Managing Configuration Options for Build-to-Order highly Customized Products with Application to Specialty Vehicles

by

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Submitted to the System Design and Management Program
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To my beautiful family Felicia, Diego and the one to come

To my mother Virya

In memory of my father Jorge E. Amador M.

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Abstract:

In the past decades there has been a shift in customer expectations that has had a significant effect in the business models of manufacturing companies. Customer requirements have shifted from accepting standardized products to demanding highly customized products that satisfy their specific requirements. To cope with this change companies have quickly increased the variety of products that they offer in the market place. Unfortunately, often this variety is provided without understanding the implications of the added complexity on the different internal processes. This thesis research focuses on analyzing this fundamental conflict that exists in manufacturing and tries to answer the question: Is there a middle way? A compromise that will balance variety and complexity with the need for efficient production processes. A large data set containing more than 27,000 records was obtained from a software product configuration tool in use by a specialty vehicle company. This data was evaluated utilizing several methods including statistical and network analysis. It was observed that option proliferation was common during the vehicle configuration process which had an option approval rate of more than 50%. In addition, options tended not to be shared among vehicles and reused in vehicle designs. Overall there were 6,848 dormant options out of a total of 17,007. This complexity resulted in low and often negative margins for the vehicles manufactured. An option strategy model was created to aid firms in managing complexity. The model was tested using the available data and it was observed that in general improvements in option management were obtained.

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List of Acronyms

AFI, Inc	The Company
NFPA	National Firefighting Protection Association
SCBA	Scuba
SCT	Software Configurator Tool
CRs	Customer Change Requests
COO	Chief Operating Officer
ECR	Engineering Change Request
ECO	Engineering Change Order
BTO	Build to Order
MTO	Make to Order
BTS	Build to Stock
MTS	Make to Stock
BOM	Bill of Materials
ERP	Enterprise Resource Planning

Chapter I. Project Motivation and Research Methodology

"Any customer can have a car painted any colour that he wants so long as it is black"

Henry Ford, in reference to the Model T, 1909 (Ford, 2003)

I.1 Introduction

In the last 100 years since Henry Ford, the father of mass production, created the Model T for his customers, only in black and with few options, to gain operational efficiencies, a significant change has taken place. The market landscape has evolved to one were increased competition, new technologies and more demanding consumers have led companies to adopt customization strategies as the basis for competition (Lampel & Mintzberg, 1996).

Companies have adapted to the new customer requirements by adding variety to their product offering. Often this variety is added without deeply understanding the implications of the added complexity on the different processes throughout the value chain of the company. The result is a product portfolio that can satisfy the market needs but that causes inefficiencies and cost overruns within the organization.

This is caused by a fundamental tension in manufacturing. Highly standardized offerings are easy to build efficiently, while a high degree of customization is responsive to customer needs but adds complexity. The fundamental question is if there is a middle way? A compromise that will balance variety and complexity with the need for efficient production processes. This thesis tries to find this balance through the analysis and development of product option strategies.

To perform the analysis a data set was obtained from a specialty vehicle company. The company, AFI, Inc, is the leading designer, and manufacturer of emergency specialty vehicles (fire fighting apparatus). The data supplied by AFI was used first to perform a statistical analysis in order to determine basic relationships and patterns. In addition, a network analysis was performed to observe if there were natural clusters of options that could be bundled. These analyses were the basis for the definition of the recommendations and option strategy for the company. This approach is generalizable to other firms offering a variety of products.

I.2 Research Objectives

- To perform a critical analysis of the current methodology used in managing configuration options for the specialty vehicles.
- To perform a historical review of options in order to define the most common options sets.
- To define an option strategy for the company in line with market needs.
- To evaluate the software configuration tool (SCT) that is currently used by the specialty vehicle company and propose enhancements to its functionality.

I.3 Research Methodology

The study presented in this document analyzes data from several different systems that contain similar elements of form and function. All fire fighting apparatus contain similar elements: pump, water tank, body, chassis, and cab. However, they also contain unique elements that characterize each apparatus and give it the ability to perform unique critical functions. The main drivers of the vehicle differences are related mainly to the operating environment in which they will operate and perform the required tasks:

- City (Urban) vs Country Side (Rural)
- Civil environment vs Industrial, Military or Airport Environments
- Flat vs Hilly Topography
- Tempered climates vs Cold Climates

The methodology used to perform the research takes into account the characteristics of the different vehicles developed by the company. A summary of the processes followed to perform the analysis is presented in the following figure:

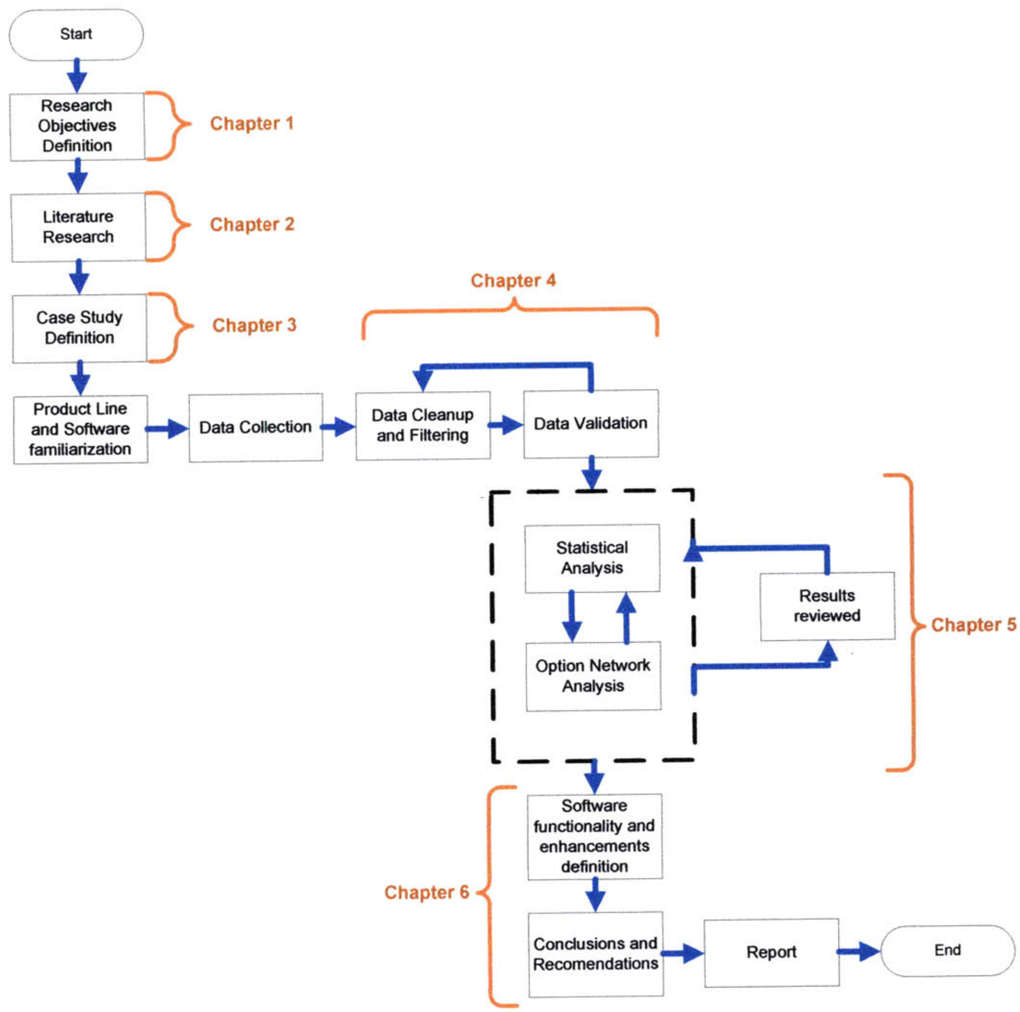

Figure 1: Thesis Roadmap

The first step in the analysis process was to clearly define the research goals and objectives. It was observed that there is significant research on mass customization and build to order manufacturing but most of the literature and research focuses mainly on supply chain and manufacturing strategies for customizing and delivering products. There is little research that ties product option definition and management to support of build to order and customization strategies. In other words, most of the existing literature assumes that the product customization options are already defined.

In addition, during the goal definition stage, several meetings were scheduled with the main stakeholders of the project: the researcher, the faculty advisor and the company representatives. Once the goals and objectives were defined and with the guidance of the faculty advisor, a literature research was performed on the recent developments in engineering change propagation. Focus was placed on observing new research on modularity, options strategies and customization strategies. In addition, several discussions took place with personnel from the IT and engineering departments of AFI to assess the extent of data availability in order to perform the case study.

A period of familiarization with AFI's product line, process and organization as well as the configuration software tool (SCT) was necessary to understand the data relationships and the characteristics of the organization. Familiarization with the product families was achieved through interviews and documentation reviews. In addition, several projects in operations management and engineering were developed during a three-month internship at the company. To get acquainted with the software tool, the IT group at AFI provided access to the production database with read rights. In addition, documentation and basic training on the tool was provided.

Data collection was performed with the assistance of the IT group, which created the required queries to extract the necessary data from the main database. After the data extraction process was finalized, and with the assistance of the IT group, the engineering manager and the faculty advisors, several cycles of data validation and review were performed in order to eliminate any inconsistent data.

Data validation was followed by a cycle of data analysis. This analysis included a statistical analysis to understand the basic data patterns and to observe basic data relations. In parallel to the statistical analysis and with the support of a postdoctoral fellow, the network analysis was performed.

Based on the conclusions from the analysis the recommendations for the company and several functionality enhancements for SCT were developed. These recommendations were presented to the company for their review.

In Chapter II presents the result of the literature research and theoretical foundation. The gaps in the current state of research are described and an original model for options management is presented. Chapter III introduces AFI, Inc. and presents an overview of the emergency specialty vehicle industry and the current challenges that the company is facing. In addition, a description of the SCT is presented in this chapter.

The main focus of Chapter IV is to describe the characteristics of the dataset obtained from the SCT. Chapter V focuses on developing the detailed analysis of the dataset. The first section of Chapter V presents the results of the statistical analysis of the dataset. Emphasis is placed on observing the different relationships among the options used across the models and vehicle types. In addition, the second section of Chapter V presents the results of the network analysis performed to the dataset.

The final chapter of the thesis, Chapter VI, describes the main conclusions and recommendations. In addition, it is in this chapter that the suggested model for managing options, described in Chapter II, is used to develop an option strategy for one of the vehicle types. The results of this exercise are presented and analyzed.

Chapter II. Theoretical Foundation

The previous chapter presented an introduction to the project and a description of the research methodology used for the analysis. AFI, Inc is interested in understanding how to define an option strategy that will satisfy its customers and at the same time eliminate unnecessary complexities within the internal processes. This will permit the company to create better designs, give better service to its clients and improve the profitability of its products. In this chapter, a discussion of the current state of the research is presented.

II.1 Literature Research

The literature research covered several areas of interest to the present thesis. Research was performed on understanding the terminology and latest research in mass customization and build-to-order strategies. In addition, emphasis was placed on observing current research in engineering change propagation, managing engineering changes, modularization and platform strategy as enablers of build-to-order and mass customization strategies. Initially it was thought that the dataset obtained could be used to perform a change propagation analysis, unfortunately it was observed that this was not possible to achieve and the research was re-focused on the analysis of option package strategies. Research was performed on literature related to the definition and management of option packages and strategies to implement options sets that would maximize profits. Special interest was placed on researching methods for managing options and configuring products using software tools.

The following table presents a summary of the key words utilized to perform the literature research classified by area of interest:

Table 1: Literature Research Key Words

		Customization Implementation	
Concepts	**Build to Order / Mass Customization Concepts**	**Engineering Change Propagation**	**Option Strategy / Packages**
Key Words	Build to Order BTO Make to Order Mass Customization Customization Design to Order Assembly to Order BTO product design BTO product configuration	Engineering Change Propagation Engineering Change Engineering Change Design Engineering Change Modularization Product Platform Product Families	Options Design Options Packages Options Bundles Options Package Strategies Options for BTO Options for Mass Customization Product Configuration Product Portfolio Planning Variety Management Product Option Combination

Multiple papers were found and classified according to the concepts they covered. Since the areas are related, in multiple instances a paper was related to more than one area. The result of the literature search is presented in the next sections.

II.1.1 Build to Order (BTO) and Mass Customization

The first step in the literature research was to establish a clear definition of the concepts of build to order (BTO) and mass customization. The research on build to order and mass customization strategies is relatively new and often there is still some confusion in the literature on the use of both terms.

Dr. David Anderson, in his book *Build to Order & Mass Customization (2008)*, classifies BTO as one of the approaches for building products. He defines BTO or make to order (MTO) as the method that builds mass-customized or standard products on-demand without keeping any forecast or inventory. The other methods for building products defined by Anderson are build to stock (BTS) or make to stock (MTS), in which products are manufactured typically in batches based on a forecast and they are placed in inventory waiting for a customer order, and finally, assemble to order (ATO) in which products are assembled based on customer demand using parts that are kept in inventory. In an ATO environment, lower components are built to stock and only the final product is assembled when an order is placed by the customer (Hopp & Spearman, 2000). Research by Professor David Simchi-Levi has found the optimal boundary between where to build-to-stock and where to assemble based on orders. This is known as the push-pull boundary (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008)

Other authors define BTO in a similar way as a demand driven production approach where an item is manufactured in response to a confirmed order from a customer (Parry & Graves, 2008).

Hopp & Spearman (2000) go one step further in the description of the concepts by defining them in terms of the customer lead time[1]. In a BTS environment, the customer lead time tends to be zero, since when the customer arrives; the product is available from inventory or it is un-available and the order is lost. In a BTO environment, the customer

[1] Lead Time is a constant used to indicate the maximum allowable cycle time for a job. The customer lead time is the amount of time required to fill a customer order from start to finish (Hopp & Spearman, 2000).

lead time is the time required to produce and deliver the requested product. This time is based on the customer's expectations and requirements as well as the firm's speed at fulfilling customer orders.

Mass customization and mass production are related to high-level production and market strategy rather than the tactical approach to production. During most of the last century mass production was used successfully by companies to deliver products to the markets. Henry Ford, the father of mass production, designed the first assembly line to built Model T's in his Highland Park, Michigan plant, in 1913. Under mass production, companies saw the opportunity to reduce cost and improve consistency by building highly standardized products that were distributed through standardized distribution channels and marketed using standardized advertisement (Lampel & Mintzberg, 1996). As markets expanded, they grew more complex and diverse. It was no longer feasible to present the customers with only the "average" product for the "average" customer and the need for product customization became prevalent and a requirement for competitive advantage.

Product customization is defined as variations of standard or generic products that are developed to satisfy specific customer needs (Ulrich & Eppinger, 2007). Another definition for customization in which the author makes reference to modularity is the one given by Sievanen (2002). He defines customization as the development of a special product from standard modules combined in a way to satisfy customer requirements. Lampel & Mintzberg (1996) establish that in a pure customization strategy, a product can be customized from scratch. However, there has to be some standard configuration, otherwise this strategy should be called prototyping rather than customizing.

The closer a product's features, functions and capabilities is to what customers want the higher the price the customer is willing to pay for the product. However, this price is ultimately dependent on the value that the customer places on the degree of customization (Kumar, 2004). In general, all the authors we found agreed that customization can lead to a higher market share but also to a proliferation of products, complexity and cost overruns.

The term mass customization was first coined by Stanley Davis in his book *Future Perfect* in 1987 (Duray, Ward, Milligan, & Berry, 2000). It is a strategy, at the intersection of mass production and customization, which requires the delivery of highly customized products at the same costs or just slightly more than mass produced items (Sievanen, 2002). The concept was further refined by Joseph Pine II (1992) who distinguishes four types of mass customization. Piller (2004) defines mass customization as the technologies and systems that are required to deliver goods and services that meet specific customer requirements at near mass production efficiencies. There are two themes on all the definitions of mass customization: the product is required to have high levels of customization and the price of the product corresponds to the prices as if it were mass produced (Kumar, 2004).

BTO, BTS and ATO being production approaches at the tactical level, can be applied to mass customization or mass production. In essence, a company that decides to have a mass customization strategy to compete in the market place can implement the strategy by implementing BTO or ATO production approaches. This will assure that a product is build to the customer expectations once an order is placed. A BTS strategy cannot be applied under a mass customization strategy since it is not possible to deliver highly customized products that are kept in inventory, unless all possible variants are built ahead of time, however this approach would lead to very large inventories of product configurations that are never ordered and would therefore be very inefficient. BTS is more applicable to mass production. However, it is also possible to build to order or assemble to order mass-produced products. The following table presents the relationship between the manufacturing strategies and the production approaches described previously:

Table 2: Relationship Manufacturing Strategy and Production Approach

Manufacturing Strategies	**Manufacturing Approach**
Mass Customization	BTO, ATO
Mass Production	BTS, BTO, ATO

II.1.2 Customization in Practice

In practice, most manufactured products that are available in the market do not belong to the two extreme poles of fully standardized or fully customized. Instead they can contain customized and standard elements that place them somewhere in between both poles. In addition, customization for a product or elements of a product can occur at any point throughout the value chain. Depending on the degree of customization required, all or only a portion of the value chain processes may be used to add individualization to the product (Silveira, Borenstein, & Fogliatto, 2001). MacCarthy, Brabazon, & Bramham (2003) present a detailed description of the multiple customization frameworks that have been presented in literature.

Pine & Gilmore (1997) distinguish four basic approaches to customization. In collaborative customization, the designers interact with their customers to help them establish their specific needs. In adaptive customization the company offers a standard product that is designed to be easily altered by the users. Under cosmetic customization a standard product is presented differently to different customers. It requires the packaging of a standard product differently for each customer. The final approach is transparent customization. Under this approach, the company provides the customer with unique products without letting them know explicitly that the products have been individualized to their needs. It is important to note that the authors also indicate that at any moment an organization can combine multiple approaches of customization in order to provide better products and services to their customers.

One of the most relevant frameworks it the one presented by Lampel & Mintzberg (1996) which is cited by multiple authors. They propose a continuum of five strategies with different degrees of customization. On one end there is pure standardization and on the other pure customization. The following figure shows the framework described by the authors:

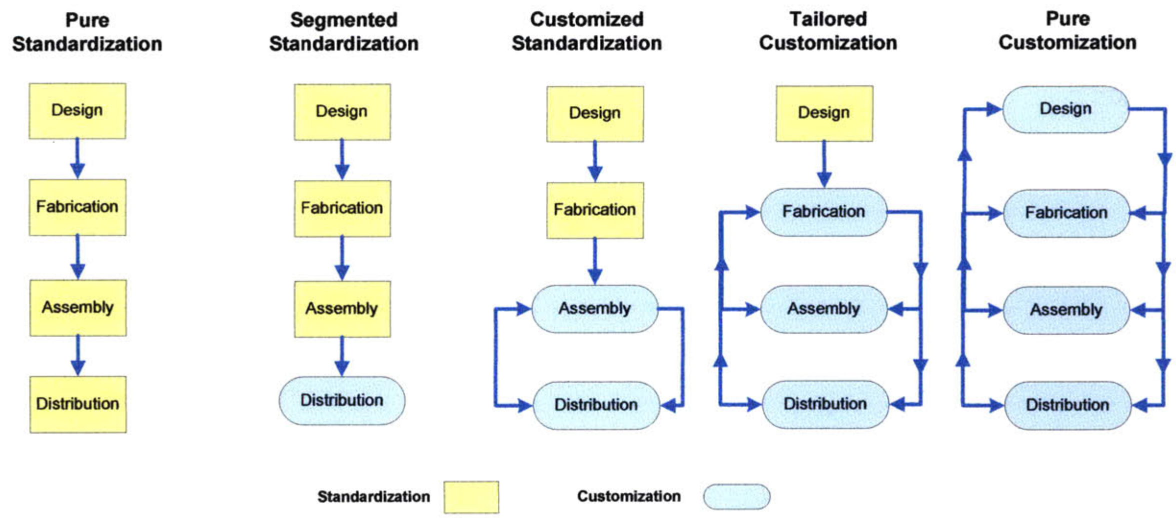

Figure 2: Lampel & Mintzberg (1996) Framework for Customization[2]

In Pure Standardization, there is no differentiation among products. The customer has to adapt or find another product. The whole value chain is designed to produce standardized products. Segmented Standardization introduces individualization based on the need of groups of buyers (within that group the product is standardized). Groups of buyers with similar needs are often clustered in market segments. Typically a base design is adapted to satisfy these groups. Under customized standardization the customers are allowed to select from a predetermined set of standard elements or modules in order to customize the final product. We typically refer to these as "options". Customization occurs in the assembly process in which the selected elements are installed into the product. This type of customization is the one currently used in the automotive industry. In tailored customization the differentiation occurs at the fabrication stage. Prototypes

[2] Figure taken from (Lampel & Mintzberg, 1996)

are created and the customer reviews them and requests individualization. Finally, in pure customization, the products are designed to order based on specific customer requirements. This is similar to craft design and manufacturing or commissioning a unique work of art.

Under all customization strategies all the different internal processes, such as design, production, supply chain management, sales, should adapt to the specific level of customization of the different products. In all cases customizing products requires an intimate connection between every process throughout the value chain (Spring & Dalrymple, 2000). Information management and flow becomes critical to the success of effective BTO and product customization strategies. Salvador and Forza (2002) not only indicate that product configuration systems significantly contribute to increase the effectiveness and efficiencies by which companies translate customer requirements into product specifications but also they argue that these systems help incorporate product knowledge into organizational memory. Other authors also identify product configurators as key applications that can align all functions within an organization to facilitate the production of customized products (Shamsuzzoha, Kyllonen, & Helo, 2009) (Helo, Xu, Kyllonen, & Jiao, 2010). However, they argue that existing product configurator tools are mainly used as sales tools and most of the time do not meet the requirements of the different stakeholders in the customer fulfillment process (Helo, Xu, Kyllonen, & Jiao, 2010).

II.1.3 Individualization Methods and Option Strategies

The implementation of any of the customization strategies described in the previous section requires the right method for achieving individualization at the right cost (Duray, Ward, Milligan, & Berry, 2000). Several of these methods have been described extensively in literature.

Modularity is one of the methods that facilitates the effective customization of products. Efficiencies are achieved through the production in volume of standard modules or elements of a product. These are combined or modified in multiple ways to achieve the customization (Duray, Ward, Milligan, & Berry, 2000) (Kumar, 2004). In the specialty vehicle and automotive industry the creation of product family platforms across models has enabled companies to share common parts and design elements to achieve economies of scale. This method in combination with modularity has enabled companies to increase the number of product offerings while reducing the amount of product complexity (Gardner, 2009).

Another area of research that is critical for effective and efficient product individualization is engineering change propagation. Most of the current products and systems in the market place are based on previous designs and not on totally new designs (Giffin, de Weck, Keller, Eckert, Bounova, & Clarkson, August 2009).

Finally, research has also focused extensively on the definition of supply chain, and manufacturing execution strategies to allow the firm to operate more effectively when performing the customizations (Pil & Holweg, 2004).

The methods described previously tend to focus on the management and elimination of complexity and variety internal to the organization. However, externally (facing the customer) due to market pressures and differentiation strategies, companies view the availability of product options (variety) as a competitive advantage (Pil & Holweg, 2004). Kahn (1998) proposes that a variety-seeking product strategy (customization strategy) in which customers enjoy a diversity of options will ensure that the customers find exactly what they need.

It is clear that there is a conflict between the amount of variety that is required to satisfy customer expectations without losing competitiveness and the desired internal variety that will allow for efficient processes. To resolve this conflict it is necessary to develop the right option strategy that not only will offer the right variety to the customers but at the same time will assure that the internal processes are capable of designing, fabricating, assembling and distributing the product efficiently and that the company generates the desired profit margins.

Part of the research that has been done here - rather than trying to define comprehensive option strategies - has been focused on the creation of models to calculate optimum option sets or bundles. Option bundling is a strategy used to reduce external and internal variety while maintaining an attractive offering to the customers. Sellers could decide to offer the options to consumers either as bundles, individually or as a mix of both (mixed bundling). Research has revealed that by using a mixed bundling strategy, options tend to be perceived by customers to be more important and are more likely to be chosen than if they were offered only individually (Hamilton & Koukova, 2008). An example of an option bundle for an automobile is a "winter package" that contains a more powerful windshield heater, spiked wheels, fog lights, heated seats and steering wheel and so forth. Perlich & Rosset (2007) suggest a methodology based on hierarchical clustering to identify meaningful option sets that can be combined to increase standardization. Even though, this options bundling is important to define external variety, it has been observed that the only benefits of bundling in build to order highly customized environments tend to be the reduction in the manufacturing error due to work standardization since the production operations will always install the options in specific combinations (Pil & Holweg, 2004).

