negative signs. They are being reported, however, as having 0.00 impact to CSI as seen by the reported coefficient column in Table 5.1. Thus, the next three positive variables (*serviceability, fuel consumption,* and *steering system*) are reported in their place.

There are two explanations for why their value is changed to 0.00 before being reported. First, it would not make sense to focus on a question with a negative coefficient that would reduce the overall satisfaction score. That is, it is very hard to explain how increasing the CSI score of a functional area (e.g., usefulness of operator's manual and instructional material) would lead to a lower overall satisfaction score. However, while there is no intuitive explanation of a factor with a negative coefficient, simply ignoring them, or changing them to 0.00 is likely not appropriate for reporting purposes. The second explanation is that the coefficient values are close enough to zero that they essentially have no impact on the overall satisfaction score. This is not always true though. As shown in Table 5.1, *engine oil consumption* has a coefficient in the top five in absolute value and is very close to a cutoff of 0.10 for high impact. The two explanations currently given for reporting the negative coefficients as zero are very concerning.

Another concern with how the PLS model results are reported has to with the handling of the reported positive coefficients. As seen in Table 5.1 the reported coefficients are different than the model-estimated coefficients. To account for the fact that negative coefficients are essentially ignored, TCI "adjusts" the positive coefficients by dividing each positive coefficient by the sum of the positive coefficients. This effectively scales all of the positive coefficients down. It is not entirely clear as to why this is done other than it serves as an ad-hoc adjustment for the fact that negative coefficients are ignored. A result of this scaling, and setting negative coefficients to zero, is that the sum of the coefficients equals 1.0 and the resulting predicted values of dependent variable are constrained to falling between 0 and 100.

5.2 Ordered Logistic Model Results

As previously discussed, it is commonly thought that there are distinctly different drivers to the overall satisfaction score by region. Models were estimated including a regional dummy variable and the results showed that regional data had no statistical significance. Thus, this information was removed from the final model estimations.

Table 5.2 displays the results of estimating the data with an ordered logit model, where the overall satisfaction score was redefined as detractor = 0 (0-6 scores), passive = 1 (7-8 scores) and promoter = 2 (9-10 scores). The model has a Pseudo R-squared of 48.7% indicating that 48.7% of the variability in the 0, 1, 2 *NPS* score is explained by the independent variables. The likelihood ratio chi-square of 1295.26 with a p-value of 0.0000 indicates the model is statistically significant as compared to the null model with no predictors.

Of the 33 independent variables 11 were statistically significant at the 95% confidence interval: *quality of manufacturing (MFG) workmanship, reliability/operational* *availability, machine productivity and capacity, engine oil consumption, fuel consumption, engine cooling system, transmission shifting, serviceability, ride comfort, seat comfort,* and *unresolved problems.* Of the 11 significant variables *engine oil consumption, seat comfort,* and *unresolved problems* have negative coefficient signs. The negative sign on *unresolved problems* is expected, but the negative signs on *engine oil consumption* and *ride comfort are not.* Recall that with PLS model *engine oil consumption* was also negative. However, the sign on *ride comfort* was not negative in the PLSmodel. It does not realistically make sense that as the scores of *engine oil consumption* or *seat comfort* increase the result is a decrease in the likelihood or probability that a customer would be a promoter.

Though they were not statistically significant, other variables with negative values *include clutch, power takeoff (PTO), lighting, brakes, fuel tank capacity, hitch, usefulness of operator's manual and instructional material, control placement and operation,* and *cab air quality (a/c, heater, filter).* The signs of these coefficients were expected to be positive. This further indicates that even with proper modeling the negative coefficients are not explainable.

The results of the coefficients in ordered logistic regression are interpreted differently than with PLS models, and slightly different than binary logit models. For example, for a one-unit increase in *quality of MFG workmanship* (i.e., going from 3-4) we expect a 0.444 increase in the log odds of being a higher level of *NPS* score, holding all other variables constant. The same is true for *unresolved problems*, for a one-unit increase in *unresolved problems* (i.e., a customer answering "Yes" versus "No" to unresolved problems) we expect 0.770 decrease in the log odds of being a higher level of *NPS* score, holding all other variables constant.

Table 5.2 Ordered logit model coefficients, standard error, P-value, and 95% confidence interval

Variable	Coeff.	Std. Error	P>|z|	95% Confidence Interval	
Quality of MFG Workmanship	0.444	0.070	0.000	0.306	0.581
Reliability/operational avail.	0.433	0.059	0.000	0.317	0.549
Productivity and capacity	0.303	0.107	0.005	0.094	0.513
Power level	0.027	0.110	0.807	-0.189	0.243
Engine lug down and recovery	0.123	0.092	0.177	-0.056	0.303
Engine oil consumption	-0.262	0.095	0.006	-0.449	-0.075
Fuel consumption	0.144	0.051	0.005	0.044	0.244
Engine cooling system	0.117	0.045	0.009	0.029	0.204
Transmission speed selection	0.055	0.078	0.478	-0.098	0.209
Transmission shifting	0.139	0.063	0.027	0.016	0.263
Clutch	-0.033	0.080	0.675	-0.190	0.123
Power take off (PTO)	-0.028	0.066	0.671	-0.157	0.101
Ease of attach/detach imp.	0.014	0.074	0.850	-0.132	0.160
Implement hydraulics	0.039	0.066	0.552	-0.090	0.168
Lighting	-0.034	0.109	0.755	-0.248	0.180
Brakes	-0.096	0.055	0.083	-0.205	0.013
Steering system	0.060	0.059	0.306	-0.055	0.175
Wheels/tires or tracks/undercar	0.063	0.061	0.299	-0.056	0.183
Fuel tank capacity	-0.090	0.083	0.280	-0.253	0.073
Hitch	-0.031	0.060	0.606	-0.148	0.086
Fuel system	0.045	0.083	0.583	-0.117	0.207
Usefulness of OM and instructional material	-0.049	0.063	0.445	-0.173	0.076
Serviceability	0.187	0.063	0.003	0.063	0.311
Ease of adj. conditions	0.022	0.093	0.814	-0.160	0.204
Control placement and operation	-0.081	0.085	0.344	-0.248	0.087
Noise level during operation	0.064	0.039	0.101	-0.012	0.140
Visibility	0.121	0.095	0.207	-0.067	0.308
Cab air quality (a/c, heater, filter)	-0.079	0.061	0.192	-0.198	0.040
Ride comfort	0.327	0.085	0.000	0.160	0.494
Monitors/displays	0.084	0.067	0.212	-0.048	0.215
Seat comfort	-0.238	0.088	0.007	-0.410	-0.066
Sound system	0.003	0.060	0.966	-0.115	0.120
Unresolved problems	-0.770	0.173	0.000	-1.109	-0.430