Finally, another area of research also related to option bundling is focused on the modeling and calculation of the optimum pricing for the options from the marketing perspective (Chakravarti, Krish, Paul, & Srivastava, 2002).

The literature search reveals that there is a clear gap in research related to the definition of comprehensive options strategies that not only will present the customer with enough variety to make the product attractive but at the same will not create unnecessary complexity within the internal operations.

II.1.4 Option Strategy Model

The previous sections presented the results of the literature research related to customization approaches and strategies. In this section we define a model for analyzing product options and establishing an option strategy.

We propose the creation of an option strategy based on the characterization of each available option. Based on the result of the characterization each option will be classified into three different types. This will give the company a sense on how each of the options should be managed. Following is a description of the three types of option classifications:

- Standard Option: Is an option that is offered individually but it tends to be standardized across a product family or model. This type of option includes any incremental options that are added to a base configuration of the vehicle.

- Option Bundle Sets: Options classified in this category can be aggregated into a bundle set that is offered to the customer.

- A la Carte Premium Option: This type of option is an individual non-standard option that satisfies very specific customer needs. It could be an option that has been used before but in low volumes or could be a totally new customization. A premium price would be charged for the selection of such option.

The suggested model requires the characterization of the options related to a specific product or family of products. The following criteria are suggested for performing the characterization:

- Volume: The expected or historical volume of the option (how often the option is ordered by the customers).

- Cost / Margin: This criteria refers to the total cost of the option (materials, labor, overhead). It could also be defined in terms of the gross margins of the option.

- Ease of Implementation: This variable refers to the amount of manufacturing effort that is required to implement the specific option. This could be defined in terms of the extent to which implementing the option requires additional changes in other elements of the vehicle (the extent to which change propagates). If this data is not available, this variable could also be defined based on the number of products sharing the option (option commonality among products). One can assume that the more common the option, the easier it is to implement.

The proposed model is presented in the following figure:

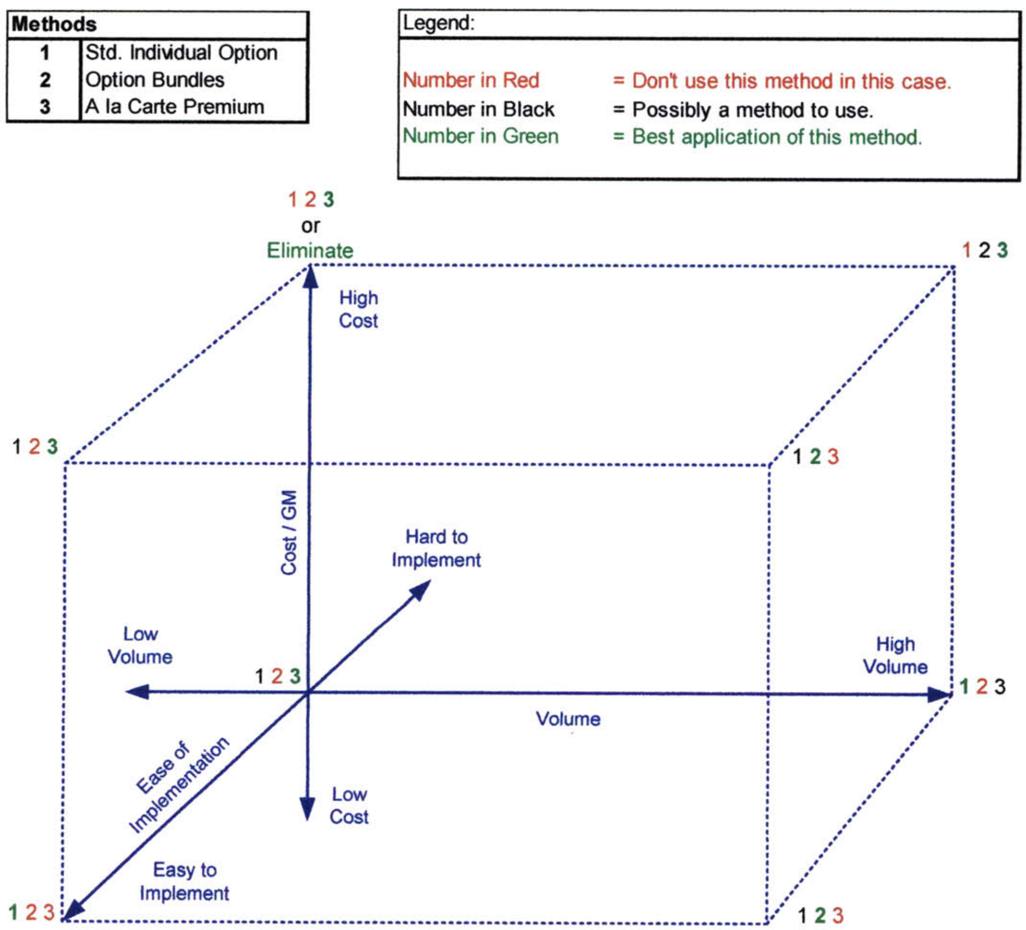

Figure 3: Proposed Options Strategy Model (*The Options Cube*)

The *Options Cube* model represents the logic for classifying the options and defining the option strategy. Each option is characterized based on the values of each one of the three variables defined in the model (Volume, Ease of Implementation, Cost / GM). Based on the values of the variables the model will deliver a suggested classification of the option as standard individual option, bundled option, or a la carte premium option.

The implementation of the Options Cube requires careful data collection and definition of the threshold values for each of the variables. Following is a proposed process for applying the option strategy model (*The Options Cube*):

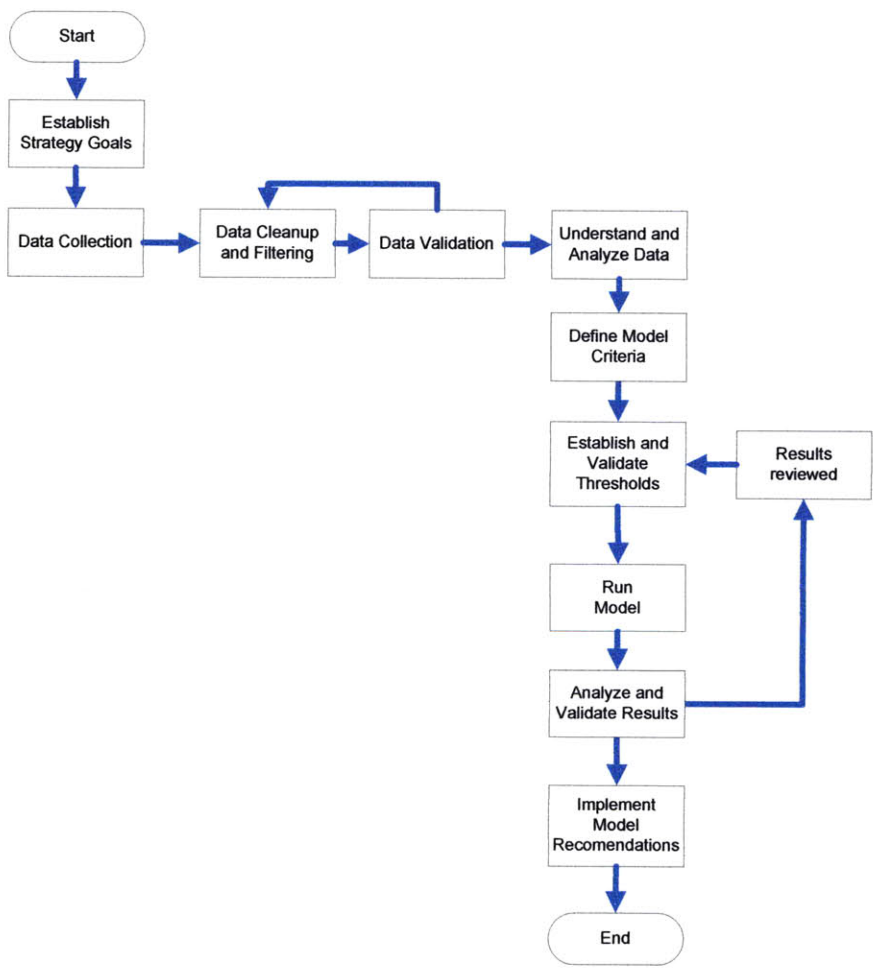

Figure 4: Option Strategy Model Implementation Process.

Chapter III. Case Study: Change Propagation and Option Strategy at AFI, Inc

The basis for the case study presented in this document is a large dataset made available by AFI. This dataset was obtained from the database of the software configurator tool (SCT) used by the company. The SCT is a tool developed internally by AFI's IT department to improve the process through which the customers and dealers have to go through for configuring and customizing the specialty vehicles.

The focus of the present chapter is to give a brief description of the company (AFI) and to introduce the functionality and overall architecture of the software configurator tool (SCT).

III.1 Company and Market Overview

AFI, Inc is a leading worldwide designer, manufacturer and marketer of emergency specialty vehicles. It was founded more than 60 years ago and it has always been at the forefront of innovation and technology. This permitted the company to experience a rapid expansion in market share and significant growth in revenue since the start of operations.

The specialty vehicle market in which the company operates is mainly a replacement market for a product that is critical to public safety services and with a finite life (established by regulation). The market is highly regulated by federal and local laws and also by specific industry associations, such as the National Firefighting Protection Association (NFPA).

The following figure shows the demand for specialty emergency vehicles for the United States and Canada between 1997 and 2010.

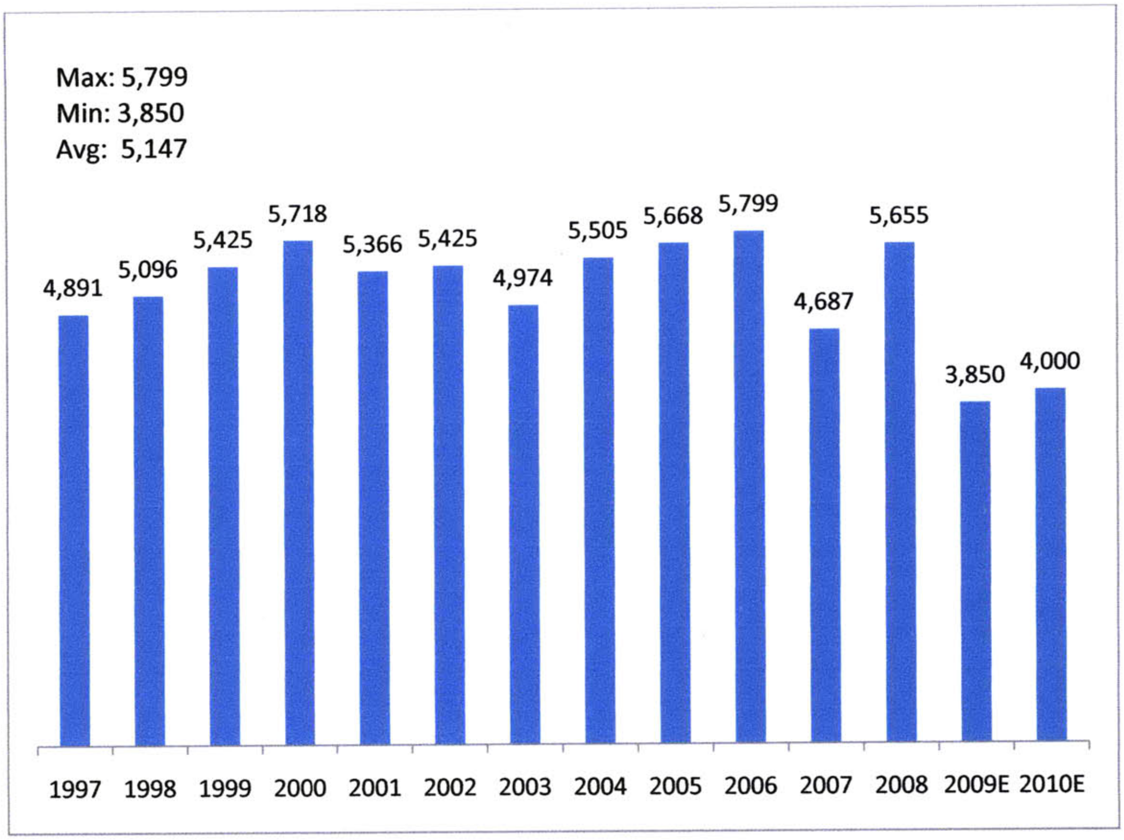

Figure 5: Demand for Emergency Specialty Vehicles in North America (US and Canada)[3]

It can be observed from the previous figure that in the past 11 years the market had an average volume of 5147 vehicles per year with a peak of 5799 trucks or 11% over the average. In addition, the lowest level of 3850 vehicles in 2009 was due to the current

[3] From NFPA market data.

economic recession[4]. For 2010 the expectation is for the market to recover slightly to 4000 vehicles.

Long term demand drivers for the industry are new residential and commercial developments; taller buildings; the expansion of cities into rural areas away from hydrants; changes in building materials; and government regulations. The cost of an emergency specialty vehicle goes from $150,000 for an entry level truck to more than $1.2 million for a specialized, fully equipped vehicle. The market is dependent on the amount of financing available to the cities and municipalities.

AFI, Inc. has one of the largest installed bases with more than 20,000 vehicles. The brand is recognized in the market as a premium apparatus and the company has a reputation for producing and pricing vehicles at the higher end of the market. The fact that the company has always had a reputation for quality, technology and innovative features has enabled it to maintain a leading position among companies in the industry.

The company's corporate headquarters and main manufacturing facilities are located in the United States. It currently employs more than 800 people and has more than 600 thousand feet of production facilities.

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[4] Most of these vehicles are purchased with public funds and when town and city budgets are under pressure demand shrinks.

III.2 Product Overview

The typical emergency specialty vehicle that AFI builds is a complex integrated system that performs multiple functions. It is a mission critical vehicle used to respond to life and death situations. The vehicles are designed with high performance capabilities and are able to deliver multiple functions at the same time. The following tablet summarizes the most typical functions of the vehicle:

Table 3: Functions of an Emergency Specialty Vehicle

Crew Hauler	Toolbox on Wheels
Rolling water tank	Pumping Station
Electrical Generator	Audible warning tower
Emergency Scene Lighting	SCBA bottle filling station
Rescue Platform	Cherry Picker
Communications Platform	Trailer Towing
Moving ladder	Show Vehicle and Parade Float
Water cannon	Foam Dispenser

AFI, Inc. has a diversified product portfolio that includes multiple types of emergency specialty vehicles. Different vehicle types combine a sub set of the functions shown in Table 3. Following is a list of vehicles manufactured by AFI, Inc and a brief description of their characteristics:

a. *Pumper Trucks*: Pumpers are the bread and butter of the fire departments and it is the highest volume vehicle build by AFI. According to the NFPA, a pumper is a fire truck that is capable of pumping at least 750 gallons of water per minute, with a hose that is at least 1000 ft long and a water tank with at least 300 gallons (NFPA, 2009). The capabilities of the vehicle vary depending on the customer requirements. A pumper truck's retail price starts at around $150,000 and can go up to $650,000.

AFI builds two types of pumpers: commercial pumpers and custom pumpers. Commercial pumpers are built on a chassis that is commercially available in the market from vendors like Mack and International. Custom pumpers are built on a chassis that is manufactured by AFI.

b. *Aerial Vehicles:* An aerial is a fire fighting apparatus that has a permanently mounted aerial device[5] (NFPA, 2009). The retail prices for aerial apparatus start at $475,000 and can go up to $1.2 million. All aerial apparatus manufactured by AFI are built on a custom chassis.

c. *Command Centers*: A command center is an apparatus that is used for communications and command activities and typically has sophisticated electronics equipment. They can range from $300,000 to more than $1.5 million depending on the equipment requirements.

d. *Rescue Apparatus*: This is a vehicle that is used for performing special types of rescue operations. The rescue apparatus has the required equipment and tools to perform specific rescue operations that can include but are not limited to mountain rescue, water rescue, high angle, and building collapse. A rescue apparatus is offered in commercial or custom chassis options. The typical retail price of a rescue apparatus is from $250,000 to $ 1 million.

e. *ARFF*: The Aircraft Rescue and Fire Fighting Apparatus (ARFF) is a special type of vehicle designed to conduct rescue and fire fighting operations in aircraft related

[5] An aerial device is a ladder, platform, or water tower that is designed to deliver equipment, personnel or fire retardant at elevated heights from the ground. Typical height of the ladders are from 50 ft to 134 ft.

emergencies or in the vicinity of an airport. The ARFF apparatus is a very robust vehicle that has to meet stringent performance requirement defined by the FAA. All ARFF vehicles are built on a custom chassis produced at AFI. Their retail price can go from $650,000 to $850,000.

f. *Wildlands*: The Wildland fire fighting apparatus is a vehicle designed to fight wild fires. It typically has a pump with capacities between 10 gpm and 500 gpm. The price range for a Wildland vehicle is between $140,000 and $170,000.

III.3 Company Challenges

The Emergency Specialty Vehicle industry is normally a very competitive industry. In the past two years competition has become even more significant due to the current economic conditions which have resulted in the reduction of customer demand (refer to Figure 5: Demand for Emergency Specialty Vehicles in North America (US and Canada). In addition, customers in the industry tend to be very demanding with the OEMs and require a high level of customization in order to tailor the vehicles to their specific needs, desires and local governing regulations. These requirements sometimes can be significant and the level of customization varies on every vehicle. According to the perception of several managers at AFI, the company has been able to adapt its organization and processes to manage the customization requirements that are necessary to be successful in the industry. In fact, they believe that one of the competitive advantages of AFI, Inc is precisely its ability to meet customer demands and create a fully customized apparatus[6]. However, it is important to note that a high degree of customization can also imply higher manufacturing costs due to more complex workflow management, higher inventory of parts and related carrying costs, and quality costs. At the time this research began AFI had recently discovered that it was losing money on the production of some units.

In response to significant internal inefficiencies and cost overruns, 18 months ago the company launched an initiative to improve the overall processes through which the vehicles were customized, engineered and manufactured. This improvement process is based on the elements of the Lean Manufacturing Philosophy (Womack & Jones, 2003) and required all functions of the enterprise to participate, break any departmental barriers and align themselves with the goal of producing efficiently the required vehicle, with the required quality and delivered at the required time.

Before the improvement initiative was launched, the company was highly departmentalized with each function working in silos. Through the improvement initiative the company was re-organized into Value Streams. Product oriented focus factories were created in order to improve communication and responsiveness of the organization. The following figure shows the organizational transformation of the company:

[6] Interview with AFI company executives during a January 2009 visit to the facilities.

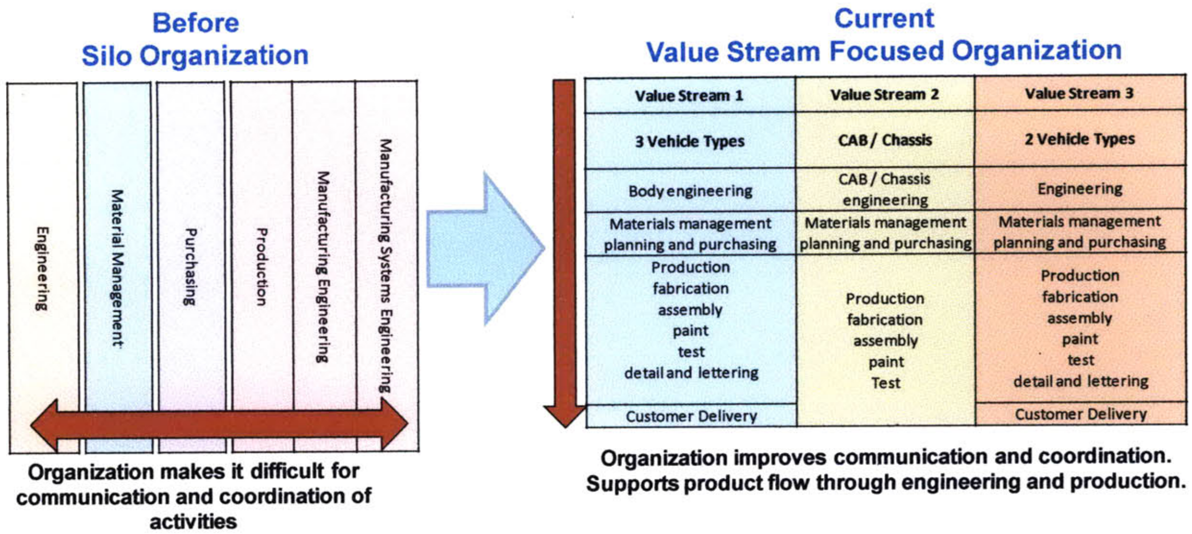

Figure 6: AFI Organizational Transformation

As of today, the improvement process at AFI has been successful; however, there are still numerous challenges for the company.

Another improvement implemented by AFI in the past years to support the improvement initiative has been the software configuration tool. The SCT has been successful in improving the process of configuring and customizing the vehicles beginning with the dealer-customer interaction and configuration of the individual orders. It has enabled the customer, dealer network and company to communicate effectively as to what are the requirements for the trucks. In addition, the SCT has been effective in capturing customer requirements data (in the form of customer requests) since its implementation. However, the company still lacks a clear understanding of the real cost of implementing a specific customization requirement. There is not clear understanding of how engineering changes propagate through the different vehicles. This creates confusion and potentially rework not only in design but also on the production floor.

In addition, the implementation of lean manufacturing and the drive for increased efficiencies and margins is creating pressure on the organization to develop an understanding of the cost of complexity and to observe what are the real implications of implementing the customizations required by their customers. The company needs to develop a portfolio of viable options and option packages that are attractive to their customers in order to increase revenue but at the same time maximize profitability for the company.

Finally, AFI is interested in improving the SCT in order to more effectively support its business and also to potentially offer it to other companies as a commercial application for product configuration and option management.

III.4 Software Configurator Tool (SCT)[7]

In the past, AFI faced increased challenges during the sales process that resulted in lost sales and confusion during the design, and production process of their vehicles. The product data and configuration was managed through spreadsheets, paper and an antiquated sales application. In response to this situation the executive management at AFI, created the AFI Systems Group, a team of IT, software and product development professionals that were given the responsibility of developing a tool to manage the front end process of configuring the vehicles based on customer requirements.

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[7] Based on internal AFI documentation and interviews with IT and Engineering personnel

The result was the development of AFI's software configuration tool (SCT). The SCT is a workflow based sales configurator that uses attribute sets and rules to guide the user through the process of configuring a product. Pre-engineered options are defined within the SCT and they can be selected by the user during the vehicle configuration process. In addition, the user can request engineering changes to these options, totally new options (customizations) for the vehicle or if desired a combination of both. Currently, the tool is in use by the company's dealer network which comprises several dozen dealers and also internally within the product management and engineering departments. It is noteworthy that many dealers are themselves current or former emergency response professionals and are therefore intimately familiar with the required functionality and operational requirements in which these specialty vehicles will be operated. It must be understood that a fire truck is to a fire fighter what a piano is to a professional musician or a scalpel is to a surgeon; it is a highly valued hand-in-glove instrument of work that is designed to save lives, prevent injuries and prevent unnecessary property damage.

Following is a brief explanation of the tool functionality and workflow.

III.4.1 SCT Functionality and Technical Features

The SCT uses an open framework web interface to deliver its functionality to the end user. The application uses the 10g Oracle Application Server Portal with an Oracle Database backend. The application is currently in use by AFI, its dealer network and another sister company. In total there are 450 users with access to the application. These include dealers and internal administrators.

The following figure presents a network diagram for the SCT:

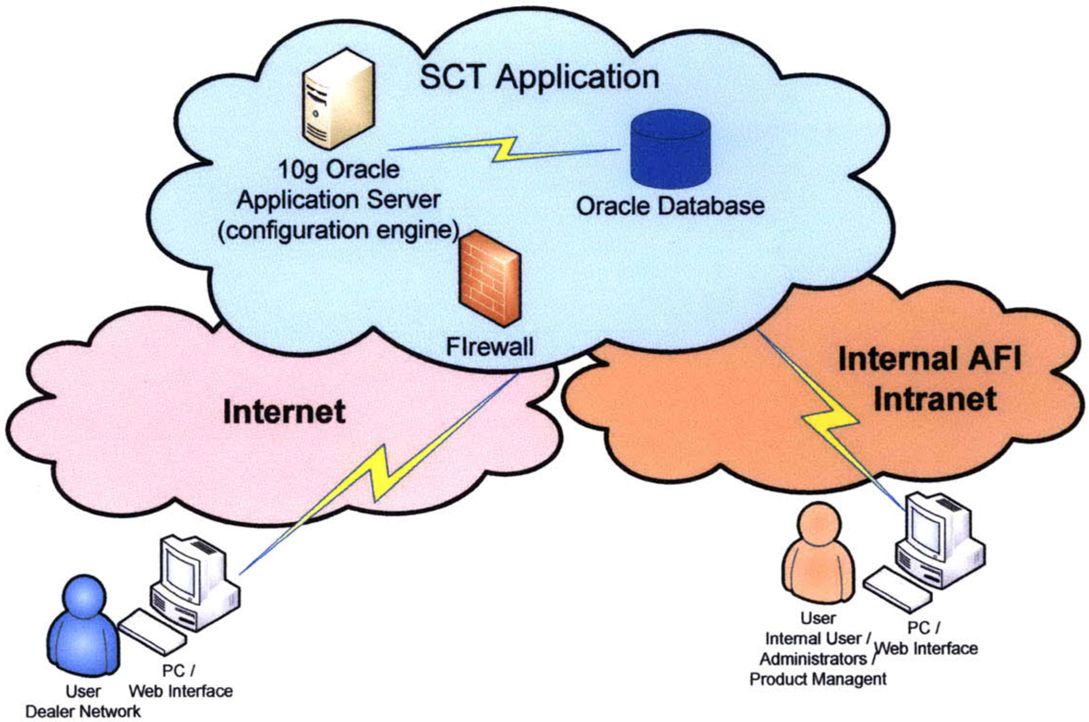


Figure 7: SCT Network Diagram

Other key features of the software are:

- 10g Oracle Application Server Portal
- Oracle Database Backend
- Open Framework
- Customizable for Tailored Experience
- Highly Available / Scalable
    - Load Balanced capability
- Secure
    - LDAP Compliant Security
    - Single Sign On (SSO)

III.4.2 Software Functionality

The SCT contains a series of modules some of which represent the core functionality of the software. Others are optional modules that could be implemented if desired in any Greenfield implementation of the SCT. However, at AFI all modules of the tool are currently in use.

The following figure shows the functional modules of SCT.

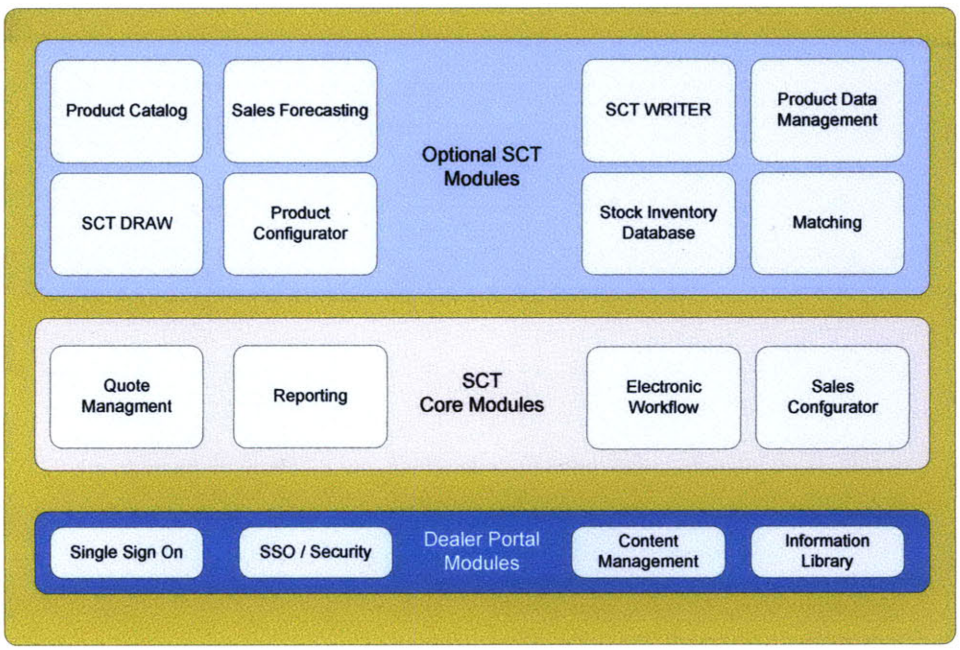


Figure 8: SCT Functional Modules[8]

The core modules of the SCT include the Quote Management Functionality, in which quote information is kept and updated as the quote evolves toward a final order, the

[8] Taken from SCT marketing documentation.

Reporting module that can be customized with any required reports, the Electronic workflow tool and the Sales Configurator module.

The logic for the definition of sellable product configurations resides within the Sales Configurator module. Through the use of a tree based graphical configuration tool the set of available options, rules and prices are defined for each vehicle type creating as a result the option sets and the valid configurations available to the customer (refer to the figure below). The Sales Configuration functionality has close integration with the optional Product Catalog module which contains the detailed description, images and attributes of the options and products.

In addition to the Sales Configurator tool, an optional Product Configurator module is also available if required (in use at AFI). The Product Configurator module expands the functionality of the Sales Configurator and enables the sales order integration to the engineering BOM, with the capabilities of flagging inconsistencies and any missing design elements.

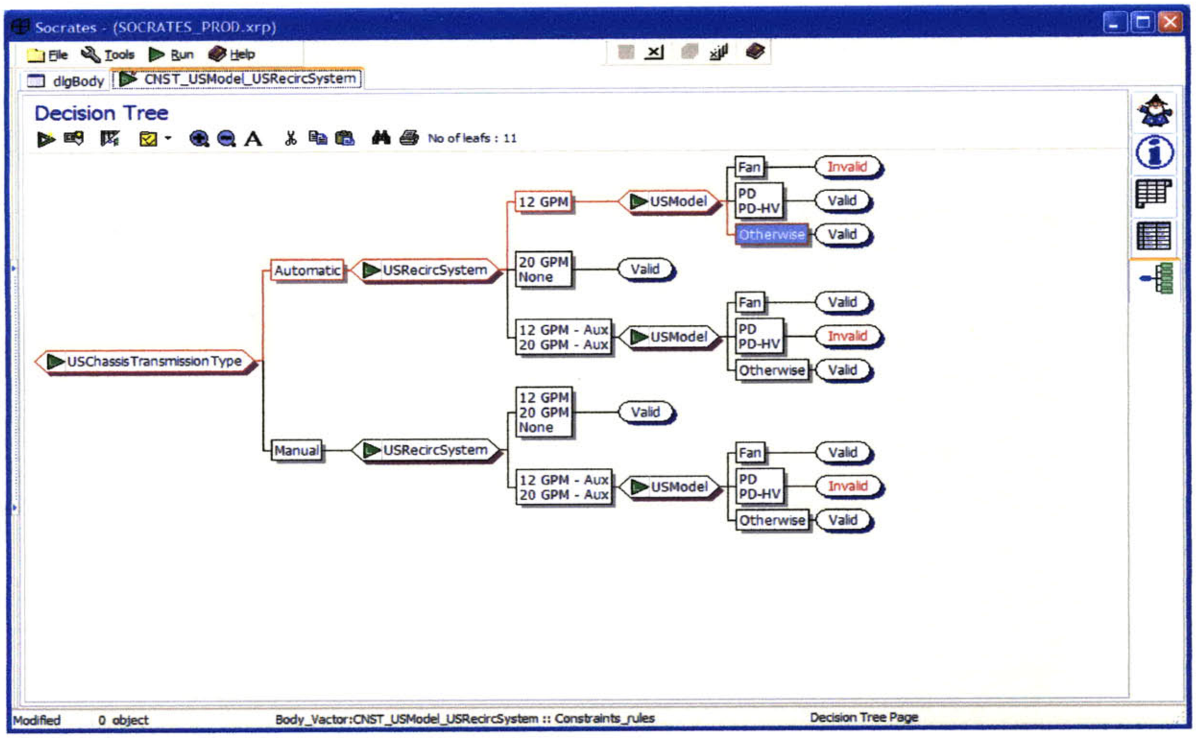


Figure 9: Sales Configurator Module[9]

Other optional modules available within SCT are:

- Sales Forecasting Module: This module contains functionality to aid the company in forecasting the demand of products/options based on the current sales history.

- Stock Inventory Database: Keeps track of any on hand inventory for options, products.

- Quote Matching: This module contains logic to search bit and quote history.

- Product Data Management: This module integrates with the product and sales configurator module. It is used to manage the product/option attributes, characteristics, images and descriptions defined in the system.

[9] Taken from SCT marketing documentation

- SCT Writer: The SCT writer module allows external users (non-dealers) to configure vehicles, download brochures and product information and request a follow up from a dealer or the company. It also keeps track of the leads generated, dealers involved and any conversion of the lead to quote/order.

- SCT Draw: The SCT Draw module generates automatically a 2D drawing based on the configured product. Through the definition of server side application programming interfaces (API's) that link to specific configurator rules and attributes, it assembles the required blocks and creates the drawings.

The dealer portal modules contain the functionality that is required for the dealers to access the SCT securely, manage their relationship with the potential clients, create configurations of vehicle and submit quotes. Following is a summary of the functionality available within the dealer portal modules:

- User Administration
- Specification / Report Sorting
- Monitor sales rep activity
- Maintain Dealer Supplied Equipment
- Maintain Dealer Configuration Templates
- Reporting
    - Active Bids
    - Workflow Status
    - Customer Listing / Labels
    - Dealer Supplied Parts

III.4.3 Workflow Based Configuration

One of the main features of the SCT is its configuration workflow engine. This functionality resides within the Electronic Workflow module and assures that a formal and repeatable process if followed for creating product configurations, quoting products and submitting orders.

The workflow engine automatically manages the configuration and quoting process and assures that all stakeholders are notified, and that the data requirements and approvals are in place throughout the lifecycle of the ordering process. The following figure presents a visual flow diagram of the configuration process:

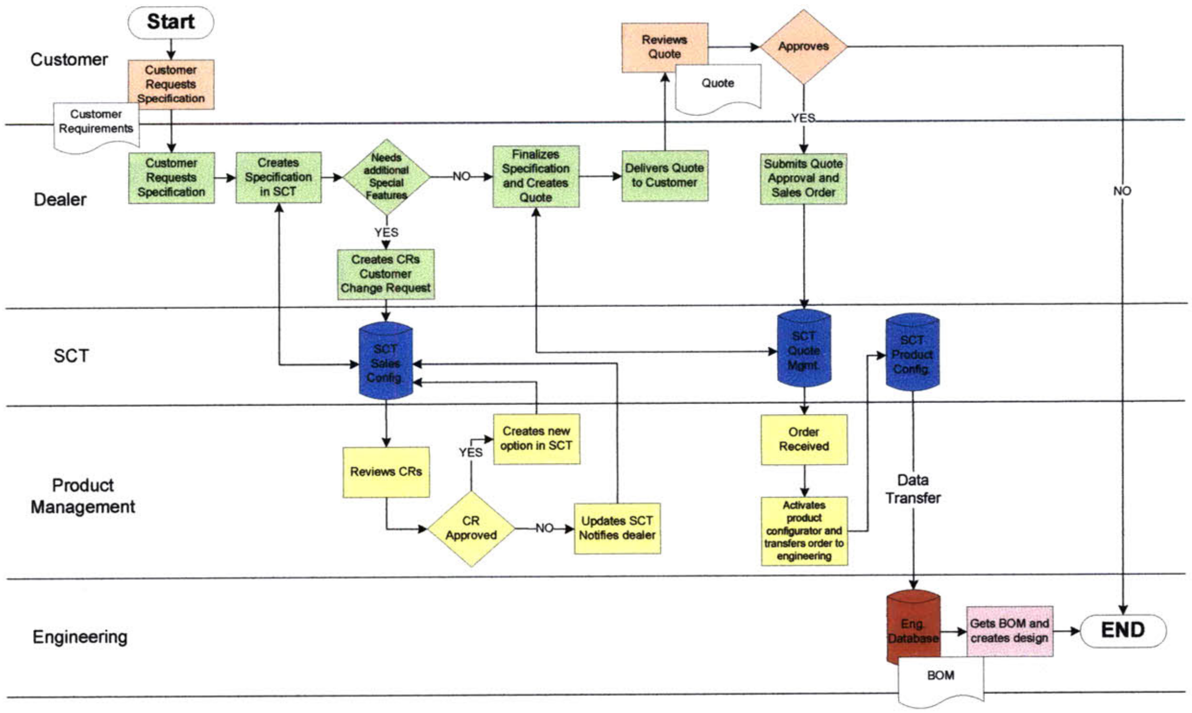


Figure 10: SCT Configuration Workflow (Proposal to BOM Generation)[10]

The first step is to gather the customer requirements and to create a specification that will be translated into a product configuration in the SCT. The dealers typically interact with the potential customers to gather their requirements and perform the initial configuration. The specification is created by adding, removing and changing options. The rules defined within SCT guide the user (dealer and customer) through the process of configuring a valid product. During this process the dealer will create a Change Request (CR) for any requirement that is not available as an option. These change requests are submitted electronically to AFI where the product management and engineering team will analyze. There are six possible states for the change request:

[10] Based on SCT marketing documentation and interviews with the AFI IT and engineering team.

- *Submitted*: Once the change request is submitted for AFI consideration.

- *Pending*: Any change request that has been submitted and is in process of being reviewed but there is still no resolution from the company.

- *Approved*: The change request has been approved by AFI and an option has been created. This option becomes part of the option portfolio within SCT database and is available to be added (per the appropriate rule set).

- *Declined*: The change request was not approved by the company.

- *Exists*: After reviewing the request, it was determined that there is an option already defined in the system that corresponds to the request.

- *Similar*: There is an option in the system similar to the change request that could satisfy the same customer requirements.

It is important to note that after the initial product configuration is done and until the quote is created and submitted for customer review, it is possible to continue to request additional customizations and changes to the product configuration. In fact, the process is sometimes iterative with AFI, the dealer and the customer reviewing requests and options and changing the product until a final configuration is defined. Of all the models that the company builds only one has a base model configuration defined. For the rest of the models there is no base vehicle configuration and the dealers create "freely" the initial specification.

Once the configuration is finalized and all the features and special requests are finalized and defined, a quote is created by the dealer and AFI, and then submitted to the customer for review. The quote created within the system can have one of three possible states:

- *Draft*: The quote is not finalized and is still work in process.

- *Bid Review*: The quote has been finalized and is being reviewed by the customer.

- *Order-submitted*: The quote was approved by the customer and became a firm order.

Unfortunately, if an order is not approved by the customer, the quote status is not changed and it stays at Bid Review indefinitely. This makes it impossible to document the possible causes for lost quotes since currently the system has no capabilities to track them and assign a cause. It is recommended to create an additional status of "*Rejected*" for the quotes within SCT with the appropriate functionality to track and report on potential causes and issues of lost orders during the quote submission process.

Once the quote is accepted by the customer and its status becomes *Order-submitted*, a formal order is created and the configuration data is transferred to another system outside of SCT, namely the engineering database where the defined configuration is converted to a BOM and the product development process starts.

Chapter IV. Dataset Availability and Overview

The previous chapter presented a brief company overview and a discussion of the SCT functionality and characteristics. In this chapter the discussion focuses on the data available for the analysis and its characteristics.

IV.1 Engineering Change Data Availability

The engineering change and configuration data available at AFI is a reflection of the legacy organization that was in place before the improvement process initiated several months ago. There are three different databases where engineering change requests and actual engineering changes are stored.

Initially it was believed that all data related to engineering changes throughout the life cycle of the vehicle (configuration process, sales, engineering, manufacturing and delivery) were contained in the software configurator tool (SCT). Upon additional exploration and interviews with company employees, it was observed that sales/product management, vehicle engineering and manufacturing utilize three different databases to track the engineering change requests and engineering change orders. The figure below presents the different databases that store engineering change data.

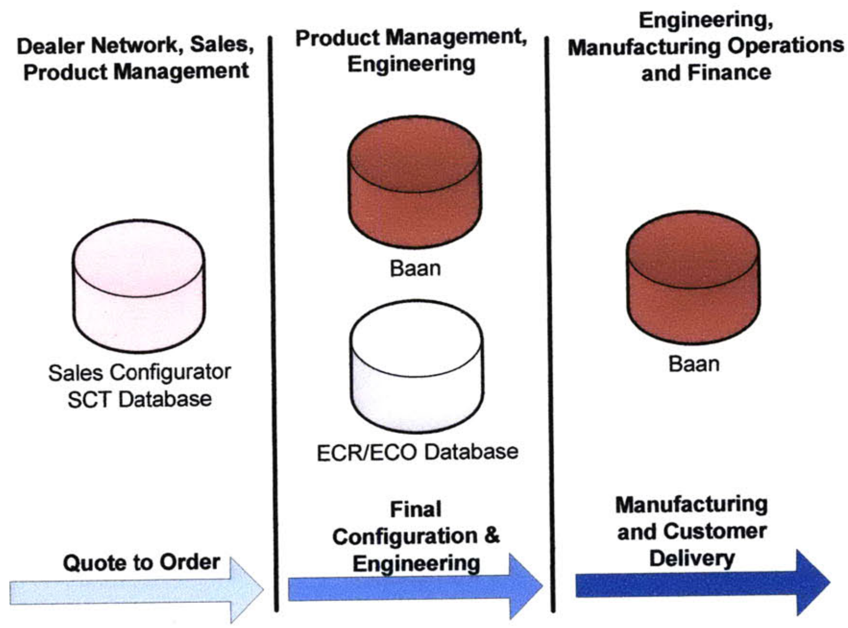


Figure 11: Databases Used to Store Engineering Changes at AFI, Inc

The dealer network, sales and product management utilizes the software configuration tool (SCT) as the main tool to configure the vehicles and track customer change requests (Change Requests or CRs). The system tracks CRs and the vehicle configuration until an order is placed. At this point the vehicle order with the agreed-to configuration is transferred to an engineering database (ECR/ECO Database) and the configuration is converted to a BOM that is managed through the engineering database but for which the system of record is Baan[11]. A production order is assigned and at this moment any new ECR (engineering change request) or ECO (engineering change order) is tracked only in the engineering database (ECR/ECO Database) therefore the "as ordered" configuration in SCT and the resulting "as built" configuration in Baan may be different.

[11] Baan is a commercially available ERP (Enterprise Resource Planning) system originally developed by Baan Corporation.

The engineering database tracks the changes not on an order by order basis but instead tracks revisions to the specific BOM elements of the vehicles. It was observed that between the original database in SCT and the engineering database there is no primary key or link to identify the original sales order. It is strongly recommended that any change to a vehicle configuration during detailed design and manufacturing can be linked back to the order number that is associated with said vehicle.

Finally, once the design portion of the vehicle is finalized, it is delivered to the shop floor for production, and the ECOs are tracked by the ERP system Baan and are updated in this database. Unfortunately, there is also no traceability in Baan to the original sales order in SCT. Therefore it was found that traceability and reconciliation of change data across these three systems is a major challenge.

IV.2 Dataset Characteristics

The data collection process was difficult due to the fact that there is not a unique database that tracks the vehicles from their initial configuration (including customer requirements) and through the engineering and manufacturing process. The lack of a unique repository of configuration data creates confusion and communication issues among the different functions and is currently preventing the company from having visibility into the as-built vehicle configuration.

Through the analysis of the different databases it was decided to use the data contained in the SCT database. This database contained the most relevant and complete set of data on vehicle configurations, customer change requests and order configurations. In addition, it contained close to three years of data while the engineering database only had three months worth of data. Figure 11 below presents a summary of the data availability and characteristics.

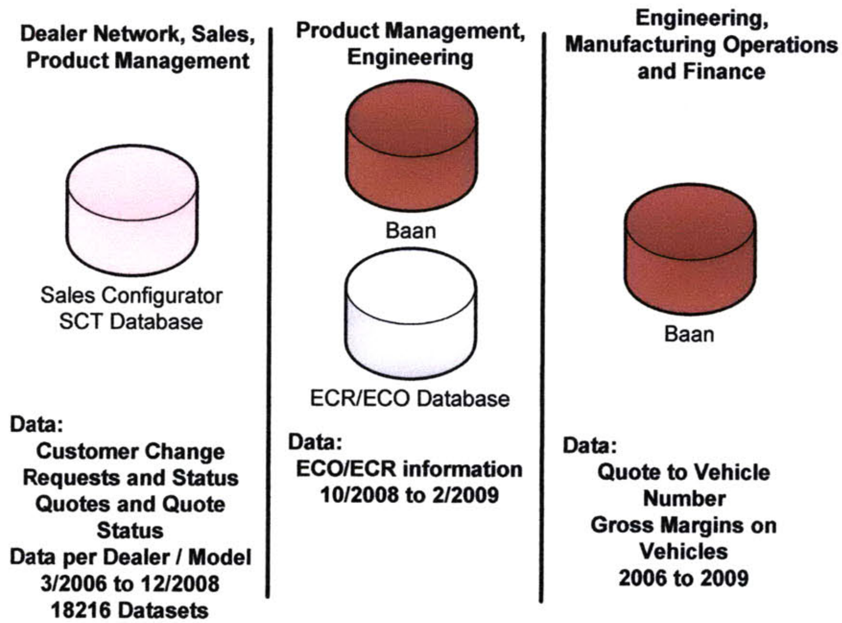


Figure 12: Data Characteristics

The SCT database contains multiple data tables and data fields. It contains information on customer requests, request detailed descriptions, status of the requests, request date and decision dates. In addition, it is possible to link the customer quotes with the related option sets. The main data used in the analysis came from the following tables in the database:

- *Requests Table*: This is the main table of the database since it contains the full set of customer change request records. These records are the initial requests that the customers and dealers create in the system during the process of configuring the vehicle. The

Requests table obtained from the SCT database contained 18216 records. The relevant fields are described in the following table:

Table 4: Relevant Fields of the Requests Database Table from SCT

Database Field	Description
CR_ID	Unique identification number for each change request
QUOTE_NO	Unique identification number of the quote
DEALER_NUMBER	Identification number of the dealer generating the quote / request
DEALER_NAME	Name of the dealer generating the quote / request
SALESPERSON	Sales person name assigned to the quote process
CUSTOMER_NAME	Name of the customer for which the request / quote is generated.
PRODUCT_LINE	Name of the product line (e.g. Pumper, Aerial, ARFF)
MODEL_NO	Specific model identification for which the quote / request is generated
SIMILAR_OPTION	Identification of an option that is similar to the request
EST_SELLING_PRICE	Estimated prices for the request
CR_DESCRIPTION	Detailed description of the change request
REQUEST_DATE	Date when the change request was made
MOD_DATE	Date when the last modification to the record was made
REQUEST_STATUS	Status of the request (Submitted, Pending, Approved, Declined, Exists, Similar)
COMPLETE_FLAG	(Y/N) Defines if the change request has been analyzed and a final decision has been made.
COMPLETE_DATE	Date when the change request final definition occurred

- *Requests Actions*: This table contains the set of options that were added, removed or changed to a specific vehicle (quote). The relevant fields from this table are described in the following table.

Table 5: Relevant fields of the Request Actions Database Table from SCT

Database Field	Description
QUOTE_NO	Unique identification number of the quote
OPTION_NO	Unique option identifier used to configure the quote
ACTION	The option can be added (ADD), removed (REMOVE), changed (CHANGE) to a quote
APPROVED_BY	Who approves each of the actions / quote configuration
APPROVED_DATE	The date the action is approved
NOTES	Field for any relevant note related to the option implementation in the quote
ACTIVE	(Y/N) Defines if the option / action is active or not
CR_ID	Unique identification number for each change request

- *Categories*: This table contains a decomposition of the vehicle into 10 parent categories and 155 child categories. These will be discussed in more detail in the results chapter of the report. The relevant fields of this table are described below.

Table 6: Relevant fields of the Categories Database Table from SCT

Database Field	Description
PARENT_ID	Unique identifier for the high level parent category
CHILD_ID	Unique identifier for the child category
DESCRIPTION	Description of the child category

- *CRS_Options*: All the options that have been created in SCT are stored in the CRS_Options table. This table also links each one of the options to a specific vehicle decomposed category. Below is a description of the relevant fields.

Table 7: Relevant fields of the CRS_Options Database Table

Database Field	**Description**
OPTION_NO	Unique option identifier
SHORT_DESC	One sentence option description
LONG_DESC	Detailed description of the option
BASE_OPTION	Indicates an option on which the current option is based.
CATEGORY	Child category number to which the option is linked (CHILD_ID)

- *Quote Status*: This table contains the status of the quotes in the system. These states are DRAFT, if the quote is still in process of being created, BIDREVIEW if the quote is being reviewed by the customer and ORDERSUBMITTED if the customer decided to purchase the vehicle(s) and the quote became a firm order. The relevant fields of this table are described in the following table.