The coefficients from the model do not provide an accurate representation of the relationship between the response and the covariates (Williams 2012). To manage this, the marginal probabilities around the means of the coefficients were estimated. Table 5.2 displays the marginal probabilities at the means estimated by the ordered logit model.

The marginal probability values for continuous variables (all variables accept *unresolved problems*) measure the instantaneous rate of change from each response, i.e., 0-1, 3-4, 5-6, etc. The marginal probabilities should sum to zero as the change in one probability will cause opposite, incremental effects of the others. The marginal probabilities for binary independent variables (*unresolved problems*) measure discrete change, i.e., how do predicted probabilities change as the binary independent variable changes from 0 to 1 (Williams 2012). For example, a one-unit increase in *quality of MFG workmanship* decreases the probability a customer will be a detractor by 1.3%, decreases the probability a customer will be a passive by 9.7%, and increases the probability a customer will be a promoter by 11.0% holding all other variables constant at their means. All other positive continuous variables are interpreted the same. Likewise, customers with *unresolved problems* (binary variable) have a 5.4% probability of being a detractor, 55.4% probability of being a passive, and 39.2% probability of being a promoter holding all other variables constant at their means. The variables with significant p-values in the ordered logit model are also significant when estimating the marginal effects.

Table 5.3 Ordered logit model coefficients, standard error, P-value, and marginal probabilities (at means)

	Marginal Probabilities (at means)		
Variable	**Detractor**	**Passive**	**Promoter**
Quality of MFG Workmanship	-0.013	-0.097	0.110
Reliability/operational avail.	-0.013	-0.095	0.108
Productivity and capacity	-0.009	-0.066	0.075
Power level	-0.001	-0.006	0.007
Engine lug down and recovery	-0.004	-0.027	0.031
Engine oil consumption	0.008	0.057	-0.065
Fuel consumption	-0.004	-0.032	0.036
Engine cooling system	-0.003	-0.026	0.029
Transmission speed selection	-0.002	-0.012	0.014
Transmission shifting	-0.004	-0.030	0.035
Clutch	0.001	0.007	-0.008
Power take off (PTO)	0.001	0.006	-0.007
Ease of attach/detach imp.	0.000	-0.003	0.003
Implement hydraulics	-0.001	-0.009	0.010
Lighting	0.001	0.007	-0.008
Brakes	0.003	0.021	-0.024
Steering system	-0.002	-0.013	0.015
Wheels/tires or tracks/undercar	-0.002	-0.014	0.016
Fuel tank capacity	0.003	0.020	-0.022
Hitch	0.001	0.007	-0.008
Fuel system	-0.001	-0.010	0.011
Usefulness of OM and instructional material	0.001	0.011	-0.012
Serviceability	-0.006	-0.041	0.046
Ease of adj. conditions	-0.001	-0.005	0.005
Control placement and operation	0.002	0.018	-0.020
Noise level during operation	-0.002	-0.014	0.016
Visibility	-0.004	-0.026	0.030
Cab air quality (a/c, heater, filter)	0.002	0.017	-0.020
Ride comfort	-0.010	-0.072	0.081
Monitors/displays	-0.002	-0.018	0.021
Seat comfort	0.007	0.052	-0.059
Sound system	0.000	-0.001	0.001
Unresolved problems	0.028	0.162	-0.190
Unresolved problems = 0	0.026	0.392	0.582
Unresolved problems = 1	0.054	0.554	0.392

To assist with interpreting the results of the marginal effects the predicted probabilities of a customer being a detractor, passive, or promoter were graphed for several significant variables. Figure 5.3 shows the predicted probabilities for *quality of MFG workmanship*. The model estimated that at a *quality of MFG workmanship* score of 0 the predicted probability of a customer being a detractor is 57.0%, passive is 40.3%, and promoter is 2.7% holding all other variables constant at their means. As expected, as the score of *quality of MFG workmanship* increases the probability of a customer being a passive or promoter increases. The model estimated that at *a quality of MFG workmanship* score of 10 the predicted probability of a customer being a detractor is 1.5%, passive is 28.3%, and promoter is 70.1% holding all other variables constant at their means.