Table 8: Relevant fields of the Quote Status Database Table from SCT

Database Field	Description
QUOTE_NO	Unique identification number of the quote
UNIT_QTY	Number of vehicles ordered in the quote
AFI_DEALER_PRICE	Price to the dealer
TOTAL_CUST_COST	Price to the end customer
CONCESSION_AMOUNT	Amount of the discount to the customer
ORDER_STATUS	Indicates the status of the quote (DRAFT, BIDREVIEW, ORDERSUBMITTED)

The following table presents a summary of the data obtained from the SCT database:

Table 9: SCT Data Summary

18216 change requests (17109 after data cleaning)
1522 Quotes (330 ordered) / 53 dealers / 36 models
17007 Options defined in the system
27170 Option change actions

Additional data regarding gross margins per order was obtained from the financial module of the ERP database. The data obtained from the Baan database contained labor and material cost per vehicle, labor hours, the sales price, profit and gross margin per vehicle. However, the data was incomplete and it was not possible to obtain margin information for all the ORDERSUBMITTED quotes (actual orders).

Following is a summary of the data characteristics used for the analysis. It indicates the database from which the data was obtained.

IV.3 Data Cleaning and Anonymization

After studying the data tables obtained from the SCT database it was noticed that not all the change requests in the different tables had an assigned change request ID / CR_ID (the data was incomplete in some instances). Due to this issue it was necessary to use the quote number as the key when creating the different queries that associated the data between the different database tables. It is not unusual to find missing or spurious information in industrial data sets as reported by previous authors.

The database contained 1107 records that did not have any information regarding truck model, client, dealer and/or request dates. These records were eliminated from the data set. In addition, the change requests from 2/06, 3/06, 4/06 were eliminated since at this time the software was not fully operational. Finally, for 12/08 the data was eliminated from the calculation since it was not a full month. This process of data gathering, filtering and anonymization is typical for research on large industrial datasets. See also (Giffin, Change Propagation in Large Technical Systems, 2007). We are continually amazed how "noisy" industry data often is and data quality is often a reflection of the overall process quality and discipline of the firm.

In order to protect the identity of the company any reference that could identify the organization or its dealers and customers was eliminated or changed in the dataset. This included change in names of the customers, models, and dealers. The following table presents the result of the anonymization of the data for the vehicle models built by the company and contained in the SCT database:

Table 10: Model Table (Post-Anonymization)

	Vehicle Model
Pumper	Pumper 1
	Pumper 2
	Pumper 3
	Pumper 4
	Pumper 5
	Pumper 6
Aerials	AERIAL 1
	AERIAL 2
	AERIAL 3
	AERIAL 4
	AERIAL 5
	AERIAL 6
	AERIAL 7
	AERIAL 8
	AERIAL 9
	AERIAL 10
	AERIAL 11
	AERIAL 12
	AERIAL 13
	AERIAL 14
ARFF	ARFF 1
	ARFF 2
	ARFF 3
	ARFF 4
	ARFF 5
	ARFF 6
	ARFF 7
	ARFF 8
Rescue	Rescue 1
	Rescue 2
	Rescue 3
	Rescue 4
Other	Other 1
	Other 2
	Other 3
	N/A
	No Entry

Chapter V. Analysis and Results

The current chapter presents the detailed results obtained from the analysis of the data presented in Chapter IV. The data was analyzed using statistical techniques in order to search for patterns and interesting relationships. In addition, in parallel with the statistical analysis a network analysis was performed with the assistance of a postdoctoral fellow. In this section we try to answer the following questions:

- What vehicle categories are the most affected by change requests and what are the areas with the highest number of defined options in the system?
- What vehicles tend to have the highest number of requests and options?
- What are the most popular options by vehicle type?
- What are the most profitable vehicles for the company and what are the most profitable options for the company?
- What is the right set of options that can maximize the company's profit?
- Which dealers tend to have the highest number of change requests and options?
- What is the profile of a successful order? Is there a correlation between the level of customization and the probability of an order success?

V.1 Statistical Analysis, and Data Relations

The first step in the analysis was to develop an understanding of the data and to observe the different relationships among the different elements of data. The analysis is presented and divided into several elements of the data based on the different perspectives taken while looking for relationships.

- Quotes and Change Request Relationships
- Options Related Relationships
- Model Related Relationships
- Dealer Related Relationships
- Order Success
- Gross Margin Analysis

V.1.1 Vehicle Decomposition

In the SCT database the vehicle has been decomposed into 10 parent elements or categories. Out of these 10 main categories, 9 refer to form elements and 1 refers to documentation and warranty. These 10 elements are further decomposed into 155 child subcategories. All the options defined in the system are related to one of the 155 child subcategories through the first four digits of the unique option ID. Table 11 below shows the 10 main parent categories. In addition, the 155 child subcategories can be observed in Appendix 1:

Table 11: Parent Categories in the SCT

Category	Description
500	Base Model
1000	Chassis
1500	CAB
3000	BODY
4000	PUMP AND PLUMBING
5000	ELECTRICAL
6000	AERIAL
7000	LOOSE EQUIPMENT
8000	PAINT
9000	WARRANTY

V.1.2 Quotes and Change Requests Relationships

As described previously in Chapter III, options are selected every time a customer configures the vehicle in the SCT. If an option is not available a request is placed to approve the new requirement. Product management analyzes the requests, which can be approved, or declined. In some cases a similar option may be offered to the customer and in other cases it is discovered that the actual option already exists in the system. Once the request status is defined the option is added to the quote and to the available options in SCT. After the change requests are analyzed and approved or declined, the vehicle is configured by adding the options (ADD), removing options (REMOVE) or changing options (CHANGE).

The data indicate that there are a total of 18,216 requests in the system. When compared to the number of options in the database (17,007) it can be observed that there are 0.934 options per change requests. This result suggests that almost every time there is a new change request there is a tendency to develop it into an option without performing a detailed analysis to look for similar options and making the substitution. The engineering director and the COO (chief operating officer) suggested that this result may also indicate that the sales team or dealers rather than working with the customer to try to understand his requirements to guide him to an existent option are just creating new options in the system that AFI's product management team is easily approving. This appears to be – at first sight – the path of least resistance. This conclusion is also supported by the fact that 50% of all the requests in the system were approved and only 7.9% were found as similar or already existing in the system. The following table presents a summary of the results:

Table 12: Summary of Requests Status

	Approved	Declined	Exist / Similar	Pending / Submitted
Percentage of total requests	50.0%	17.8%	7.9%	21.6%
Number of Requests	8,554	3,052	3,148	2,350

An additional interesting result that may be having an effect on the number of requests approved is that the average number of requests per month is relatively high at 548.13 (standard deviation of 158.73). This large number of requests that need to be resolved (27.40 per day assuming 20 working days per month) is putting significant pressure on the Product Management team and may be one of the reasons for the large number of approved requests. The following figure shows the requests per month:

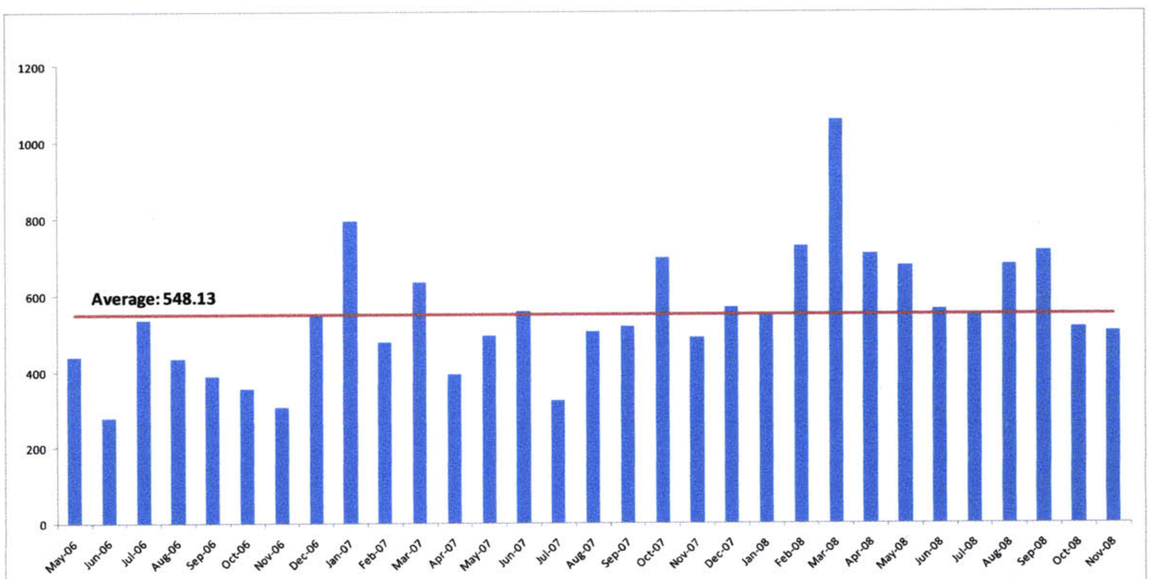


Figure 13: Number of Change Requests per Month

There are a total of 1,522 quotes in the system, which means that the average number of CRs per quote is 11.24. When analyzing the histogram of requests per quote (refer to Figure 14 and Table 13), it can be observed that most of the quotes have between 1 and 5 requests. It is interesting to observe that there are a number of quotes with more than 30 requests. These quotes represent 12% of the total number of quotes. This might not seem significant but may cause disruption in the work of the resources of product management and engineering due to the spike in the amount of work for one particular quote. As we will see later, however, these highly customized quotes also have a higher probability of turning into orders and are therefore important to the firm's revenue stream. Finally, from the data, it was observed that three quotes had 105 requests.

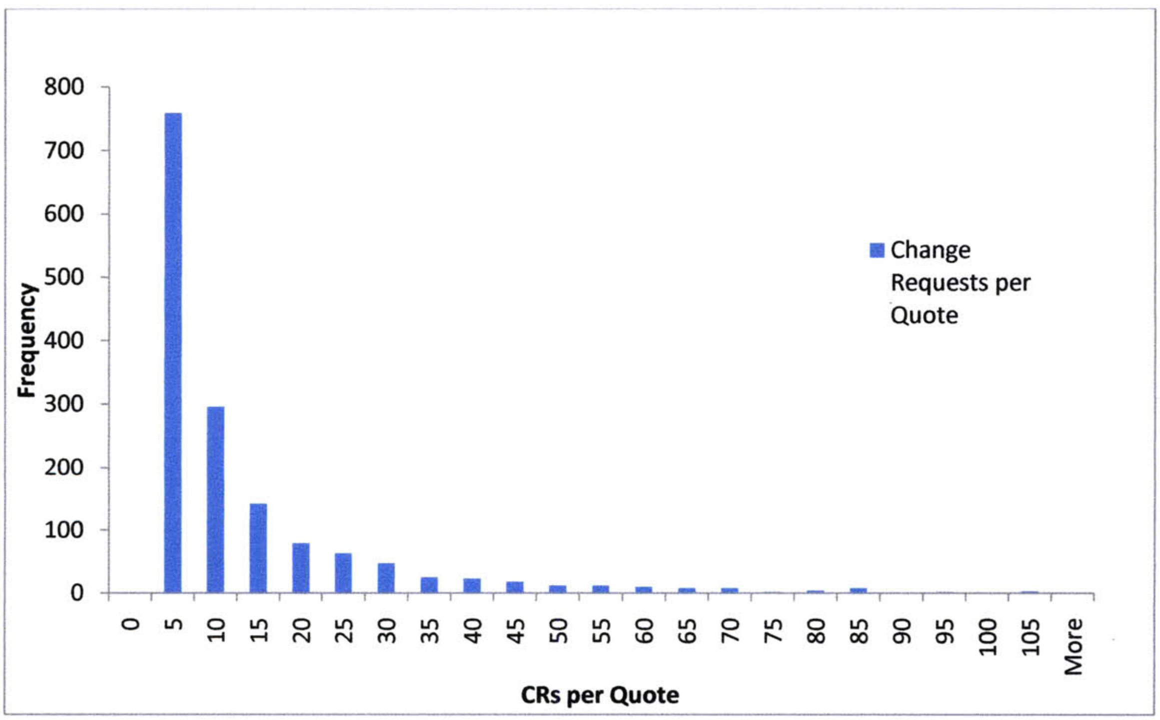


Figure 14: Histogram of Requests per Quote

Table 13: CRs per Quote Frequencies

CRs per Quote	Frequency
0	0
5	759
10	296
15	142
20	79
25	63
30	47
35	25
40	23
45	18
50	12
55	12
60	10
65	8
70	8
75	2
80	4
85	8
90	1
95	2
100	0
105	3
More	0
	1,522

V.1.3 Options Relationships

It was discussed previously that any option or customization that is defined in SCT is classified and "coded" based on the area of the vehicle that it affects. For example if an option is related to the bumper trays (code 1150), the option will be numbered starting with element number (1150 in this case) followed by a sequential number (1150-0011). If there are additional options or customizations related to the higher-level option, then additional sequential numbers are added (for example 1110-0000-277).

It was observed that 49 categories (31% of all categories) represent a total of 13,999 options or 80% of all the options in the system. The following figure shows a Pareto distribution of the options in the system:

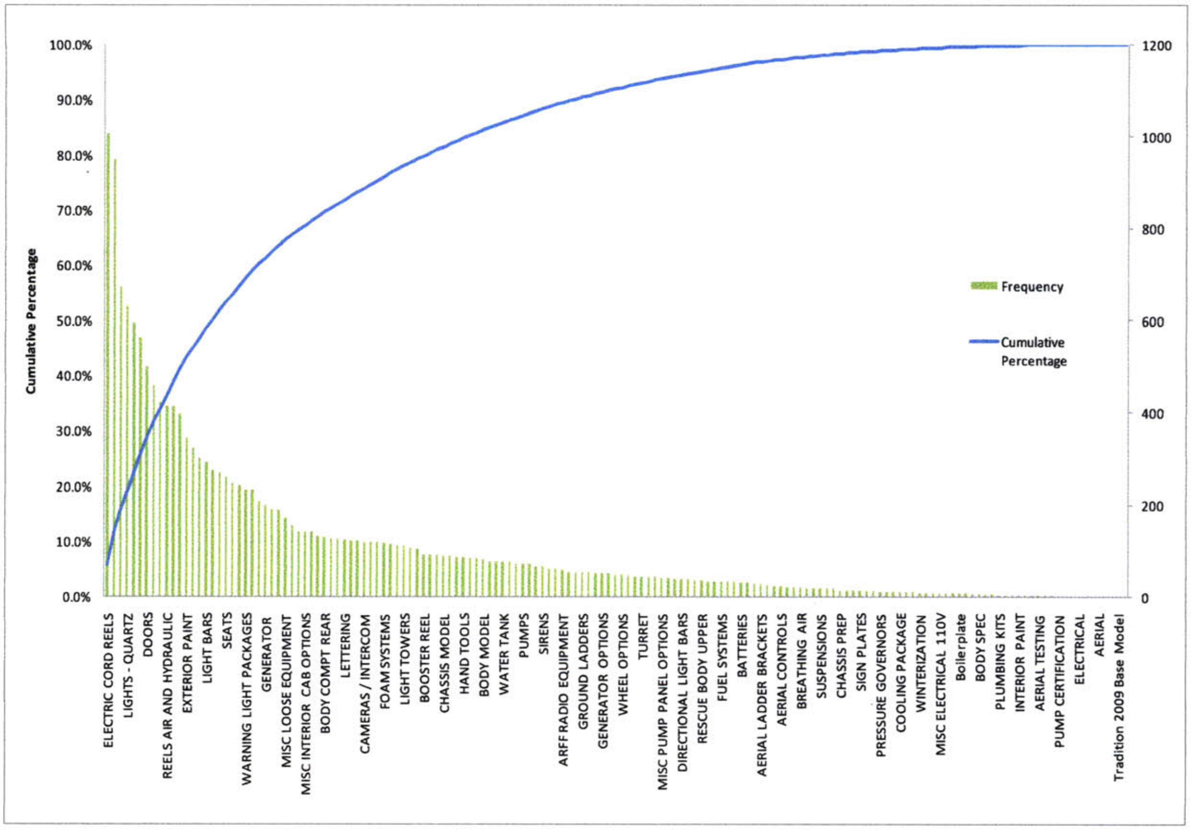


Figure 15: Pareto Distribution of Options Defined in SCT (by category)

The following table presents the categories with the highest defined number of options. It can be observed that the electric cord reels is the category with the highest number of options (1,008) followed closely by warning lights (953) and gages (672). Thus it appears that the electrical system is the one that sees the highest degree of customization.

This is followed by customization of doors, receptacles and special configuration requirements for the vehicle body.

Table 14: Categories with the Highest Number of Options Defined in SCT

Child Sub category	DESCRIPTION	# of Options defined in System	% of total Options	Cummulative %
5130	ELECTRIC CORD REELS	1008	5.9%	5.9%
5600	WARNING LIGHTS	953	5.6%	11.5%
4435	GAUGES	672	4.0%	15.5%
5450	LIGHTS - QUARTZ	632	3.7%	19.2%
4415	DISCHARGES AND PRECONNECTS	594	3.5%	22.7%
5470	RECEPTACLES	562	3.3%	26.0%
3300	DOORS	500	2.9%	28.9%
3340	MISC BODY OPTIONS	460	2.7%	31.6%
3380	TRAYS / TOOLBOARDS	422	2.5%	34.1%
3350	REELS AIR AND HYDRAULIC	415	2.4%	36.6%
1750	CAB ELECTRICAL OPTIONS	414	2.4%	39.0%
8300	STRIPING	397	2.3%	41.3%
8100	EXTERIOR PAINT	346	2.0%	43.4%
3365	LADDER STORAGE / RACKS	324	1.9%	45.3%
3130	PUMP MODULE	300	1.8%	47.0%
5300	LIGHT BARS	293	1.7%	48.8%
4432	FOAM SYSTEM OPTIONS	276	1.6%	50.4%

It was described previously that when a quote is created and during the negotiating process with the client, the change requests are generated. Through this process, and based on the customer requested options or customizations a series of actions take place. An option is considered used if it is assigned to a quote through an action. There are three different actions that can be taken ADD, CHANGE or REMOVE. The ADD action adds the option to the vehicle configuration. The CHANGE action, changes the option for another or it modifies the quantity of the option. Finally, REMOVE will remove an option from the quote. Every time there is an action, the SCT reviews it against the rules defined in the graphical configurator engine that resides within the sales configurator module. If the action does not violate any rule then it is allowed, and if not the system displays an error message and the user has to make the necessary changes.

The table with the full set of actions for each one of the orders configured in the last three years was analyzed. There were a total of 27,170 transactions overall with 16,383 ADD transactions, 469 CHANGE transactions and 10,318 REMOVE transactions.

It was also observed that only 10,159 options out of the 17,007 defined in the system had any transaction (only 2.68 transactions per option). This means that 6,848 options have not been used at all since the SCT database was implemented and that on average there is low re-utilization of options when configuring vehicles. This is an important result since even "dormant" options can create significant complexity and cost.

In addition, only 8,377 different options have an ADD action, 144 a CHANGE action and 2,857 a REMOVE action (the same option can be assigned to different quotes through multiple actions). The following table summarizes these results:

Table 15: Option Transaction Results Summary

	ADD	CHANGE	REMOVE	Grand Total
Total Transactions	**16,383**	**469**	**10,318**	**27,170**
Number of Different Options Used	**8,377**	**144**	**2,857**	**10,159**

A histogram with the frequency of option utilization was created for all the options available in the database (refer to Figure 16: Frequency of usage for available options (includes ADD, CHANGE, DELETE)). It can be observed that 6,163 options have been used only once and 1,380 only twice. In fact only 480 options or 2.82% of the total options in the system have a frequency of usage of more than 10 times with the highest number of transactions (uses) for an option of 70 (option number 4417-0058-573). These results support the conclusion that there is a very low re-utilization of options and there is a tendency to approve change requests and to create new options.

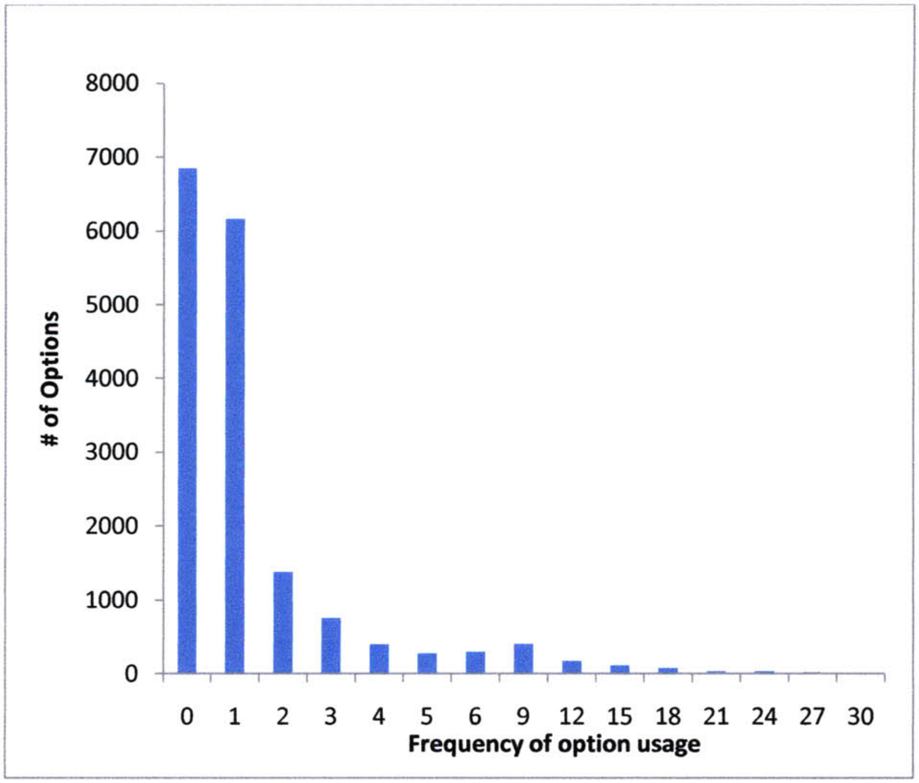


Figure 16: Frequency of usage for available options (includes ADD, CHANGE, DELETE)

V.1.4 Model Relationships

When the requests per quote are analyzed for each one of the individual models, it can be observed that the Aerial and Rescue vehicles have the highest number of change requests per quote. This may be due to fact that these are the most complex vehicles. In the case of the Aerials, they not only contain similar systems as the Pumper vehicles but also an aerial element. The Rescue vehicle tends to be configured with special optional equipment tailored to the needs of the city or municipality. In fact, a special type of Rescue vehicle is the Command Center, which is typically customized with electronics and specialized communications equipment. The results are presented in Figure 17 below:

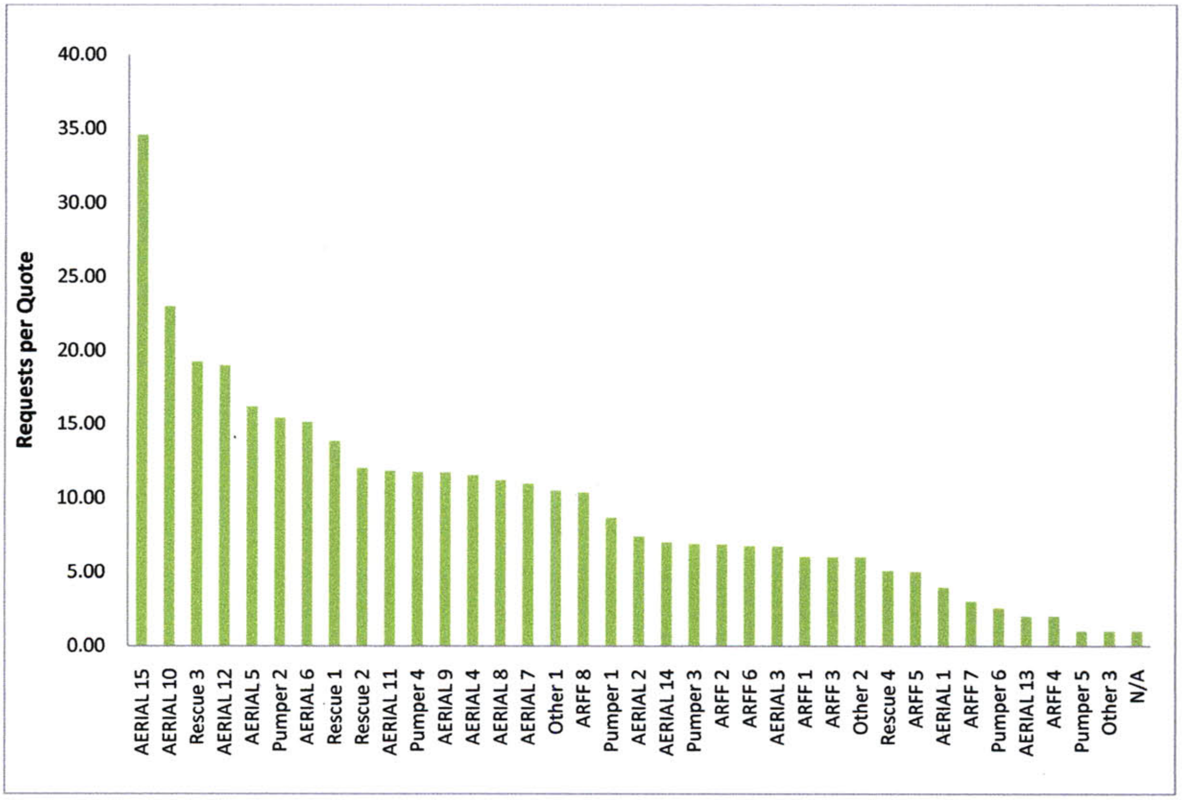


Figure 17: Requests Per Quote for Each Model Type

The Aerial 15 has the highest number of requests per quote for any vehicle with 34.57 on average. Aerial 10 is the model with the second highest number of requests per quote at 23, however in the case of Aerial 10 there is only one quote in the database. More significant results are obtained for Aerial 6 with 16.19 requests per quote and a total of 47 quotes and for Pumper 2 which has 373 quotes and 15.43 requests per quote on average.

This result suggests that even with the popular models there is no or little effort to try to reduce the amount of customer requests and option proliferation. There may be an opportunity to observe what are the most popular options requested for these models and to create a series of standardized option sets that could be offered to the customers.

It was observed that there are 7 models out of the 36 (19.4%) that generate 80% of the change requests. For these models, additional analysis was performed regarding the status of the change requests (please see figure below).

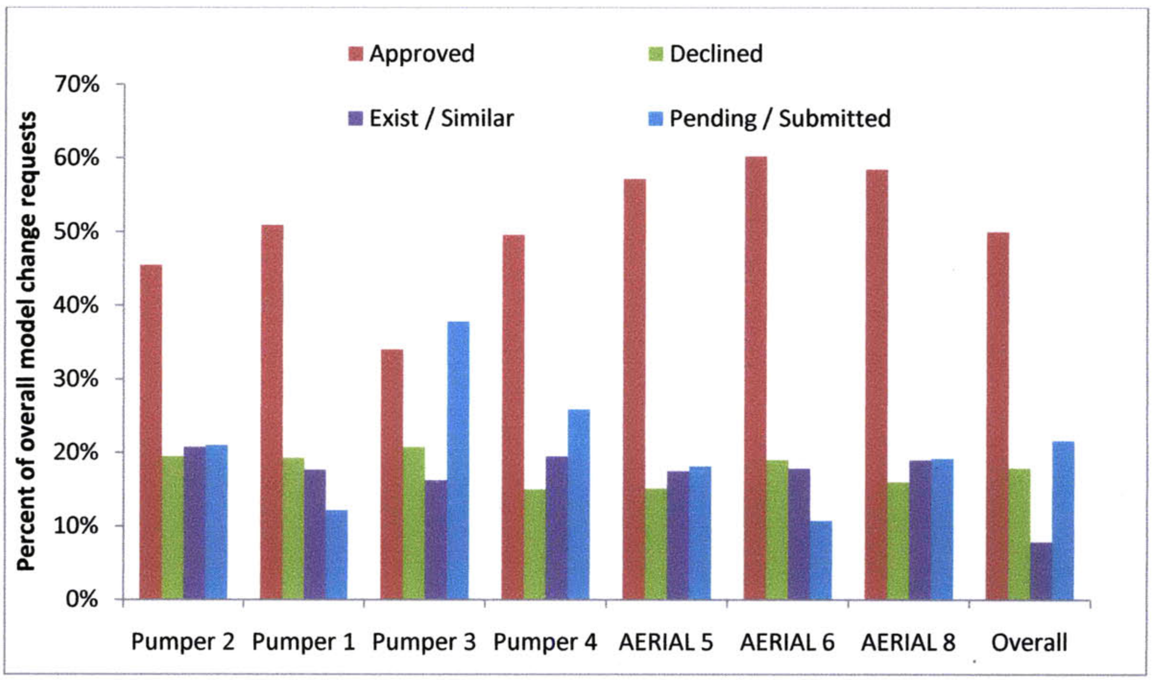


Figure 18: Request Status for Models with Highest Number of Requests

In all cases, a significant tendency to approve the change requests was observed. While this is done to satisfy customer requests and increase the likelihood of turning a quote into an order it also increases complexity of the design and manufacturing process for each of these vehicles. The model with the least number of approved change requests as a percentage of all change requests was Pumper 3 with 34.03%. However, it still has a high number of pending / submitted requests for which no decision has been made. The model with the highest number of approved requests was Aerial 6 with 60.23%.

For all the 7 models, the number of approved change requests is higher than the number of declined requests or instances where there was an existent or similar request that was used. These results reinforce the conclusion that there is a tendency for the company to constantly approve new requests to satisfy customer needs. This could reflect first that the right options or option sets are not defined in the system – since existing option sets could simply be added and would not require separate approval unless a design rule was violated - and second that the company or dealer network is not trying to truly understand the true customer requirements in order to advise them as to what are the best existing options that they could use (customer "steering"). It is recommended to review the incentives for the dealer network in order to make them guide the customers towards existing/similar options. In addition, this may reflect the need for dealer training regarding the current options available in the system and in tools that can help identify and document customer requirements.

V.1.5 Relationships by Dealers

There are a total of 53 dealers defined in the system (including AFI's own sales department). The dealer with the highest number of change requests is AFI itself with 6477 which represent 37.87% of all requests. There is a significant difference between

AFI and the dealer with the second highest number of request, Dealer 2, who had 1258 or 7.36%. Overall, there are 14 dealers (26.42%) that represent 80.43% of all the requests. Below is a Pareto distribution that shows the results by dealer:

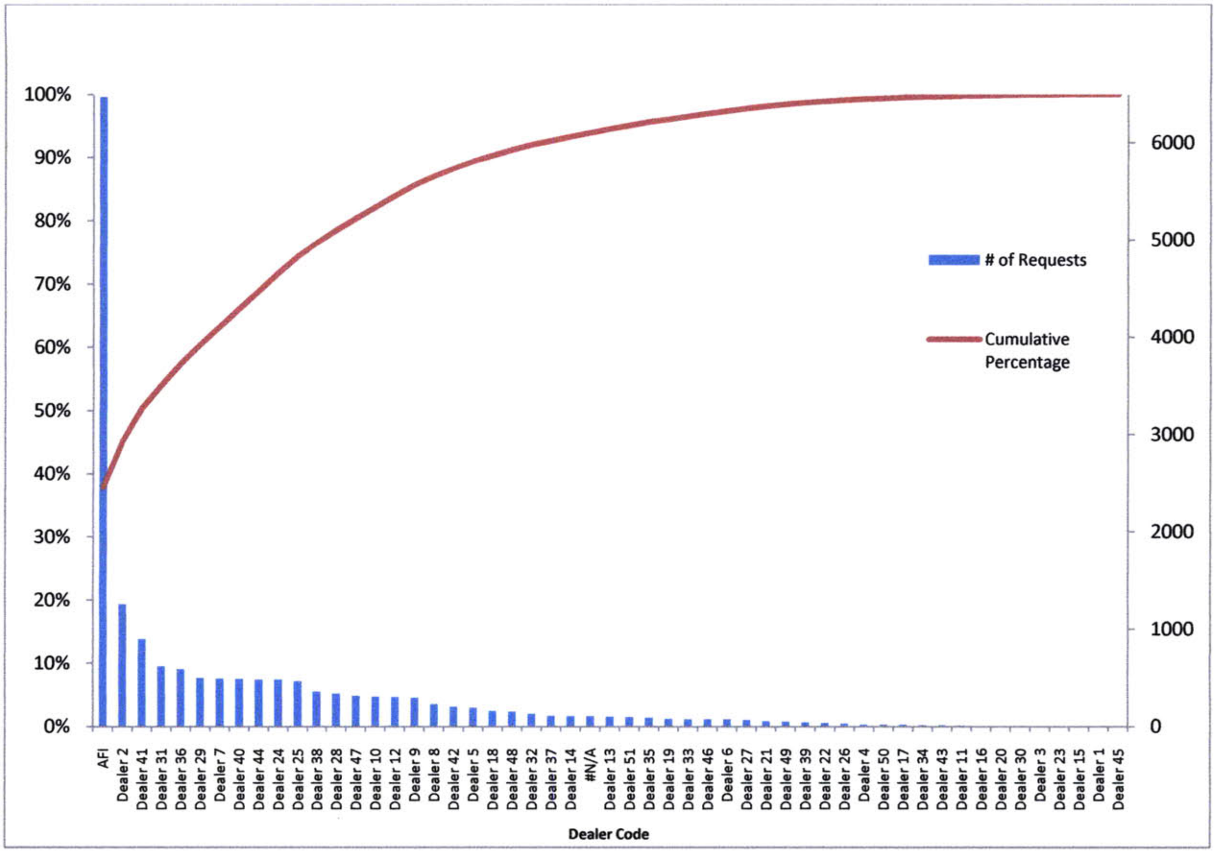


Figure 19: Pareto Distribution of Change Requests per Dealer

The previous results were discussed with engineering and product management and initially they were doubtful about the high number of requests from AFI. It was suggested that the bulk of these requests was probably done in the early months of the software implementation since at that moment the dealers, going through the learning curve were not fully trained in the software and were calling AFI to place the change requests in the SCT database on their behalf. Taking this into account, a detailed analysis of the data was performed and it was observed that it was in fact in the last 12 months of data that the largest amount of change requests were assigned to AFI. For this period there was a total of total of 3,467 requests compared to 3,015 for the first 21 months of the database. This means that the tendency of AFI to create change requests has increased rather than decreased. The reason for these results might be also a lack of training or willingness from the dealers to change and use the SCT to perform the product configuration and configuration changes rather than going through AFI directly. The problem is that company resources are being tied up in creating the vehicle configurations (which should be created by the dealers using SCT) putting even more pressure on the product management department which is already busy trying to analyze the incoming and pending change requests.

When the number of quotes was analyzed for each dealer (refer to Figure 20: Pareto Distribution of Quotes per Dealer for the Analysis Period), it was observed that AFI is also the organization that generated the highest number quotes during the three-year period of the database data with 23.26% of all quotes. The difference between AFI and the second highest dealer, Dealer 36 and the third ranked Dealer 41, is significant since they had only 6.37% of all quotes. Overall, 19 dealers of the 53 in the system (35.58%) generated 80.81% of all the quotes.

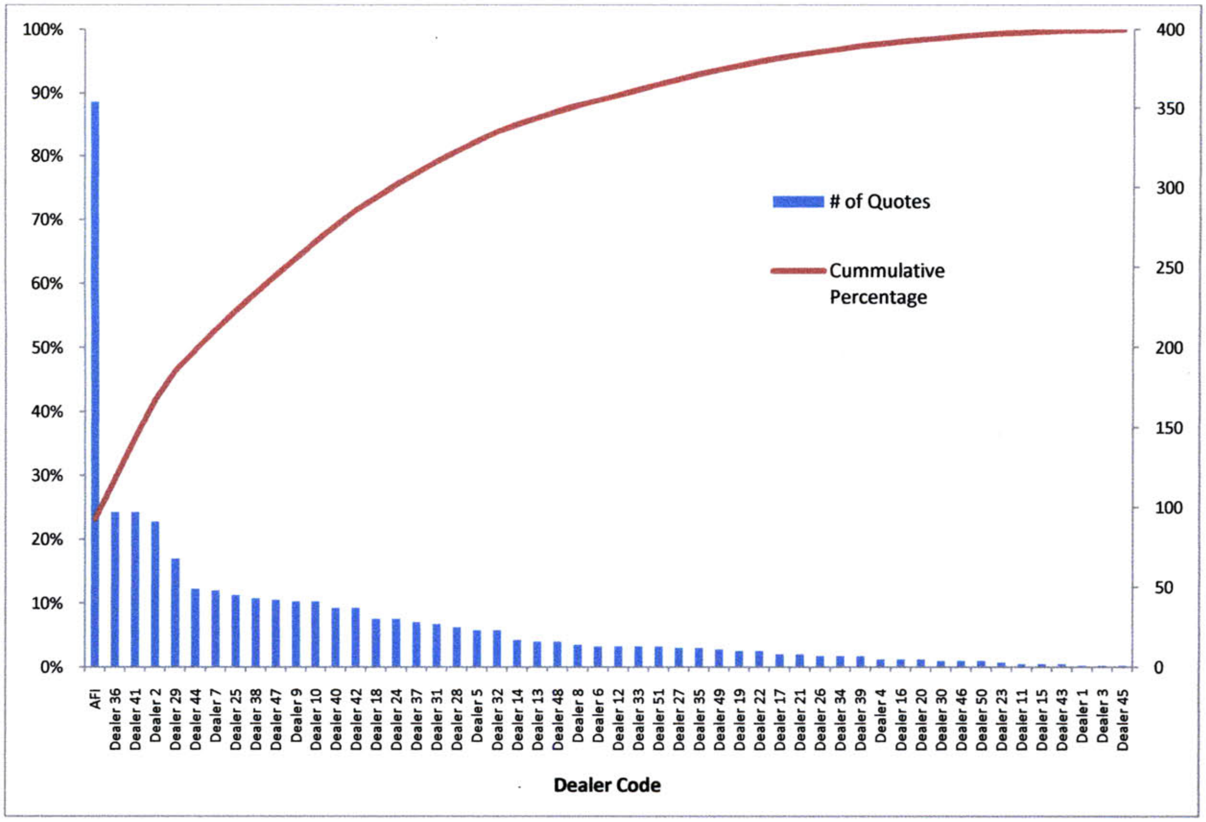


Figure 20: Pareto Distribution of Quotes per Dealer for the Analysis Period

The table below shows the analysis performed to observe the number of requests per quote for the most active dealers (the ones that represent 80% of the quotes).

Table 16: Requests per Quote for dealers with the Highest Number of Quotes[12]

Dealer Code	Requests per Quote	# of Quotes
AFI	**18.30**	**354**
Dealer 36	**6.06**	**97**
Dealer 41	**9.26**	**97**
Dealer 2	**13.82**	**91**
Dealer 29	**7.31**	**68**
Dealer 44	**9.84**	**49**
Dealer 7	**10.21**	**48**
Dealer 25	**10.36**	**45**
Dealer 38	**8.37**	**43**
Dealer 47	**7.50**	**42**
Dealer 9	**7.20**	**41**
Dealer 10	**7.46**	**41**
Dealer 40	**13.16**	**37**
Dealer 42	**5.54**	**37**
Dealer 18	**5.37**	**30**
Dealer 24	**16.03**	**30**
Dealer 37	**3.96**	**28**
Dealer 31	**22.89**	**27**
Dealer 28	**13.56**	**25**
Dealer 8	**16.57**	**14**
Dealer 12	**23.38**	**13**
Dealer 46	**18.75**	**4**

It can be observed that the 7 dealers with the highest number of requests per quote also generated a high number of quotes. However, three dealers (Dealer 8, Dealer 12 and Dealer 46) that generated just a few quotes have also a high number of requests per quote. Dealer 12 generated only 13 quotes but has the highest number of requests per quote with 23.38 and Dealer 46 has only 4 quotes but has a total of 18.75 requests per

[12] The shaded rows highlight the dealers with the highest number of requests per quote.

quote. This might make the company rethink its dealer support strategy. It may be possible to implement support levels for dealers based on the number of quotes (potential business) that they tend to generate. It is important to support more closely dealers that are constantly generating quotes and have a high quote volume.

Finally, the following figure shows the change request approval percentage for the dealers with the highest number of quotes. It can be observed that for certain dealers there is a tendency to approve a high number of requests. In addition, only Dealer 40 and Dealer 31 have a relatively high percentage of instances in which existing or similar requests tend to be used. It may be useful to perform further research on these dealers to better understand what caused the generation of new options in the system when similar options already existed. In addition, there is a need to establish a more focused dealer training and support strategy. This result is somewhat unexpected as we did not apriori expect the large variation and influence that individual dealers would have on the customization process.

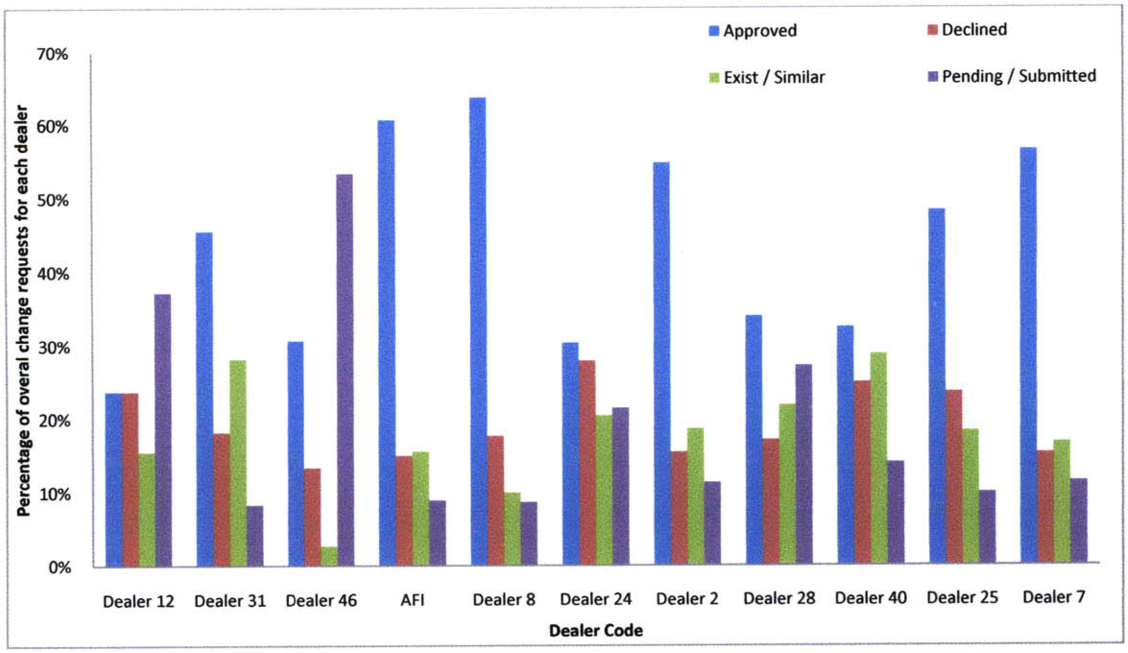


Figure 21: Request Status for Dealers with the highest number of Requests per Quote

V.1.6 Order Success

The SCT database contains information regarding the quotes that were accepted by the customers and became firm orders. There are three possible states that an order can have:

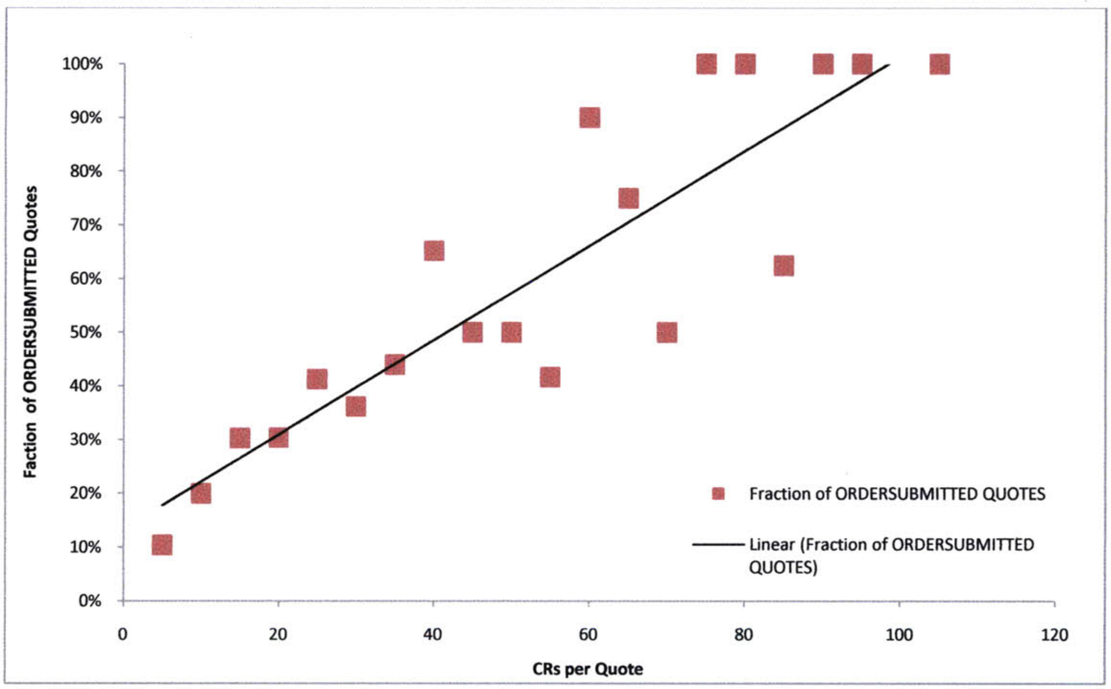
- DRAFT: When the order is being created.

- BIDREVIEW: After the quote is sent to the customer for review the quote status is changed to BIDREVIEW. At this point no decision has been made on the quote.

- ORDERSUBMITTED: The quotes that are placed as firm orders.

One problem that was found with the data in the Order Status table is that there is no status for LOST orders in the ORDER_STATUS field of the database. This makes it impossible to differentiate if an order is still in review (BIDREVIEW) or if it has been lost to a competitor or if a potential customer retreated altogether. It is recommended that a change in the system is made in order to start tracking lost orders and the root cause of the lost order. This is valuable competitive information that can be used in the future to improve the bidding process.

For each one of the bin categories of the histogram presented in Figure 14 the average fraction of quotes that was ORDERSUBMITTED was calculated. It was observed that there was a positive correlation between the number of change requests per quote and the quotes that became firm orders. The results are shown in the following figure:



r = 0.89

Figure 22: Fraction of ORDERSUBMITTED QUOTES vs CR's per Quote

The results presented in the previous figure are a very important result. This supports the view that specialty vehicles are indeed a made-to-order business and that in order to be successful one has to work very closely with a potential customer which means to understand and include customization requests in the bidding process. Since the quotes with a higher number of change requests tend to become orders with a higher probability the company is motivated to try to submit and satisfy any new request from the customer. This result shows that the industry in which AFI sells is definitely a build to order industry with high levels of product customization. If the company does not understand the real cost of a change, however, then there is the potential for losing money in transactions with higher numbers of change requests. The previous results were discussed with the engineering manager and he indicated that the company may be winning quotes with high number of change requests because AFI may be the only company willing to do that.

The overall successful rate of the quotes is 21.7%. That is one out of five quotes turns into an actual order. For the models with the highest number of quotes Pumper 1, the success rate was 24.6 % and for Pumper 2 the success rate was 22.4%. Overall, for the orders that were ORDERSUBMITTED, it was observed that, only 6031 different options were used to configure the vehicles. The histogram of options usage shows that most of the options on the quotes that became actual orders were utilized one or two times (3937 options are used only one time and 971 are used twice). For only 83 options the frequency of use is 10 times or more.

AFI was the "dealer" with the highest success rate in converting quotes into firm orders with a total of 34.5%. This represents $158.5 million in business. The dealer with the second highest quote conversion rate is Dealer 7 with 27.1% and $14.3 million in business volume followed closely by Dealer 44, Dealer 31 and Dealer 9, each with a quote conversion percentage around 25%. The following chart presents the order success rate by dealer. It can be seen that the core business volume of AFI depends on roughly a dozen dealers including the orders generated by the mother firm itself.