Figure 5.3 Predicted probability of being a detractor, passive, or promoter against quality of MFG workmanship (all other variables at their means)

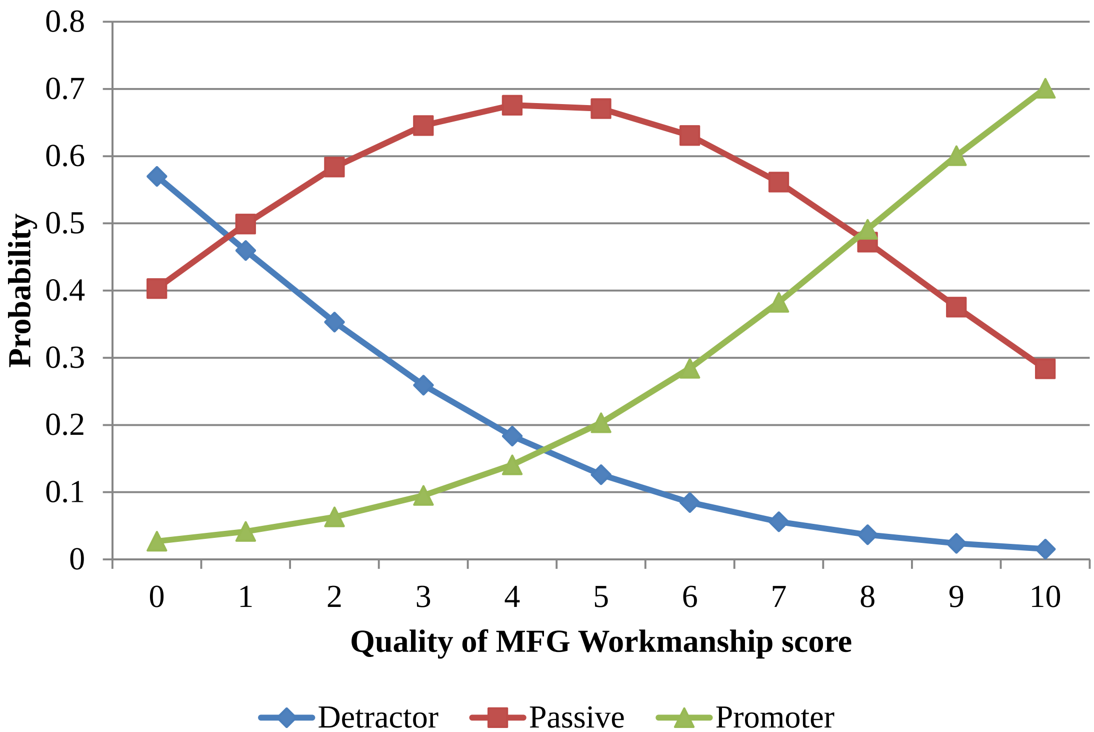
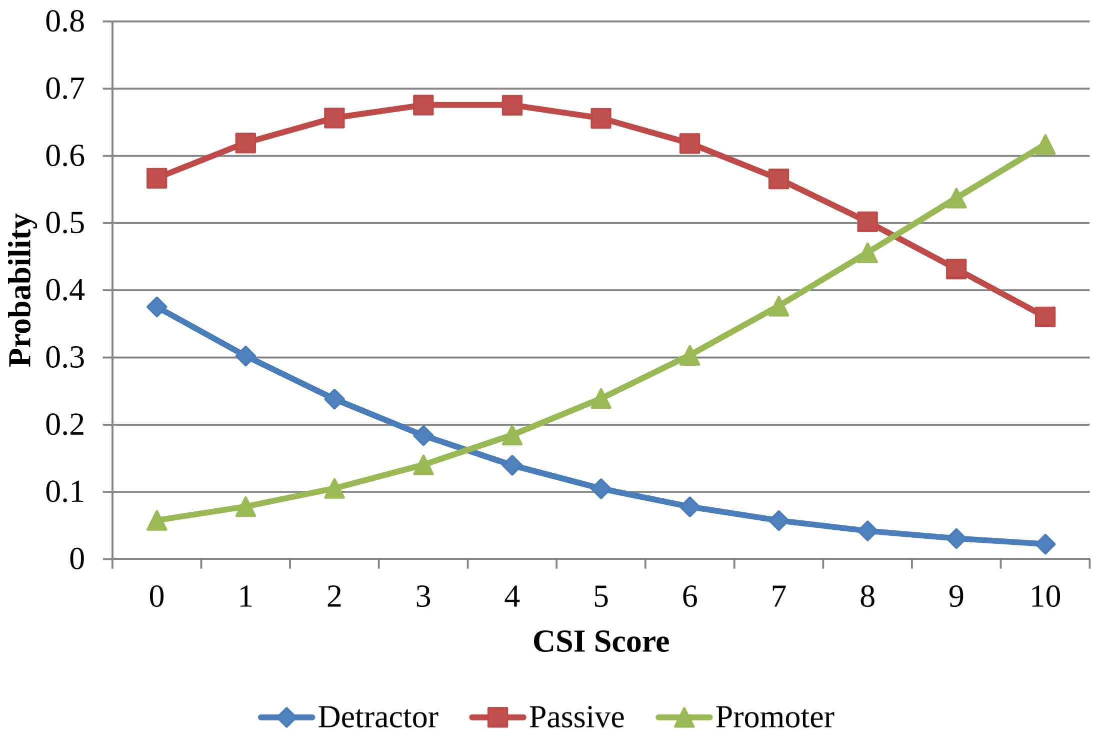


Figure 5.4 displays the predicted probabilities of a customer being a detractor, passive, and promoter using the variable *ride comfort*. The model estimated that at a ride comfort score of 4 the predicted probability of being a detractor is 14.0%, passive is 67.6%,