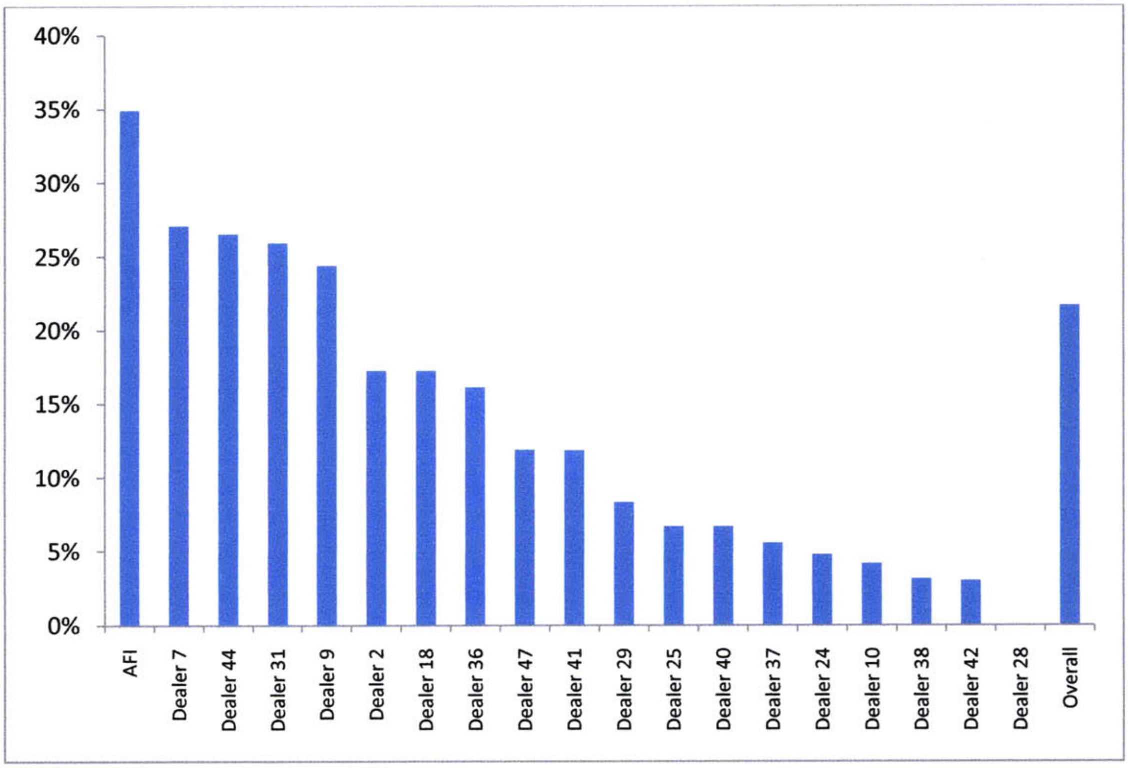


Figure 23: Percentage of Quotes becoming Orders for dealers with the highest number of quotes

It is important to note that there are other factors that contribute to an order success that need to be taken into account. These factors include[13]:

- Previous ownership of an AFI vehicle by the potential customer (customer loyalty)

- Regional presence of the company (dealer network).

[13] From interviews with company officials, (IBIS World, 2010) and (IBIS World, 2009)

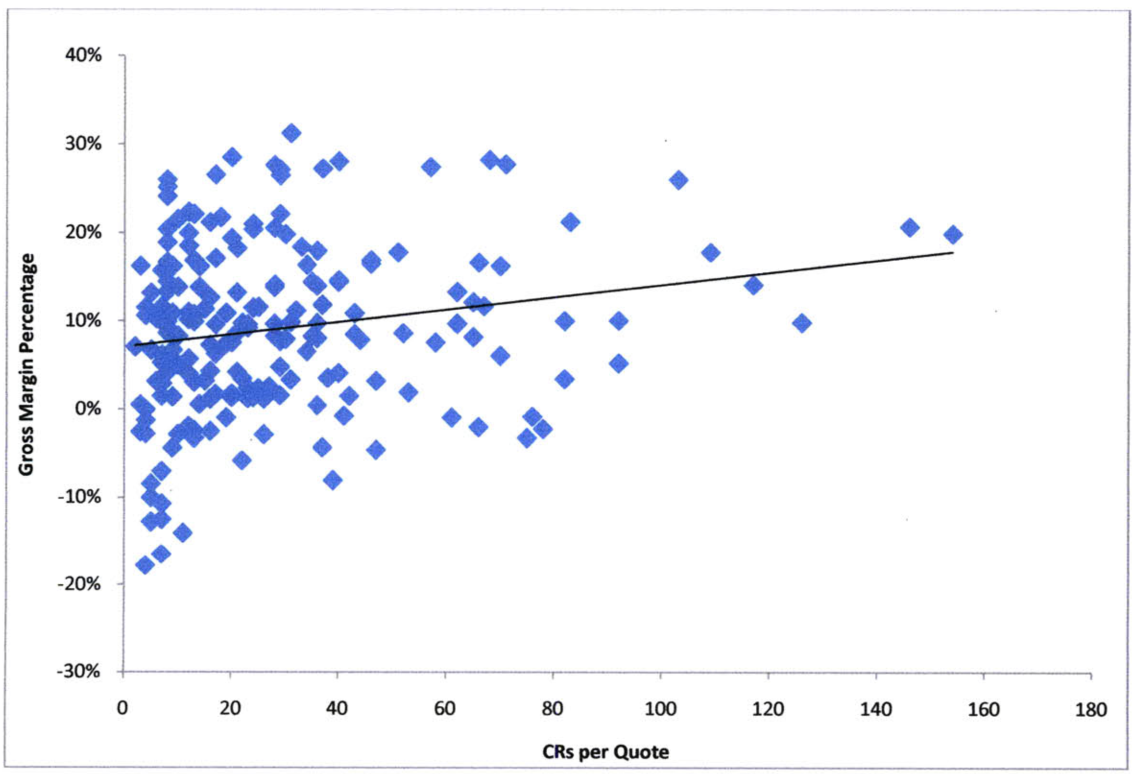
- Relationship of the dealer with the potential customers (trust and affinity).
- Degree to which the vehicle meets the customer specifications (compliance).
- Degree to which the vehicle meets the customer price requirements (price sensitivity).
- Company's and dealer aftermarket support and service availability (service).
- Company's industry perception (reputation).

V.1.7 Gross Margin Analysis

The SCT database does not contain reliable data on the final dealer price, cost and margins for the vehicle. These data resides in the ERP system of the company and it was necessary to create a series of queries using Crystal reports to mine the data out of the database. Unfortunately the data obtained was by vehicle number and not by quote number. To solve this issue the IT department created a table that linked each vehicle number with a quote. Finally, using Microsoft Access a query was designed to join the financial data with the change request and option data.

The data obtained from the ERP system did not contain information for all the ORDERSUBMITTED quotes in the SCT database. Of the 330 firm quotes in the system it was possible to obtain the financial data for only 196. However, this still made it possible to perform additional analysis.

The number of change requests per quote was plotted against the average gross margins of the vehicles (average gross margin is used since for the quotes that were for multiple vehicles an average of the margins of the vehicles was used). It was observed that there is almost no correlation between the two variables ($r = -0.005$ / $p=0.948$, notice; however that it is small but slightly negative). In addition, the result shows that there is a large variance in the margin of the vehicles (refer to Figure 24). This means that the number of change requests in a quote does not have a significant effect on the gross margin of a vehicle, but it does have a significant effect on the likelihood of an order being placed for that vehicle in the first place. It seems that there are other variables in the value stream of building a vehicle that are causing the negative margins on some trucks. This could also be a reflection of out-of-control internal operating processes including high material costs and stockouts, labor inefficiencies and high overhead costs. The following figure shows the relationship between change requests per quote and the average gross margin.



R = 0.195 / P-Value = 0.006

Figure 24: Change Requests per Quote vs Average Gross Margin (for ORDERSUBMITTED QUOTES)

An interesting observation that reinforces the hypothesis of low margins created by out of control internal processes, is the fact that under closer examination it was observed that the margins could vary widely for similar model vehicles, even for vehicles within a multi- unit quote. The following figure shows a histogram of the gross margins for the 196 instances were data was available:

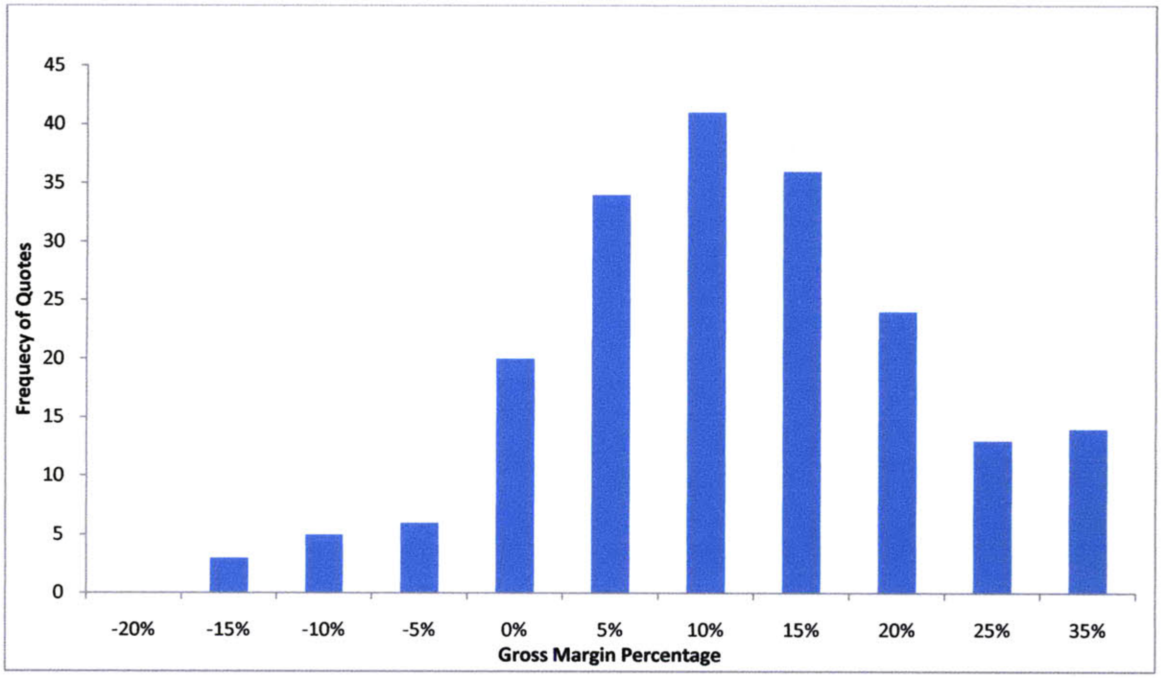


Figure 25: Histogram of Gross Margins for ORDERSUBMITTED QUOTES

It can be observed that of the 196 orders a total of 68 (37%) had a gross margin of less than 5% and 34 orders (17.3%) had a zero or negative margin. The average gross margin across all vehicles was 8.81%. According to the US Treasury website[14], the risk free rate for the period of the study (2/2006 to 12/2008) was on average 3.66%, (average Treasury

[14]Taken from http://www.ustreas.gov/offices/domestic-finance/debt-management/interest-rate/yield.shtml

bill rate) with a standard deviation of 1.6%. Any vehicle produced by the company should at least have a margin higher than the risk free rate. To achieve this, the company should bring operations under control and understand the true cost implications of implementing each option or set of options.

The vehicles that consistently have negative margins are presented in the figure below. The pumpers are the vehicles with the biggest issues since they also represent the higher volume trucks. For Pumper 2 and Pumper 4 in 70% of the orders the resulting gross margins were less than 5% and for Pumper 1 50% of the orders resulted in gross margins of less than 5%. Fortunately, the current operational improvement efforts have focused on the pumper lines. Further analysis could be performed in future research to observe if the margins have improved due to the process improvements.

Table 17: Low gross margins models

Model Code	Total Orders	Orders with GM < 5%	% with GM < 5%	Orders with GM > 5%	% with GM >5%
AERIAL 4	2	0	0%		0%
AERIAL 6	8	0	0%	8	100%
AERIAL 2	2	1	**50%**	1	50%
AERIAL 5	7	0	0%	7	100%
AERIAL 8	4	0	0%	4	100%
AERIAL 3	3	1	33%	2	67%
AERIAL 9	2	0	0%	2	100%
AERIAL 12	1	1	**100%**	0	0%
AERIAL 1	4	1	25%	3	75%
ARFF 1	4	1	25%	3	75%
ARFF 3	1	0	0%	1	100%
ARFF 2	1	0	0%	1	100%
ARFF 8	2	0	0%	2	100%
Pumper 3	21	15	**71%**	6	29%
Pumper 2	56	9	16%	49	88%
Pumper 4	10	7	**70%**	4	40%
Pumper 1	65	32	**49%**	33	51%
	193	**68**	**35%**	**126**	**65%**

Additional analysis related to the margins of the orders and the related options will be presented in section V.2.3 Model Specific Analysis. Beyond what was discussed so far, the pricing of vehicle in Table 17 should also be closely examined. It may be the case that the vehicle base price should be adjusted and that the customer should be encouraged or discouraged from adding certain options depending on their marginal price contribution.

V.2 Network Analysis

This section presents the results of the network analysis that was performed utilizing the data obtained from the SCT database. The analysis was done with the assistance of Dr. Gergana Bounova. Initially the main goal of the analysis was to perform a change propagation analysis to understand the way changes caused by new options propagated through the fire fighting apparatus and to calculate the change propagation index for each one of the decomposed elements (Giffin, Change Propagation in Large Technical Systems, 2007). During the data validation and analysis process it was observed that such analysis was not possible due to the following factors:

- As discussed in Chapter IV the data contained in the dataset is mostly configuration data for quotes created over a three-year period. It does not include any change request or configuration changes that were made after an order was placed (during the actual engineering stage of the option). This makes it difficult to truly track any related engineering changes and to develop a full propagation analysis.

- While performing the initial network analysis, it was observed that due to the proliferation of options, which was discussed in section V.1.2, the obtained network of options is highly disconnected (very low density).

V.2.1 Options Linked by Quotes (Option to Option Network)

The initial analysis that was attempted was to look at the network of options and the related network of product decomposed categories (since every option is tied to a category through the serial number). The criterion utilized was that two options and thus the related categories were linked if they were tied to a quote by an ADD, REMOVE or CHANGE operation within the database.

It was observed that there were 27,170 lines in the dataset that correspond to the total number of change requests (CRs) in the system. There are 10,159 options that are linked to any of the 1522 quotes. In addition, there are 215 options that do not share any quotes with any other option (are used in only one quote).

The network analysis returned a network with a density of 0.327 which is relatively low. There are 9944 options that participate in at least dyads and that are connected by 161,726 edges, which indicates a very large network but with loosely connected nodes. The following figure shows the degree distribution behavior of the network:

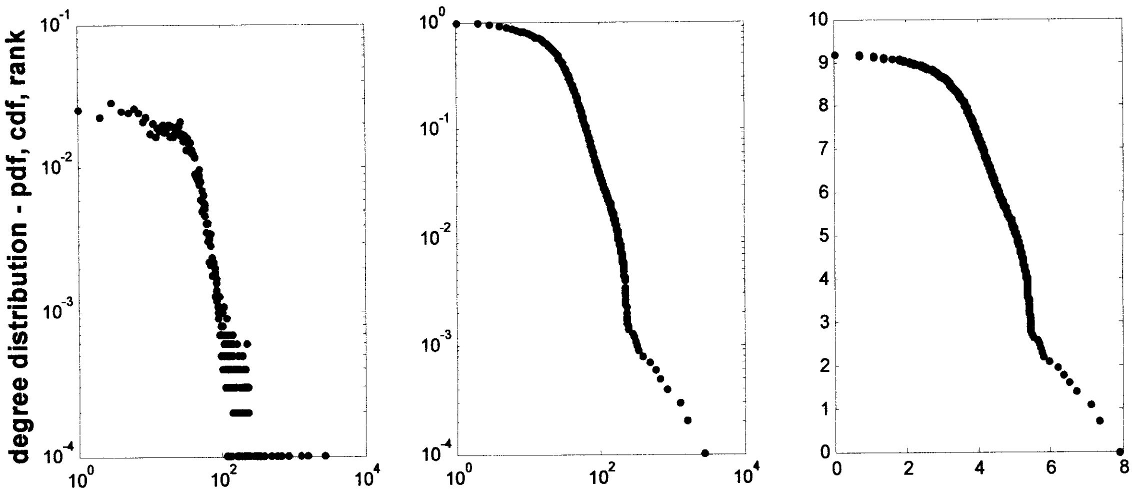


Figure 26: Degree Distribution for Option to Option Network: PDF,CDF, Rank

It can be observed from the PDF graph that there is a steep drop in the number of connections. This indicates that the number of options that are highly connected drops very quickly before 100 connections. However, it can be observed that there is a "fat tail" of various high degree nodes. Please refer to Appendix 2: for the list of high degree nodes. This indicates that there are relatively few options that are highly used and connected to each other and that many options are standalone.

The Option to Option network can be observed in the next figure:

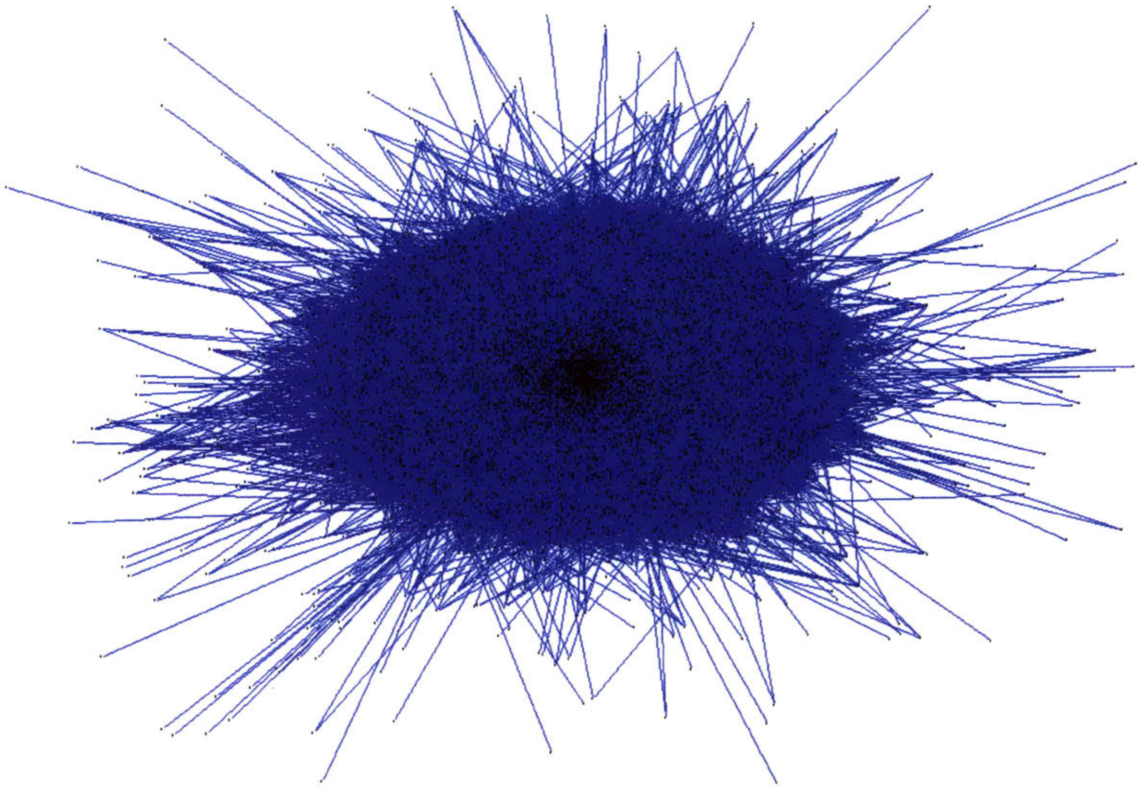


Figure 27: Option to Option Network

This representation shows that it is difficult to extract option packages or discern any patterns by considering all of the vehicles offered by AFI at once.

V.2.2 Categories Linked by Quotes (Category Network)

The next step in the analysis was to observe if it was possible to obtain better relationships by performing the network analysis at the vehicle category level. It was described previously that within the SCT, the fire trucks are decomposed in 155 areas (sub-categories). Each of the options is linked to an area through its unique ID. The criteria used for creating the category network was the following: two categories are related if they were listed under the same quote.

The result of the analysis was a disconnected network with isolated nodes and clusters. There are a total of 511 connections (edges) and 36 categories (nodes) are isolated (please refer to Appendix 3: for the list of isolated notes). The rest are smaller clusters with the largest component having 19 nodes. The following figure presents the category network (does not include the isolated nodes):

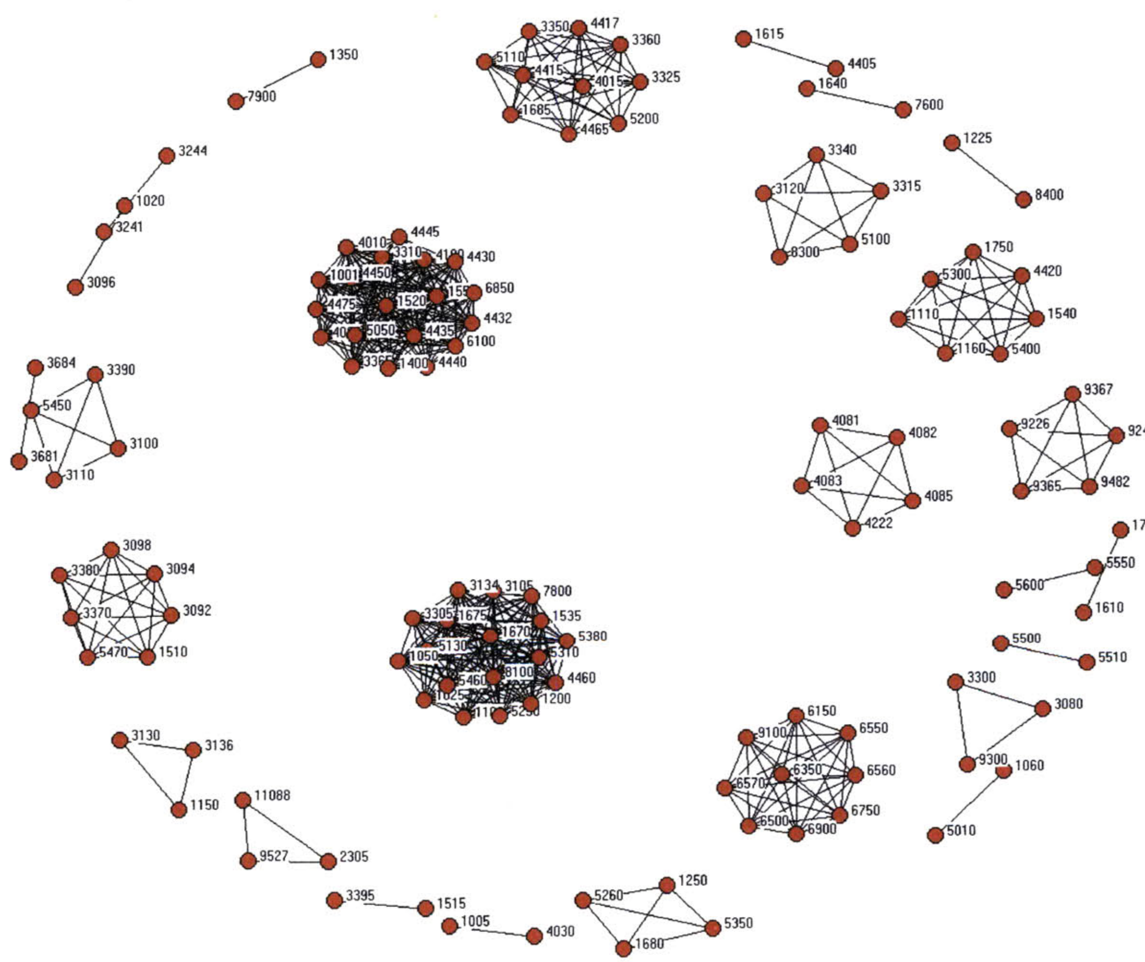


Figure 28: Category Network (isolated nodes not plotted)

The clusters presented in the previous network give an indication of the vehicle categories that may be related. This means that options tend to be selected from the related category areas (when an option is selected that affects a specific category there is a tendency to select another option from one of the related category). This is an important result since the company may want to create bundles of options based on the observed category clusters.