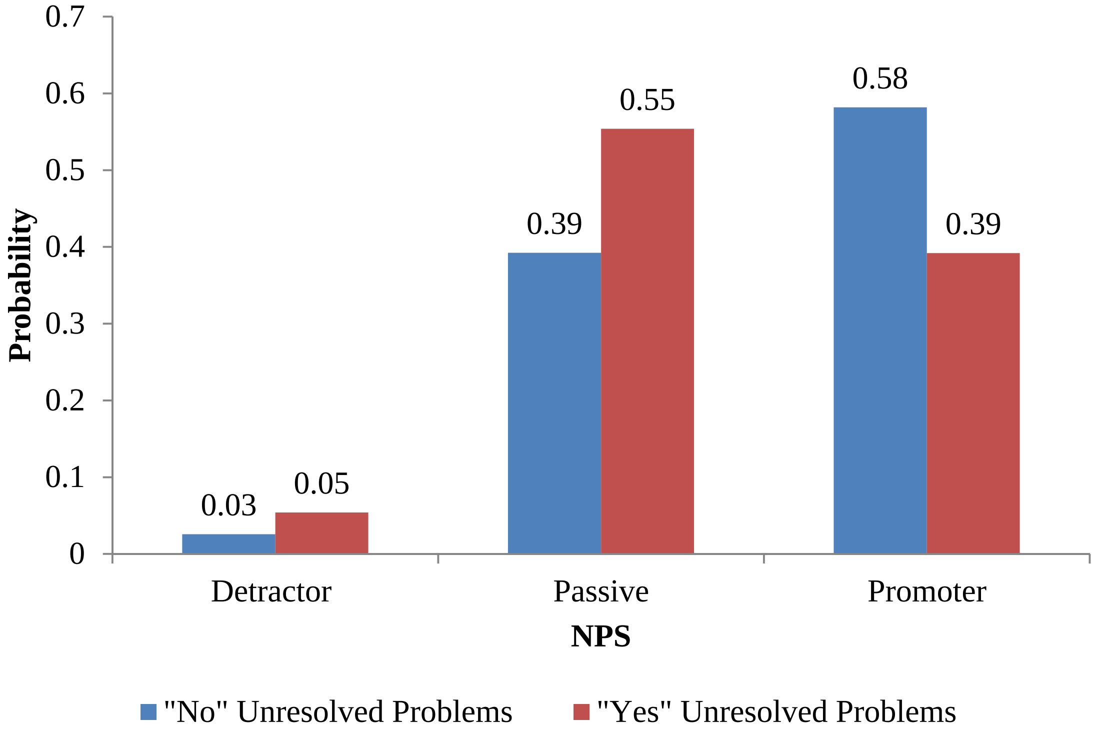
and promoter is 18.5% holding all other variables constant at their means. As expected, as the score of *ride comfort* increases the probability of a customer being a passive or promoter increases. The model estimated that at a ride comfort score of 10 the predicted probability of a customer being a detractor is 2.2%, passive is 36.1%, and promoter is 61.7% holding all other variables constant at their means.

Figure 5.4 Predicted probability of being a detractor, passive, or promoter against ride comfort (all other variables at their means)



A similar graph may be calculated for the binary variable *unresolved problems*. Figure 5.4 shows the predicted probabilities of a customer being a detractor, passive, and promoter against customers with and without unresolved problems. The model predicted that customers without *unresolved problems* have a 58.2% predicted probability of being a promoter holding all other variables constant at their means. If customers have *unresolved* *problems*, the model predicted that they only have a 39.2% chance of being a promoter holding all other variables constant at their means.

Figure 5.5 Predicted probability of NPS with and without unresolved problems (all other variables at their means)



5.3 Binary Logistic Model Results

As previously discussed, it is commonly thought that there are distinctly different drivers to the overall satisfaction score by region. Models were estimated with a binary variable for region and the results showed that regional data had no statistical significance. Thus, this information was removed from the final model estimations.

Table 5.4 displays the results the results of estimating the data with a binary logit model where the overall satisfaction score was redefined as detractor/passive = 0 (0-8) and promoter = 1 (9-10). The same variables that were used in the PLS model were included in the binary logit but it also includes a binary variable for the presence of *unresolved* *problems*. The model has a Pseudo R-squared of 52.6% indicating that 52.6% of the variability in the 0/1 *NPS* score is explained by the independent variables. The likelihood ratio chi-square of 1004.95 with a p-value of 0.000 indicates the model is statistically significant as compared to the null model with no predictors.

Of the 33 independent variables nine were statistically significant at the 95% confidence interval: *quality of manufacturing (MFG) workmanship, reliability/operational availability, machine productivity and capacity, engine oil consumption, fuel consumption, transmission shifting, serviceability, ride comfort,* and *unresolved problems.* Of these significant variables *engine oil consumption* and *unresolved problems* have negative coefficient signs. The negative sign *of unresolved problems* is expected, but the sign of *engine oil consumption* is not. Recall that with PLS and ordered logit modeling *engine oil consumption* was also negative. It does not realistically make sense that as a customer's satisfaction with *engine oil consumption* increases in value their *overall satisfaction* would decreases, which once again points to potential problems with the data itself.

Though they were not statistically significant, other variables with negative values include *power level, clutch, lighting, brakes, fuel tank capacity, hitch, usefulness of operator's manual and instructional material, ease of adjustment to various conditions, control placement and operation, visibility, cab air quality (a/c, heater, filter),* and *seat comfort.* The signs of these coefficients were expected to be positive. This indicates that even with an alternative modeling approach, which is believed to be more appropriate given the type of data being analyzed, the negative coefficients are not explainable.

The results of the coefficients in logistic regression are interpreted differently than with PLS models. For example, for every one-unit increase in *quality of MFG* *workmanship* the log odds of being a promoter (versus being a detractor or passive) increases by 0.413 holding all other variables constant. All other positive continuous independent variables are interpreted the same. The binary variable *unresolved problems* is interpreted slightly different. A customer with an unresolved problem versus one without decreases the log odds of being a promoter (versus being a detractor or passive) by 17.408 holding all other variables constant.

Table 5.4 Binary logit model coefficients, standard error, P-value, and 95% confidence interval

Variable	Coeff.	Std. Error	P>|z|	95% Confidence Interval	
Quality of MFG Workmanship	0.413	0.098	0.000	0.222	0.604
Reliability/operational avail.	0.433	0.084	0.000	0.269	0.597
Productivity and capacity	0.392	0.143	0.006	0.111	0.673
Power level	-0.040	0.142	0.778	-0.318	0.238
Engine lug down and recovery	0.164	0.115	0.154	-0.062	0.390
Engine oil consumption	-0.347	0.119	0.004	-0.579	-0.114
Fuel consumption	0.230	0.067	0.001	0.099	0.361
Engine cooling system	0.044	0.059	0.459	-0.072	0.159
Transmission speed selection	0.081	0.099	0.412	-0.112	0.274
Transmission shifting	0.164	0.076	0.032	0.015	0.314
Clutch	-0.048	0.107	0.654	-0.256	0.161
Power take off (PTO)	0.073	0.082	0.371	-0.087	0.233
Ease of attach/detach imp.	0.008	0.095	0.931	-0.178	0.194
Implement hydraulics	0.141	0.086	0.103	-0.028	0.309
Lighting	-0.057	0.138	0.679	-0.327	0.213
Brakes	-0.102	0.074	0.166	-0.247	0.042
Steering system	0.067	0.074	0.363	-0.077	0.212
Wheels/tires or tracks/undercar	0.058	0.081	0.474	-0.101	0.217
Fuel tank capacity	-0.020	0.099	0.838	-0.214	0.174
Hitch	-0.011	0.084	0.897	-0.176	0.154
Fuel system	0.039	0.116	0.736	-0.188	0.266
Usefulness of OM and instructional material	-0.009	0.076	0.903	-0.159	0.141
Serviceability	0.324	0.086	0.000	0.157	0.492
Ease of adj. conditions	-0.016	0.122	0.898	-0.255	0.224
Control placement and operation	-0.079	0.103	0.439	-0.280	0.122
Noise level during operation	0.045	0.054	0.408	-0.061	0.151
Visibility	-0.049	0.119	0.679	-0.283	0.184
Cab air quality (a/c, heater, filter)	-0.043	0.082	0.601	-0.202	0.117
Ride comfort	0.311	0.115	0.007	0.085	0.537
Monitors/displays	0.044	0.085	0.607	-0.123	0.211
Seat comfort	-0.141	0.113	0.210	-0.363	0.080
Sound system	0.029	0.079	0.712	-0.126	0.184
Unresolved problems	-0.695	0.217	0.001	-1.120	-0.269
Constant	-17.408	1.280	0.000	-19.916	-14.900

The coefficients from the model do not provide an accurate representation of the relationship between the response and the covariates (Williams 2012). To manage this, the marginal effects around the means of the coefficients were estimated. Table 5.3.2 displays the marginal effects at the means (dy/dx) estimated by the binary logit model.

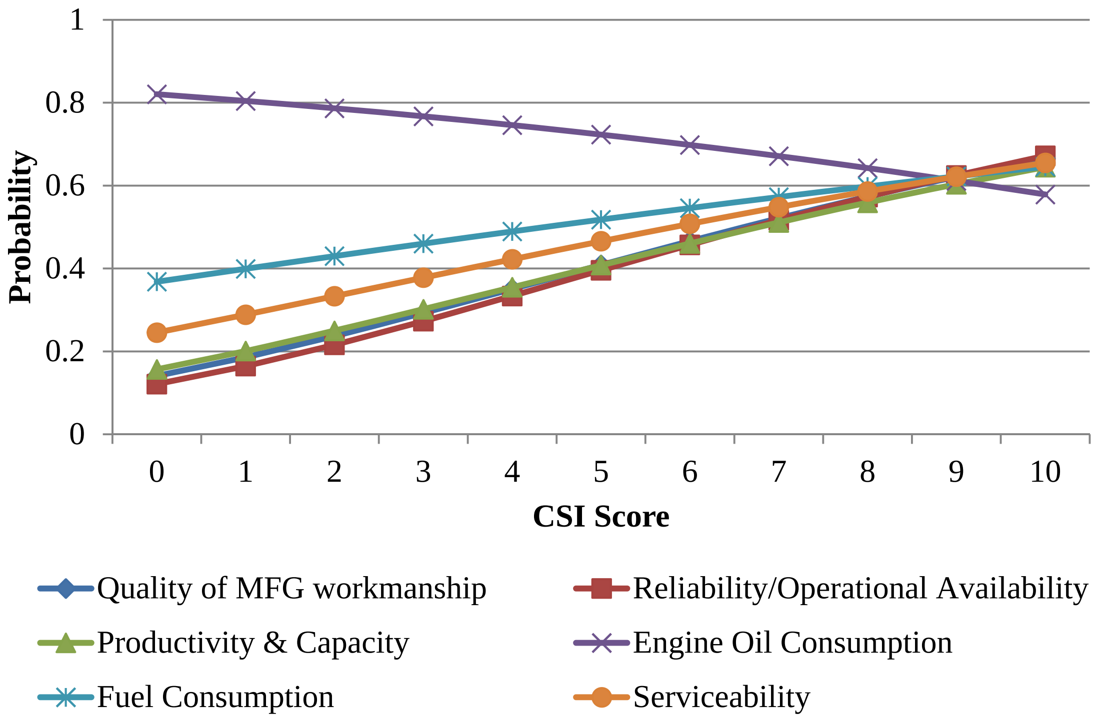
The marginal effect values for continuous variables (all variables accept *unresolved problems*) measure the instantaneous rate of change from each response, i.e., 0-1, 3-4, 5-6, etc. The marginal effects for binary independent variables (*unresolved problems*) measure discrete change, i.e., how do predicted probabilities change as the binary independent variable changes from 0 to 1 (Williams 2012). For example, a one-unit increase in *quality of MFG workmanship* reflects a 10.3% increase in the likelihood a customer is a promoter, versus a detractor or passive, holding all other variables constant at their means. All other positive continuous independent variables are interpreted the same. Likewise, customers with unresolved problems (binary variable) are 17.2% less likely to be a promoter than those without unresolved problems holding all other variables constant. The variables with significant p-values in the binary logit model are also significant when estimating the marginal effects.