It is important to note that since the data obtained is only related to the initial vehicle configuration, and did not include any engineering changes once the order was placed, it is not possible to perform a change propagation analysis based on the results.

V.2.3 Model Specific Analysis

As it was described in Chapter III, all fire fighting apparatus models have similar components (water pumps, water tanks, lights, aluminum body, among others). However, each model / vehicle type contains different options to satisfy the requirements of their specific application in different emergency situations. Analysis was performed and it was observed that most of the options are not shared among the different vehicle types (Pumpers, Aerials, ARFF, Rescue, Other). The following figure shows the number of options that are shared among the different vehicle types. The horizontal axis indicates the number of different vehicle types that share the option.

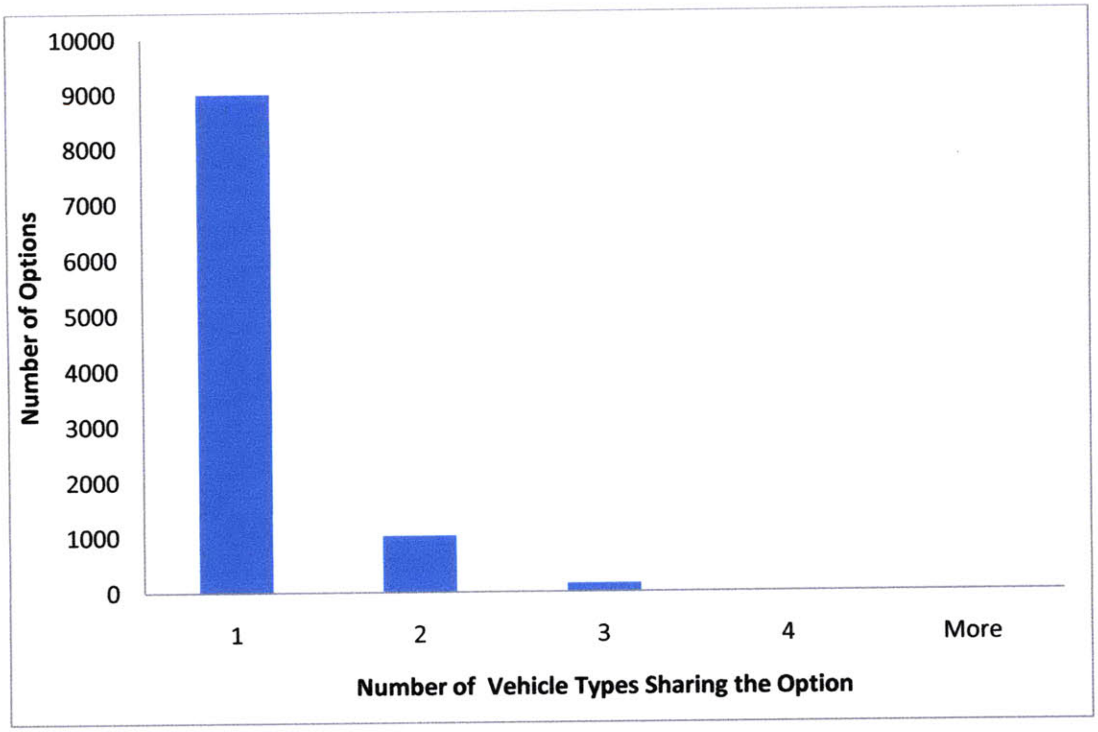


Figure 29: Number of Options Shared Among Vehicle Types

The result indicates that most of the options are used within only one vehicle type and are not shared. This reinforces that a value-stream oriented strategy within each vehicle type makes sense. There are a total of 8,994 options (88.5%) that are particular to only one vehicle type, followed by 1,017 (10.0%) that are shared by two, 147 (1.4%) by three and only one option (5500-0017) is common to four vehicle types.

At the vehicle model level the result is similar. A total of 7,421 options (73%) are used only by one vehicle model out of 36 models while 1,475 options (14.5%) are shared among two models. The following table summarizes the result:

Table 18: Number of Options Shares among Vehicle Models

Number of Models Sharing the Option	Option Qty	% of Total Options
1	7421	73.0%
2	1475	14.5%
3	626	6.2%
4	343	3.4%
5	139	1.4%
6	84	0.8%
7	38	0.4%
8	14	0.1%
9	9	0.1%
10	6	0.1%
11	0	0.0%
12	2	0.0%
13	0	0.0%
14	1	0.0%
15	0	0.0%
More than 15	1	0.0%

Based on the previous result in which it was observed that options tended not to be shared among vehicle models, it was decided, as a next step, to perform an analysis at the model level to observe if there were significant relationships. At the vehicle model level the goal was to study the option utilization among vehicles and to observe if there were clusters of options that could be defined as option packages.

The analysis was focused on the Pumper and Aerial vehicle types since they have the highest volumes and number of quotes. The summary of the number of options, quotes and orders per vehicle model[15] can be observed in Appendix 4:

[15] Total yearly volumes not presented since it was deemed confidential by AFI management.

The Pumper trucks have the highest annual volume of all the vehicles built by AFI. It was observed that a total of 6,541 options (out of the total of 10,159 active) are used across all Pumper models. However, only 187 options are shared across all the models (please refer to Appendix 5: for a list of the options). The options to options network for all the pumpers contains 6523 connected nodes (18 isolated nodes), and 458,264 directed links. The network is similar to the one obtained for the whole dataset.

The categories network for the pumper vehicles contains a total of 153 nodes connected through 5,913 links. It is a connected network with a density of 0.51. There are a total of 78 categories that are common to all the pumper models (please refer to Appendix 6: for the list of common categories). The following figure shows the categories network for all the Pumper vehicle types.

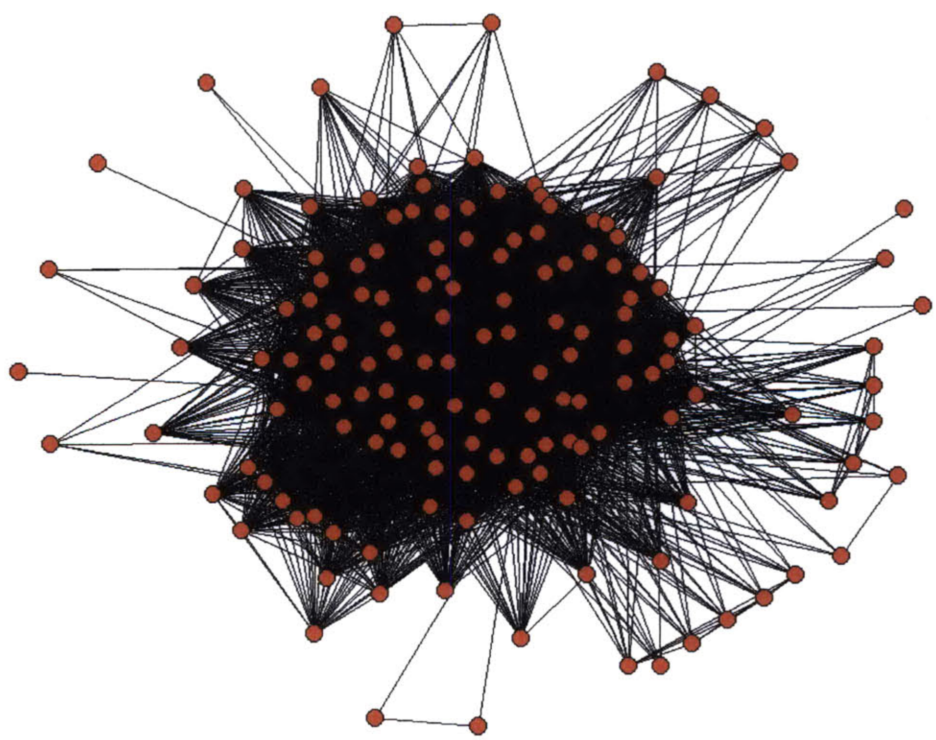


Figure 30: Categories Network for all Pumpers

The option to option network analysis for the Pumper 2 indicates that the 3706 options are linked by 225,948 edges. As with the network for all vehicles which was discussed previously, the density is very low 0.033.

The categories network for Pumper 2, contained 127 categories (nodes), liked through 4932 edges. The network is presented in the next figure:

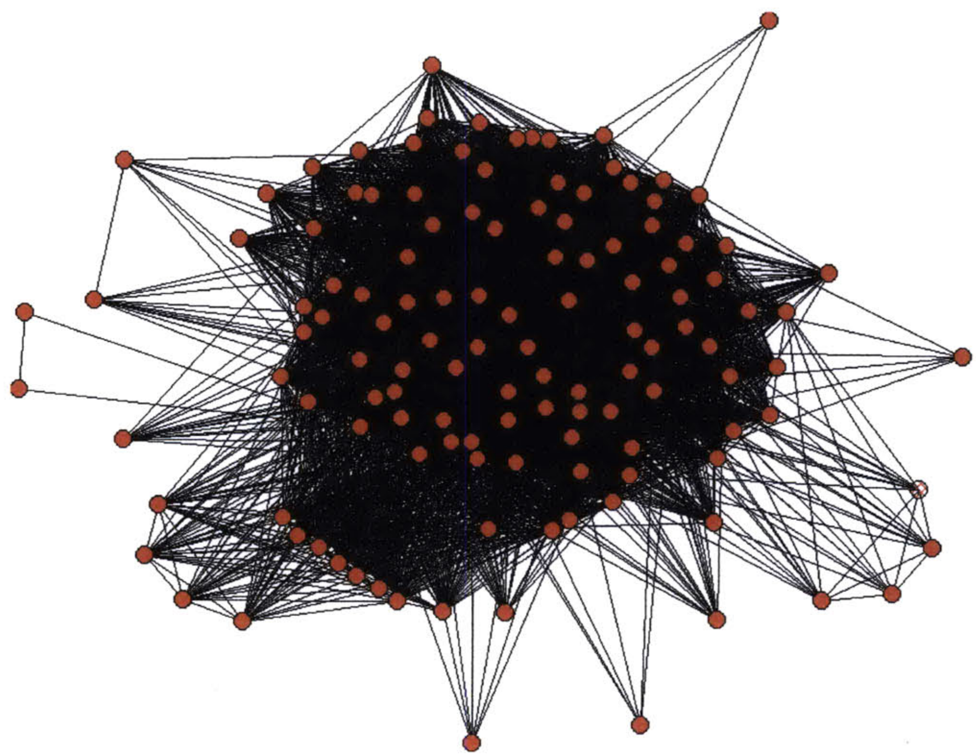


Figure 31: Categories Network for Pumper 2

It can be observed that this network is very similar to the one obtained for all the Pumper type vehicles. This can be explained by the fact that the Pumper 2 represents a significant portion of all the pumper vehicles (volume and quotes).

The results obtained for the Aerial type vehicles are similar to the ones obtained for all the vehicles and the Pumper types. It is important to note that there were more models of Aerials than any other vehicle type (15 Aerial models, 6 Pumper models, 8 ARFF models and 4 Rescue models) but the volumes were lower than for the Pumpers.

There are 3119 options used to configure the Aerial vehicles. When graphed, they are linked by 128,126 directed edges. There are no options that are common among all the 15 aerial models. However, it was observed that among the Aerial models with the highest volume and number of quotes (Aerial 1, Aerial 5, Aerial 6, Aerial 8) there were 7 common options. Please refer to Appendix 7: for a list of the options. These common options could either be included as a standard feature in the baseline vehicle or could be offered as a standard priced option. The Aerial's category network contains 118 categories, with 4,084 edges and a density of 0.592. Among the Aerial vehicles there are 38 common categories (presented in Appendix 8:).

Additional analysis at the vehicle model level was performed for the 10 highest volume models across all the vehicle types (4 Pumpers, 4 Aerials, 1 ARFF and 1 Rescue). It was observed that, the graphs tended to have similar structures. The following table represents a summary of the networks and option graphs for each one of the selected models:

Table 19: Option to Option and Categories Networks for Selected Models

		Option to Option Network			Categories Network		
Model	# Quotes	# Options	# Links	Density	# Categories	# Links	Density
Pumper 2	366	3703	225948	0.033	127	4932	0.616
Pumper 1	391	2263	51348	0.02	123	2907	0.387
Pumper 4	105	1474	99190	0.091	112	3442	0.554
Pumper 3	230	1521	85740	0.074	96	2633	0.577
AERIAL 6	39	700	22865	0.093	81	1571	0.485
AERIAL 5	46	802	29273	0.0911	93	1988	0.465
AERIAL 8	38	555	10690	0.07	86	1384	0.389
AERIAL 1	31	240	5040	0.176	56	555	0.36
ARFF 1	53	469	5398	0.049	66	771	0.359
Rescue 1	25	416	11229	0.13	57	1021	0.64

It can be observed that in general the graphs tend to be disconnected with low densities. Only for the categories network graphs for Rescue 1, Pumper 2 and Pumper 3 and Pumper 4, the graphs were connected.

For simplicity, large models are not shown due to the lack of clarity in the graph and the difficulty of performing detailed analysis. Interesting and clear results were obtained for Aerial 1 which is a high volume vehicle with 31 quotes and 10 orders. The following figure presents the option to option network for the vehicle:

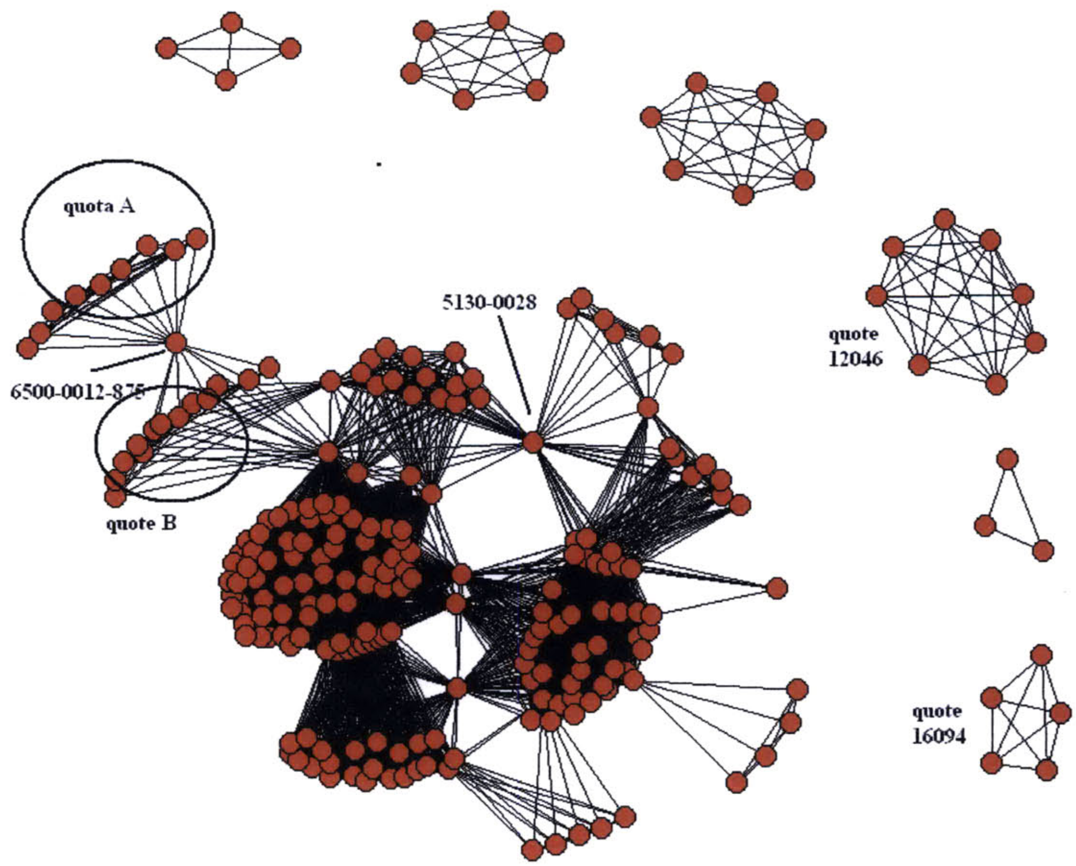


Figure 32: Option to Option Network for Aerial 1

It can be observed from the diagram that the network has a multi-partite structure organized by quote. Options are grouped in clusters, some of them disconnected, by quote. There are clear "connector" options that go across quotes (i.e. 6500-0012-875 or 5130-0028). These "connector" options are often different from the most used, highest degree options. Additional research can be performed to find the list of "connector" options for each model type and correlate the gross margin / cost of these options with the most commonly selected options. Unfortunately, cost and margin data by option was not available to perform the analysis. As discussed previously, the only financial related information that was accessible for the study were the gross margins for a sub-set of vehicles and quotes.

While performing the analysis it was observed that, from an option commonality perspective, the ARFFs are the least similar vehicles when compared to the other truck types. In general, a higher percentage of options and categories are common among vehicles within the same vehicle type. In addition, the vehicles with higher volumes tend to have a larger number of options defined. The pumpers that have the highest volumes have also the highest number of options available. The following table presents a matrix with the number of options that are common among the 10 selected models:

Table 20: Option Commonality (number of common options) among Selected Models

# common options	Pumper 2	Pumper 1	Pumper 4	Pumper 3	AERIAL 6	AERIAL 5	AERIAL 8	AERIAL 1	ARFF 1	Rescue 1
Pumper 2	**3706**	908 24.50%	700 18.89%	615 16.59%	230 6.21%	188 5.07%	160 4.32%	85 2.29%	28 0.76%	76 2.05%
Pumper 1		**2275**	486 21.36%	462 20.31%	155 6.81%	138 6.07%	101 4.44%	70 3.08%	12 0.53%	58 2.55%
Pumper 4			**1475**	294 19.93%	153 10.37%	109 7.39%	73 4.95%	54 3.66%	4 0.27%	32 2.17%
Pumper 3				**1527**	93 6.09%	63 4.13%	55 3.60%	39 2.55%	17 1.11%	64 4.19%
AERIAL 6					**700**	90 12.86%	68 9.71%	82 11.71%	8 1.14%	8 1.14%
AERIAL 5						**802**	88 10.97%	46 5.74%	5 0.62%	16 2.00%
AERIAL 8							**555**	27 4.86%	2 0.36%	9 1.62%
AERIAL 1								**240**	2 0.83%	9 3.75%
ARFF 1									**473**	5 1.06%
Rescue 1										**417**

V.2.4 Options and Gross Margins

In the previous section, it was observed that most of the options tend to be shared among vehicles of the same type (Pumpers, Aerials) rather than across all types of vehicles. The pumper type models share a total of 187 options while for the Aerial models only 7 options are common among all. Additional analysis was performed utilizing the gross margin data to observe correlations and patterns at the option level. It is important to clarify that the average gross margin data utilized for the analysis refers to the quote. Each quote is configured using a series of options, thus it was assumed that the options were related to the gross margin of the quote. The average gross margin for an option was calculated by taking into account the gross margins of the quotes where it was used. It will be interesting to perform additional analysis with actual option cost and gross margin data which at this moment is not available.

For the Pumper trucks, the 187 shared options were analyzed and it was observed that most of the options are related to quotes with a positive average gross margin (144 or 77%). In fact, a total of 100 options (53.47%) are related to quotes with an average gross margin higher than 5%. The following figure presents a histogram of the options and average gross margins.

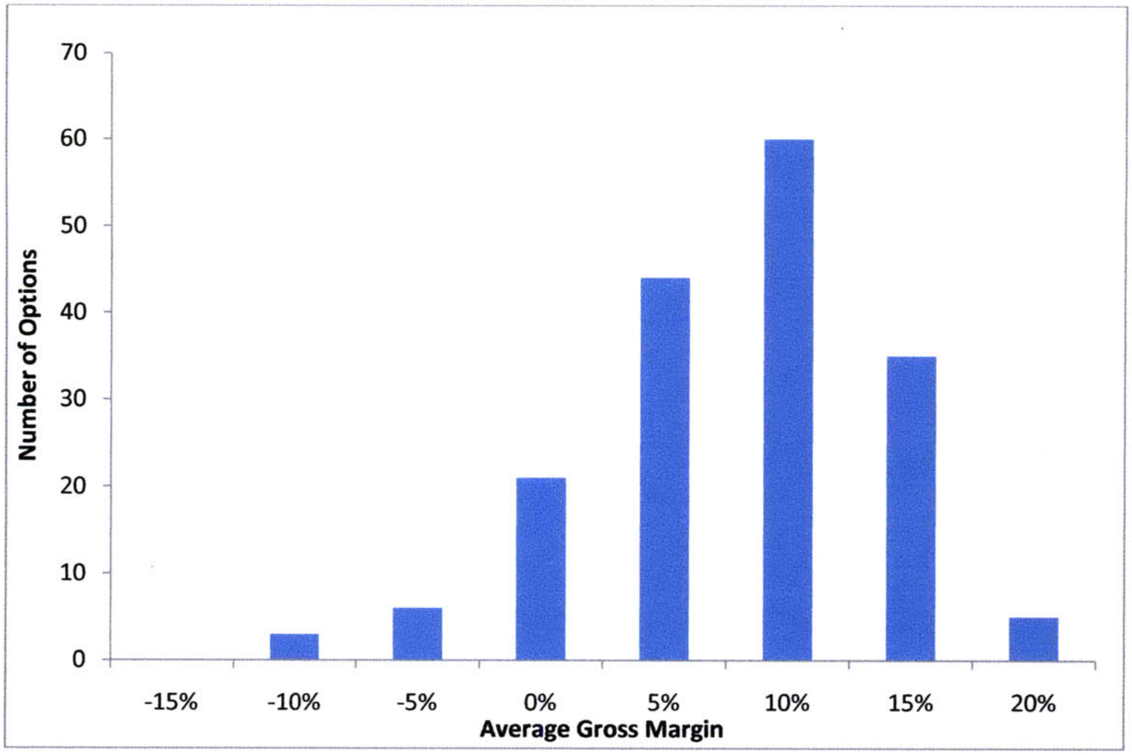
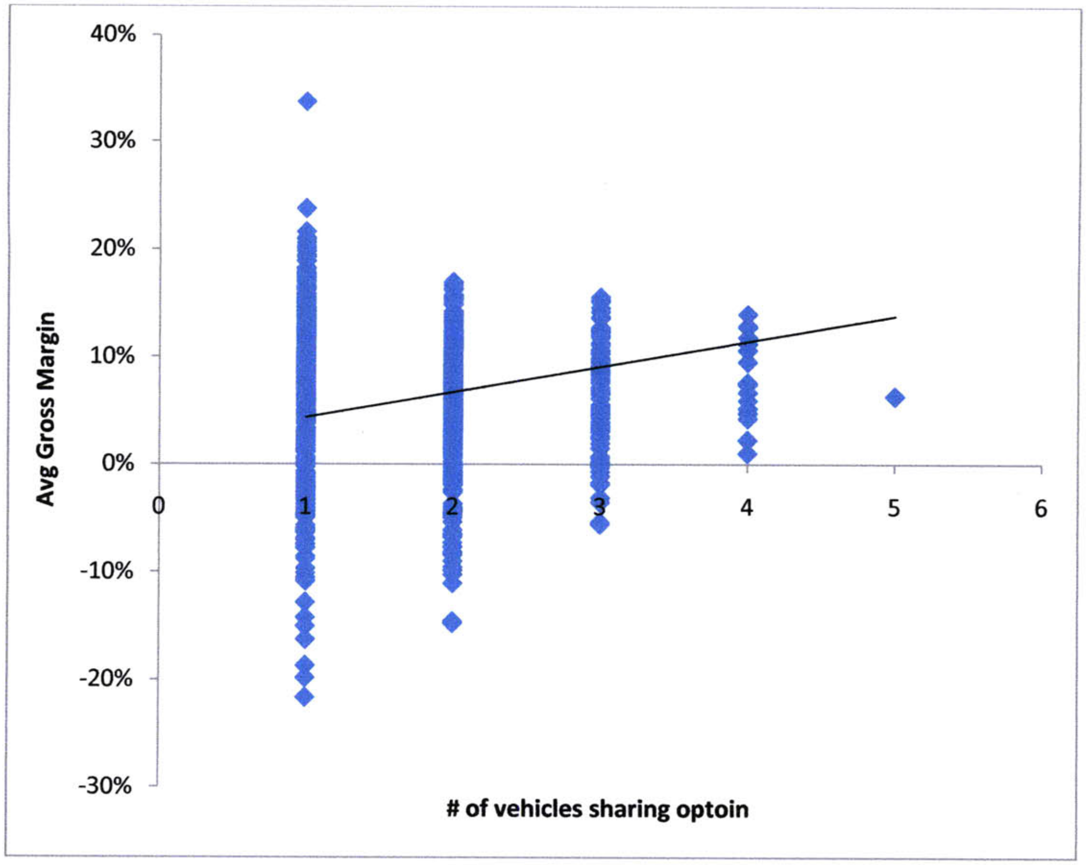


Figure 33: Histogram of Shared Pumper Options and Average Gross Margin

The analysis was also extended to include all the options that were used to configure all the Pumper vehicles for which quotes with average gross margin data is available. A total of 2931 options were analyzed and it was observed that when the number of models that share the options was plotted against the average gross margin of the option. The following figure shows the results:



R = 0.1338

Figure 34: Option Average Gross Margin vs # of Vehicles Sharing each Option

The chart clearly indicates that there is a positive correlation between the number of vehicles sharing an option and the calculated option average gross margin. In particular it appears that the more vehicles share in an option the less likely it is that selecting such an option at the time of quote will lead to a negative gross margin. This means in other words that as the option is shared by more Pumper vehicles, the expectation is that the gross margins will be positive. The company should design options that are common across vehicles in order to obtain positive gross margins. This is a logical result since by making options common across models complexity is reduced.