Table 5.5 Binary logit model marginal probabilities at the means (dy/dx), standard error, P-value, and 95% confidence interval

Variable	dy/dx	Std. Error	P>|z|	95% Confidence Interval	
Quality of MFG Workmanship	0.103	0.024	0.000	0.055	0.151
Reliability/operational avail.	0.108	0.021	0.000	0.067	0.149
Productivity and capacity	0.098	0.036	0.006	0.028	0.168
Power level	-0.010	0.035	0.778	-0.079	0.059
Engine lug down and recovery	0.041	0.029	0.154	-0.015	0.097
Engine oil consumption	-0.086	0.030	0.004	-0.144	-0.028
Fuel consumption	0.057	0.017	0.001	0.025	0.090
Engine cooling system	0.011	0.015	0.459	-0.018	0.040
Transmission speed selection	0.020	0.025	0.412	-0.028	0.068
Transmission shifting	0.041	0.019	0.032	0.004	0.078
Clutch	-0.012	0.027	0.654	-0.064	0.040
Power take off (PTO)	0.018	0.020	0.371	-0.022	0.058
Ease of attach/detach imp.	0.002	0.024	0.931	-0.044	0.048
Implement hydraulics	0.035	0.021	0.103	-0.007	0.077
Lighting	-0.014	0.034	0.679	-0.081	0.053
Brakes	-0.025	0.018	0.166	-0.062	0.011
Steering system	0.017	0.018	0.363	-0.019	0.053
Wheels/tires or tracks/undercar	0.014	0.020	0.474	-0.025	0.054
Fuel tank capacity	-0.005	0.025	0.838	-0.053	0.043
Hitch	-0.003	0.021	0.897	-0.044	0.038
Fuel system	0.010	0.029	0.736	-0.047	0.066
Usefulness of OM and instructional material	-0.002	0.019	0.903	-0.040	0.035
Serviceability	0.081	0.021	0.000	0.039	0.123
Ease of adj. conditions	-0.004	0.030	0.898	-0.063	0.056
Control placement and operation	-0.020	0.026	0.439	-0.070	0.030
Noise level during operation	0.011	0.013	0.408	-0.015	0.037
Visibility	-0.012	0.030	0.679	-0.070	0.046
Cab air quality (a/c, heater, filter)	-0.011	0.020	0.601	-0.050	0.029
Ride comfort	0.077	0.029	0.007	0.021	0.134
Monitors/displays	0.011	0.021	0.607	-0.031	0.053
Seat comfort	-0.035	0.028	0.210	-0.090	0.020
Sound system	0.007	0.020	0.712	-0.031	0.046
Unresolved problems	-0.172	0.052	0.001	-0.274	-0.069

The marginal effects of individual variables can be graphed to assist with understanding their impact to the *NPS* response variable. Figure 5.6 shows the predicted probabilities of a customer being a promoter for several variables. The model estimated that at a score of 0 for *reliability/operational availability* the predicted probability of a customer being a promoter is 12.1% holding all other variables at their means. The model estimated that at a score of 10 for *reliability/operational availability* the predicted probability of a customer being a promoter is 67.2% holding all other variables constant at their means. Likewise, the model estimated that at a score of 3 for *fuel consumption* the predicted probability of a customer being a promoter is 46.0% holding all other variables constant at their means. This helps visualize which variables have the highest impact to the *NPS*, i.e., the steeper the slope the higher the impact. It can also be seen that *engine oil consumption* has a negative impact to the *NPS*, i.e., as the score of *engine oil consumption* increases the predicted probability of a customer being a promoter decreases. As previously discussed, this does not intuitively make sense and provides further evidence as to potential data problems possibly due to the design of the survey.

Figure 5.6 Predicted probability of being a promoter (all other variables at their means)



CHAPTER VI: CONCLUSIONS

Based on the research conducted, logistic modeling can provide a more accurate analysis of customer survey data, especially given the censured nature of the data. Logit models helped answer the original questions regarding factors impacting customer satisfaction while generating new questions to be answered. They also created further confidence in our results and assisted with the next steps in the survey process. It was confirmed that survey responses are not linear indicating an alternative method of regression modeling, such as logistic regression modeling, should be used. It also confirmed that the PLS models result in estimated results that are outside the bounded 11-point survey response scale. Finally, the logistic models confirmed with confidence that customers with unresolved problems are less likely to be a promoter than those without unresolved problems indicating that this information should be included in the regression models.

Logistic modeling did not help explain the cause of negative coefficients nor what their meanings are. Some coefficients have remained negative throughout the process, yet others change from model-to-model. This leads us to believe that the current survey structure does not facilitate customers' thinking of each individual question separate from the others. The data suggest that the different subsets of questions (engine, transmission, chassis, comfort and convenience) will trend with the quality, operational availability, and productivity questions. Essentially, the survey is structured such that it does not allow customers to rank their satisfaction with features separate from these questions.

It is recommended that a new survey strategy be implemented focused around those questions of true value to the customer. Then, if there is a need to understand customers' satisfaction associated with specific features, a separate survey should be conducted. This process will enable customers to filter out thoughts about pain-points that products may have caused them and in turn truly evaluate product changes. Survey fatigue should be held in high consideration with this new process. It may be applicable to have an enterprise value survey distributed yearly with ad-hoc feature surveys when new products are introduced in the market.

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Appendix 1 Tractor survey example

Question #	Question
1	Overall, how satisfied are you with this tractor?
2	Quality of manufacturing workmanship
3	Reliability/Operational availability (Operates when needed)
4	Machine productivity and capacity
5	Power level
6	Engine lug down and recovery
7	Engine oil consumption
8	Fuel consumption
9	Engine cooling system
10	Transmission speed selection
11	Transmission shifting
12	Clutch
13	Power take-off (PTO)
14	Ease of attaching/detaching implement
15	Implement hydraulics
16	Lighting
17	Brakes
18	Steering system
19	Wheels and tires or Tracks and undercarriage
20	Fuel tank capacity
21	Hitch
22	Fuel system
23	Usefulness of operator's manual and instructional material
24	Serviceability
25	Ease of adjustment to various conditions
26	Control placement and operation
27	Visibility
28	Cab air quality (a/c, heater, filter)
29	Ride comfort
30	Monitors/Displays
31	Seat comfort
32	Sound system
33	Any suggestions or comments on this tractor?
34	Do you have any unresolved product problems? Yes No
	If yes, what is the nature of your unresolved problems?

*All questions are evaluated on a 0-10 point scale with 0 being completely dissatisfied and 10 being completely satisfied.

Appendix 2 Correlation

	Overall CSI	Quality of MFG Workmanship	Reliability / Operational Availability	Productivity & Capacity	Power Level	Engine lug down & recovery	Engine oil consumption	Fuel consumption	Engine cooling system
Overall CSI	1								
Quality of MFG Workmanship	0.787393	1							
Reliability/Operational Availability	0.814138	0.820233174	1						
Productivity & Capacity	0.724574	0.696222197	0.750633413	1					
Power Level	0.565218	0.538923376	0.547882405	0.74645356	1				
Engine lug down & recovery	0.545161	0.510249532	0.515690356	0.70608228	0.890849	1			
Engine oil consumption	0.423915	0.479129655	0.44735206	0.58868355	0.6351363	0.62084566	1		
Fuel consumption	0.508539	0.484481494	0.478494952	0.55725067	0.6014815	0.56765736	0.556986139	1	
Engine cooling system	0.566655	0.545630149	0.545212925	0.53492741	0.5447483	0.50083373	0.473952478	0.52746963	1
Transmission speed selection	0.599787	0.551065536	0.569999849	0.6504708	0.5912625	0.59566318	0.531587765	0.519272318	0.4530177
Transmission shifting	0.573468	0.489580116	0.540432447	0.58988378	0.5057349	0.50257284	0.459028437	0.492402927	0.4144025
Clutch	0.575217	0.570319453	0.59787321	0.65131809	0.5643261	0.56462929	0.581441645	0.511933082	0.4897001
Power Take Off (PTO)	0.534478	0.572410318	0.542639345	0.58345679	0.5718426	0.52647705	0.527066962	0.475580059	0.4967197
Ease of Attaching/Detaching implement	0.525157	0.558103667	0.542377158	0.6054518	0.6040433	0.57517729	0.566823856	0.57597442	0.5234124
Implement Hydraulics	0.54878	0.565749862	0.525901483	0.5889629	0.4994983	0.47625389	0.491286509	0.447218829	0.4527565
Lighting	0.468225	0.532866725	0.477708866	0.55105617	0.5089368	0.47101782	0.577137179	0.440412773	0.4251553
Brakes	0.486097	0.482797987	0.5049122	0.49690616	0.4548466	0.45273674	0.449836487	0.47643967	0.4259118
Steering System	0.495319	0.510965421	0.5084826	0.5160703	0.4366943	0.44170034	0.420469501	0.407427903	0.4062629
Wheels/Tires or Tracks/Undercarriage	0.464114	0.498827271	0.459387728	0.49777677	0.4835112	0.46812735	0.493391315	0.426370403	0.4166474
Fuel Tank Capacity	0.419543	0.479676928	0.441609028	0.51800771	0.4898246	0.46708807	0.569516471	0.507951758	0.4239904
Hitch	0.478798	0.525150321	0.478579699	0.51946514	0.4871639	0.46000508	0.486424669	0.481106872	0.4531184
Fuel System	0.528962	0.566099978	0.537265161	0.61141239	0.5686419	0.54842536	0.599794752	0.551079612	0.509196
Usefulness of OM & Instructional Material	0.469073	0.543626835	0.477977294	0.52282791	0.4922442	0.4731616	0.513243196	0.505862169	0.4419464
Serviceability	0.584622	0.608262847	0.583151184	0.56566606	0.5019051	0.49450021	0.524034564	0.475313527	0.507627
Ease of adj. to various conditions	0.620247	0.635474992	0.63817234	0.68403584	0.6080433	0.60000914	0.591458714	0.565626439	0.5239378
Control Placement and Operation	0.537504	0.56762199	0.532182902	0.60990621	0.5945501	0.56516602	0.554226989	0.529216192	0.4884363
Noise level during operation	0.529146	0.523382329	0.504712236	0.49341334	0.4243303	0.39691964	0.383162663	0.47890076	0.502304
Visibility	0.464036	0.496250539	0.463724166	0.5451771	0.5006827	0.47960063	0.594951277	0.442651613	0.4252704
Cab Air Quality (a/c, heater, fitler)	0.493147	0.515787781	0.478004709	0.50401639	0.4787327	0.46858114	0.460149081	0.45667067	0.4788112
Ride Comfort	0.503576	0.4914311	0.47118242	0.53314714	0.4993622	0.46392437	0.482427476	0.504639471	0.4354569
Monitors/Displays	0.513084	0.53389368	0.495304727	0.53746631	0.4710469	0.44500048	0.470015198	0.445288441	0.4367224
Seat Comfort	0.44915	0.475492551	0.441066666	0.48517772	0.5205182	0.49868444	0.484708952	0.479879974	0.4319745
Sound System	0.399944	0.43911636	0.397048409	0.46558329	0.4428038	0.41911664	0.474633525	0.450637054	0.4093028

Transmission speed selection	Transmission shifting	Clutch	Power Take Off (PTO)	Ease of Attaching / Detaching implement	Implement Hydraulics	Lighting	Brakes	Steering System	Wheels & Tires or Tracks & Undercarriage	Fuel Tank Capacity	Hitch	Fuel System	Usefulness of OM & Instructional Material
1													
0.799527609	1												
0.71280568	0.738360605	1											
0.572687212	0.546354648	0.65351	1										
0.553099938	0.500620268	0.56022	0.558826	1									
0.509344024	0.488015961	0.58696	0.566676	0.593070896	1								
0.491497905	0.456774756	0.5414	0.530615	0.587705267	0.5731426	1							
0.475979411	0.460145808	0.45138	0.467177	0.521376449	0.48185499	0.509909	1						
0.480368724	0.420534606	0.49959	0.410409	0.472773251	0.43595267	0.531816	0.47808	1					
0.482919514	0.439678531	0.49591	0.493505	0.512947196	0.47719486	0.559128	0.46537	0.51426	1				
0.489127255	0.41104464	0.52598	0.496626	0.57054344	0.52313296	0.619919	0.4803	0.49354	0.527523368	1			
0.494441085	0.459520686	0.51825	0.52468	0.680873134	0.54948022	0.56257	0.50304	0.46232	0.522136709	0.5844392	1		
0.521188263	0.464435921	0.57088	0.548775	0.60731912	0.56234237	0.660262	0.50238	0.51974	0.575396899	0.6787405	0.61568	1	
0.497365005	0.456281236	0.53432	0.488804	0.559969074	0.50799128	0.521344	0.39365	0.43695	0.450621789	0.536255	0.51054	0.5529844	1
0.49509755	0.483774094	0.53663	0.517517	0.564575239	0.53396971	0.52122	0.45851	0.50454	0.477367305	0.491028	0.46597	0.5472883	0.625949488
0.644748508	0.582262261	0.67227	0.61976	0.668490626	0.6513383	0.61562	0.5123	0.55309	0.546697162	0.5954683	0.5788	0.6759875	0.691002507
0.563310099	0.483709444	0.55071	0.566506	0.596182528	0.6008939	0.594937	0.43248	0.44905	0.519502893	0.5600474	0.50981	0.5965463	0.619603991
0.446870509	0.427988536	0.47572	0.436489	0.475923131	0.48572557	0.430552	0.43692	0.47369	0.412986969	0.4335371	0.44013	0.4503291	0.447051368
0.486086225	0.441393413	0.55971	0.474481	0.568101519	0.53559638	0.611808	0.43803	0.45157	0.502782928	0.5412396	0.46248	0.5874003	0.528876506
0.465981601	0.449467452	0.51323	0.483787	0.527428057	0.47395425	0.536585	0.40688	0.4539	0.457349923	0.4651007	0.43422	0.5367241	0.497753451
0.487930571	0.456450348	0.54945	0.447668	0.544051124	0.52065097	0.538649	0.43251	0.53848	0.521686674	0.5080468	0.48199	0.5525377	0.507972544
0.517289651	0.479119529	0.49578	0.502536	0.497507313	0.5051264	0.532961	0.38044	0.43186	0.467471194	0.4807605	0.43004	0.5093864	0.57529241
0.47700235	0.450100093	0.5218	0.46592	0.527902497	0.48912842	0.536072	0.39198	0.46178	0.49979391	0.4930119	0.47465	0.5248466	0.521785229
0.42234812	0.392398054	0.4631	0.426458	0.501309301	0.4546873	0.542784	0.35381	0.41458	0.425929452	0.4497043	0.4584	0.5164802	0.488447815

Serviceability	Ease of adjustment to various conditions	Control Placement and Operation	Noise level during operation	Visibility	Cab Air Quality (a/c, heater, fitler)	Ride Comfort	Monitors/D isplays	Seat Comfort	Sound System
1									
0.726312919	1								
0.634804125	0.728160533	1							
0.50990369	0.531669061	0.505168333	1						
0.567631309	0.611837782	0.63443241	0.5110268	1					
0.541976957	0.56895711	0.551163932	0.582142	0.5745417	1				
0.544047463	0.622739808	0.559999204	0.5839711	0.5925523	0.5969569	1			
0.514317017	0.628610747	0.640192958	0.4400308	0.5503084	0.5120023	0.5397472	1		
0.521727768	0.579906696	0.577936094	0.4913086	0.5709548	0.5655914	0.7202994	0.5284311	1	
0.471821747	0.552613026	0.514261748	0.4411114	0.5093388	0.4863123	0.4863033	0.5227183	0.5058141	1