The high volume Aerial selected for the network analysis had only seven options in common. Of the seven options six had gross margins higher than 5% and for one, no data was available. The next table presents the results:

Table 21: Common Options and Gross Margins for selected Aerial Models

Option	Average Gross Margin
5 130-0028	#N/A
5130-0024-392	7.42%
5130-0024-203	6.34%
5130-0022-821	7.88%
4417-0058-573	7.34%
1550-0059-000-71	13.18%
3310-0037	17.23%

Finally, it was observed that there was a correlation between the volume of an option (times it was used in quotes) and the average gross margin. The correlation is positive and very small (R=0.033), however it is not significant as to establish a clear relationship. The following figure presents the obtained result:

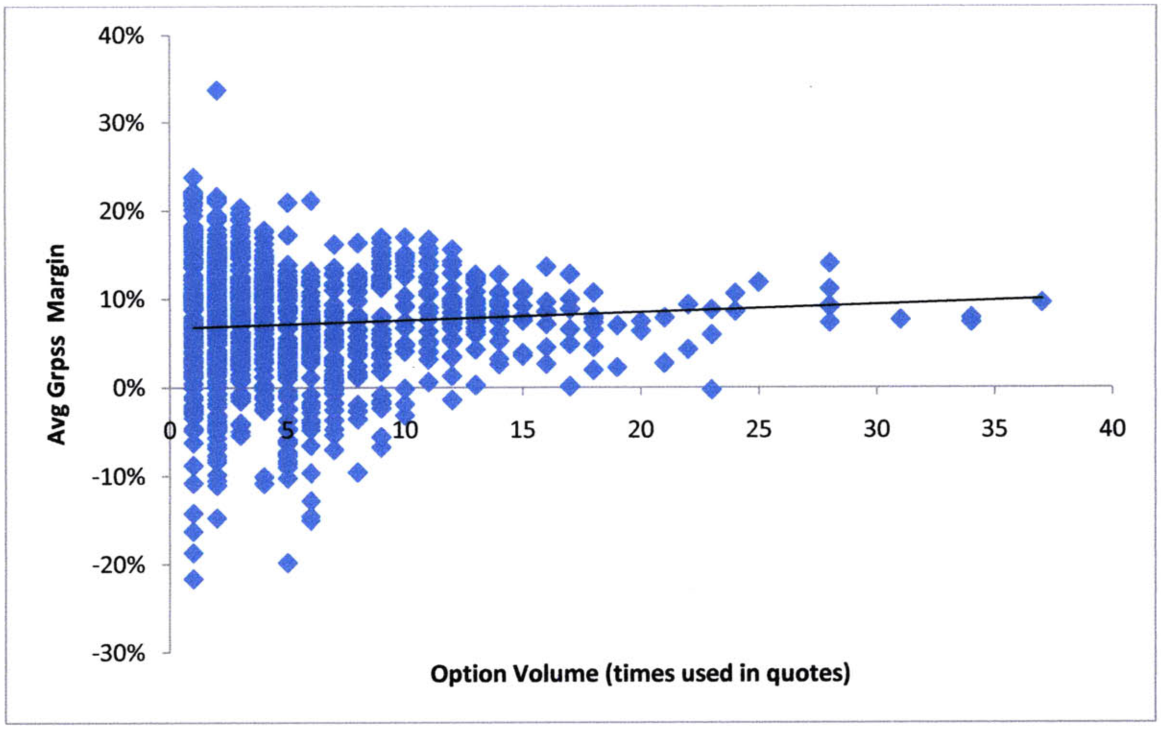


Figure 35: Option Volume vs Average Gross Margin

All the results presented indicate that the company should implement a strategy of creating options that can be made available among different vehicle models, at least within the same vehicle type. This is more difficult to achieve across truck types, so the first step should be to identify the options that can be standardized and offered across similar models.

Chapter VI. Conclusions and Recommendations

The previous chapters presented a detailed analysis of the dataset obtained from the SCT as well as a description of the configurator software. In addition, a brief description of the emergency vehicle market was presented with an introduction to AFI, Inc. This chapter presents a summary of the conclusions, a series of recommendations for process and software improvement as well as suggestions for future research.

VI.1 Summary and Conclusions

The emergency vehicle market is a very competitive market in which customers demand high levels of customization in their vehicles. Market growth is mostly tied to city and municipality budgets and to the expansion into new residential and commercial developments. AFI, Inc is one of the leading companies in the industry with an installed base of more than 20,000 vehicles and production volumes of 650 to 800 vehicles per year.

An emergency specialty vehicle is a complex integrated system that should be capable to perform multiple mission critical functions. AFI Inc, serves the market with a wide range of emergency vehicles including Pumpers, Aerials, Command Centers, Rescues, ARFF and Wildlands.

AFI is currently in the process of improving its operations through the implementation of several initiatives. One of such initiatives is the analysis and rationalization of its product offerings. In addition, the company wants to leverage the product configurator software

(SCT) that was developed in house as a strategic tool to increase gross margins and support the improvement activities.

The SCT is a workflow based configuration tool that guides its users (dealers and internal AFI departments) through the configuration and quoting process of the emergency vehicles that AFI offers. The SCT contains multiple modules that create valid vehicles based on rule sets. In addition, the software keeps track of any customization (CR) that the customer requests and once the vehicle configuration is finalized, it generates the final quote. Once the quote is approved by the customer, the SCT transfers the configuration data to the engineering database. This database generates a BOM for the vehicle and becomes the system of record of its configuration. Unfortunately, within the engineering database, any reference to a specific quote is lost and also any additional changes in the configuration of the vehicle are only updated at the BOM level but not retroactively in the SCT. Thus, the final configuration of the vehicle "as built" may not match the configuration of the vehicle "as quoted". This issue may affect clients that are interested in coming back to AFI to purchase vehicles with the same configuration as vehicles that were purchase in the past and that are currently in service. Under this scenario AFI will have to spend additional time researching if the configuration within SCT matches the configuration of the previously delivered vehicle.

The dataset obtained from the SCT encompasses three years of option, change requests and quotes data. The dataset contained 1,522 quotes, 17,109 CRs, 17,007 options and 27,170 change actions. Unfortunately, the SCT, does not keep records of final gross margin data by vehicle. These data had to be obtained from the company's ERP system but it was incomplete.

Through the analysis of the data it was observed that there is a tendency to approve change requests for customization. In general, 50% of the change requests (CRs) were approved with only 7.9% found as similar to an already defined option. When this result was discussed with the company's management they indicated that possibly it will be necessary to better train the dealers and sales team to better understand the customer requirements, work with them and potentially guide them to an already existing option in the system that would satisfy them. It is interesting to note that of all the 17,007 options defined in the system (an option is created when a CR is approved) only 10,159 are actually used in quotes. This also supports the conclusion that there may be a tendency to approve change requests and it clearly indicates option proliferation issues. In addition, these "dormant options" create significant complexity and confusion in the system. It is recommended that the system be cleaned to eliminate all the "dormant options".

Another important result obtained from the data was the fact that most of the quotes in the system saw only a few change requests but there are some that are heavily modified. On average, each quote contains 11.24 change requests.

A key result obtained from the analysis is a positive correlation between the number of CRs per quote and the fraction of quotes that became actual orders. This indicates that a quoted with a higher number of change requests has a higher chance of becoming an order. This result confirms the BTO business model of AFI. In addition, it elevates the sense of urgency for the company to understand the cost of customization and to define a relevant option strategy.

The gross margin analysis indicated that there is a large margin variance even among trucks that have the same configuration (from multi-vehicle orders). This may be an indication to the highly variable and out of control internal processes. It should be noted, however, that the majority of data analyzed in this research stems from the period before major improvements were made to AFI's manufacturing processes.

Based on the data characteristics and the fact that the only data available is initial configuration data for the quote, it was not possible to perform a change propagation analysis similar to the one presented by Giffin (2007). However, a network analysis was performed in order to determine if it was possible to identify different patterns and behaviors regarding options utilization. Two types of networks were studied, an options to options (network of options linked thorough the quotes) and a categories network (network of categories linked through quotes).

The option to option network analysis for all the models (aggregated data) revealed a loosely connected network with a very low density (0.327). The degree distribution charts for the network indicated a steep drop in the number of connections, with the number of options that are highly connected dropping to zero before 100 connections. These results made it impossible to define useful clusters of options that could be defined as options sets across all vehicle types. The categories network for the aggregated data resulted in a similar network. However, for this network, it was possible to extract relevant clusters of categories that indicate that options tend to be selected from the connected categories. The company may define option packages for options that belong to the connected categories within each vehicle type. The earlier analysis suggested that the categories that tended to see most options are the electrical systems and customization of vehicle body panels, compartments and doors. Option packages may therefore be created in the categories. It is important to note that additional analysis performed at the model level also resulted in networks with similar characteristics.

Additional analysis at the model level permitted the identification of common options for Aerial and Pumpers which are the higher volume models. It was observed that among the Pumper models, there are 187 options that are common to all the models. For the Aerials, only 7 options are common among the models. For the pumpers it was observed that out of the 187 options, 100 (53.47%) were used in quotes with an average gross margin higher than 5%, 74 (39.57%) were used in quotes with less than 5% average gross margins and the rest could not be determined due to lack of data. It was also observed that there is a positive correlation (0.1338) between the number of pumper models sharing the quotes and the average gross margin percentage (the more pumpers sharing options one could expect higher average gross margins). For the aerials, the results were limited to observe that for 6 out of the 7 common options for all the vehicle models, the average gross margins for the quotes where they were used were all above 5%.

The results described in this section and throughout the thesis report were taken in to account to define the set of recommendations for the company. These recommendations are describe in the next section.

VI.2 Recommendations

This section presents a series of recommendations for the company and for future research. Each recommendation is presented in a separate sub-section for better understanding of the issues that it addresses.

VI.2.1 Elimination of Inactive Options

The analysis of the dataset from the SCT indicated that there is a large number of options that are not utilized in the system. It was observed that out of the total 17,007 options in the database only 10,159 had any activity during the three-year period since the SCT had been active. These "dead" or inactive options are adding complexity and potentially creating confusion when trying to configure a vehicle. In fact, previous research has established that in instances of significant product or options proliferation serious bottlenecks are created in the product acquisition and fulfillment process which in turn, increases the risk of errors and delays in the production system due to variability and complexity of product information (Forza & Salvador, 2002).

AFI should resolve this issue by focusing the necessary resources in analyzing each of the 6,848 options that have not been used and define if they are true inactive options or if they should be kept for future product configurations. This analysis could be expanded to the set of active options (the ones that have been used) in order to observe the possibility of eliminating low volume options and / or consolidating them into option offerings that are relevant to the customers. Since the Pumper and Aerial vehicles are the ones with the highest volumes, it is recommended to start the analysis with the inactive options that are related to these truck types.

VI.2.2 Creation of Base Configurations for Trucks

During the research process, it was observed that only one vehicle has a base configuration in the SCT. For the rest of the trucks, the company has not defined the base vehicle, and the dealers or SCT users are free to configure the vehicle with any set of available options (that meets the set of rules defined in the system). Not having a base vehicle for most of the models in the SCT creates confusion for customers and dealers during the vehicle configuration process and may be a factor in the proliferation of options. In addition, one can argue that it may even have a negative effect in the company's order success.

It is recommended that the company create a base vehicle configuration for all the models that are configured using the SCT. To perform the analysis and definition of the base configurations it will be necessary to obtain a dataset from SCT that includes the final configuration of all the vehicles that have been quoted. Data should be analyzed, cleaned and validated. After the data cleanup process is finished, it will be necessary to observe if there are trends or common configurations used in order to define the final base configurations. Below is the proposed project flow diagram for the analysis.

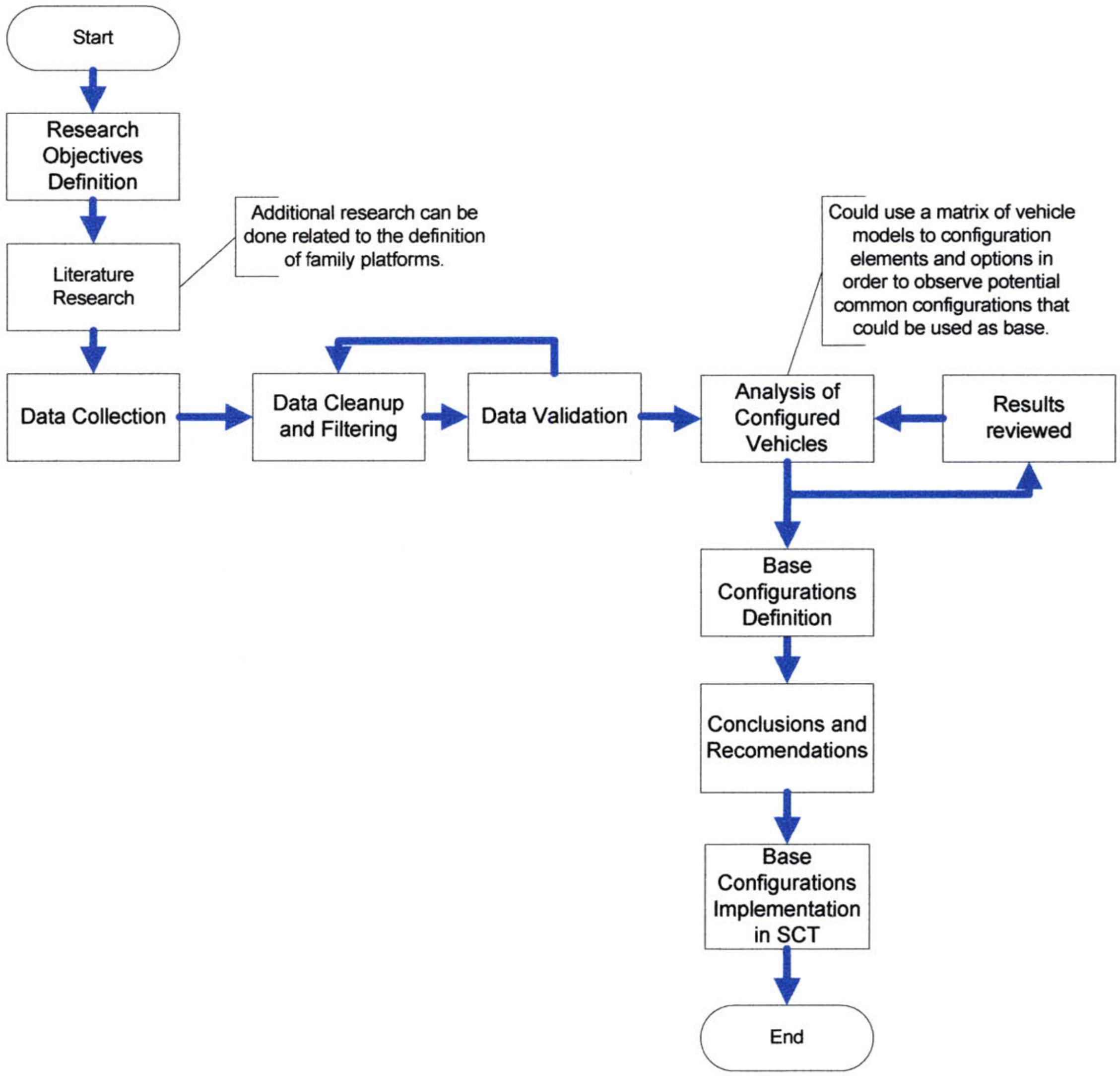


Figure 36: Base Model Analysis Roadmap (Proposed)

VI.2.3 Functional Based Option Offering

During the analysis of the dataset, it was observed that there was a tendency to approve change requests rather than to look for similar options. After discussing the results with AFI management, it was concluded that there is a need for better training of the dealer network and even internal sales representatives in techniques that can be used to understand and capture customer needs. Rather than simply taking the request for customization from the customer and creating a new CR it is necessary to perform additional research on the specific requirements for the emergency vehicle. In addition, a better understanding of the currently available options (form, function, and required performance) will permit the company to better service the true customer needs. The ultimate goal is to move from simply taking customer change request to be viewed as the experts in emergency vehicles and be the ones "suggesting" the configuration of the emergency vehicle based on the identified needs.

In addition to a training program for dealers and internal sales representatives, the logic of the SCT could be enhanced to suggest options based on a set of requirements that are input into the system. This could be implemented through a structured "interview like" application that guides the customer through a series of questions that capture all the form and functional requirements for the vehicle. At the end, based on the answers from the customer, the system will generate a suggested configuration for the vehicle. The proposed workflow for the SCT that includes all the recommendations can be observed in Appendix 9:

VI.2.4 Track Quote Rejection Reasons

It was described in section III.4.3 that the SCT does not have the necessary functionality to track the reasons for a quote rejection or even flag a quote as rejected. Once a quote is submitted to the customer its status becomes Bid Review. If the quote is accepted and the customer places the order, the status changes to Order Submitted, however, if it is rejected, nothing is changed in the system and the status of the quote remains Bid Review indefinitely. This situation prevents AFI, Inc from conducting analysis on the reasons for quote rejection and also statistical analysis on rejected quotes. This is particularly important since 4 out of 5 quotes never turn into actual orders and if information could be harnessed from the 80% of quotes that don't turn into orders AFI could presumably significantly increase its competitiveness by either adjusting the baseline vehicle, the options offered, the pricing and even making adjustments to its dealer network. If this is done well it should be possible to significantly increase the current market share.

It is recommended that the company adds an additional status to the quote ORDER_STATUS field in the Quote Status Table. This new status will identify a quote as rejected. For the quotes that are rejected, a new field to track the cause of the rejection could be added to the table. This field could be freehand text or could be a series of rejection codes that the company defines or both.

In addition, a field with the date when the status of the quote changes can be utilized to track the time a quote has been in a specific status. Below is the proposed Quote Status database table:

Table 22: Proposed Quote Status Table Fields

Database Field	Description
QUOTE_NO	Unique identification number of the quote
UNIT_QTY	Number of vehicles ordered in the quote
AFI_DEALER_PRICE	Price to the dealer
TOTAL_CUST_COST	Price to the end customer
CONCESSION_AMOUNT	Amount of the discount to the customer
ORDER_STATUS	Indicates the status of the quote (DRAFT, BIDREVIEW, ORDERSUBMITTED, REJECTED)
STATUS_DATE	Date when the status of the quote last changed
REJECTION_CAUSE	Description of the rejection causes

VI.2.5 Improve Order Traceability

It is necessary to improve the software to have traceability of the truck configuration throughout the life cycle of the vehicle from the moment it is configured until it is delivered to the customer. As it was observed previously, once the quote is created and the order is placed by the customer, the SCT interfaces with the engineering database system to generate the engineering BOM. From this point in the process forward any new change to the configuration of the vehicle during engineering development and manufacturing operations is not fed back into the SCT. The changes (ECO/ECR) are kept within the engineering database, if they are design related or the ERP system Baan if they are production related. All traceability is lost since the Baan or the engineering databases do not tie back to the specific quotes.

There are two main issues with this approach, the first one is that there is no system of record to keep track of the ECRs / ECOs during the design and engineering phase and second, there is no traceability to the original quote and configuration of the vehicle which limits the ability to keep track of "as built" configurations.

To resolve these issues, it is recommended to create additional functionality in the SCT to make it the system of record for keeping track of any configuration change. This could be achieved by creating the required tables in SCT and linking them with the appropriate tables in the Engineering Database and Baan. This integration could be achieved by running a batch process in which XML files are transferred between the databases. This will be only one way since the Engineering Database and Baan will be updating the SCT tables. The following chart shows the desired future state of the database utilization during the configuration, manufacturing and engineering process.

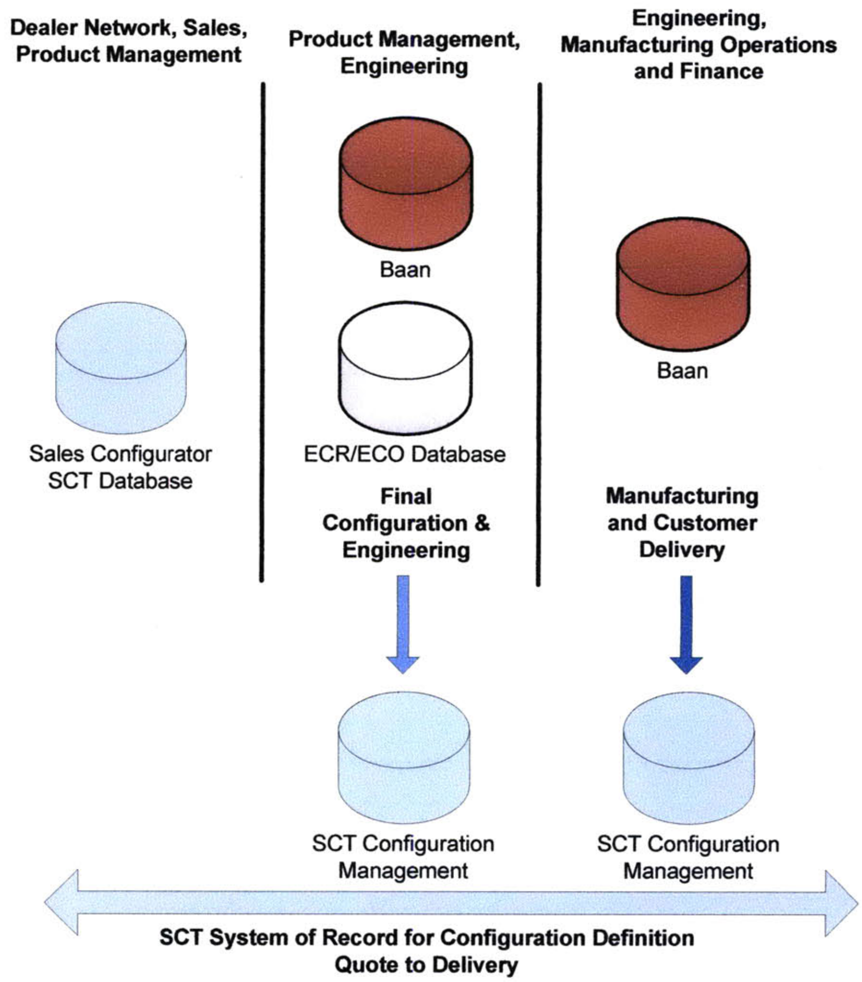


Figure 37: Future State of Database Use during Quote to Delivery Process

The workflow for the product configuration and delivery does not change significantly. The difference is the flow of data from the Engineering database and Baan to SCT, but this process is transparent to the user. Please refer to Appendix 9: for the updated workflow diagram.

VI.2.6 Application of the Options Strategy Model

It was observed in Chapter II that there is a clear gap in the research related to the definition of comprehensive option strategies. A model was suggested to characterize options based on their cost, sales volume and ease of implementation (fabrication). This model was applied to the dataset obtained from AFI in order to validate it and observe the results. Specifically, the analysis was performed to the Pumper vehicle data since it appeared that this type of vehicle had the highest option commonality among the different models and a larger portion of the dataset was related to this type of vehicle. Following are the assumptions used to apply the proposed model:

a. *Implementation*: Since there was no data available related to production requirements per option, it was assumed that a highly common option among vehicle models was easy to implement. An option common to only a few models or limited to only one was considered hard to implement.

b. *Cost*: The system did not have any available data related to the actual cost per option. The only data available was the average gross margin for a sub-set of the options used in the pumpers. It was decided to use these options for the analysis and also to assume that a high gross margin was related to low cost and vice versa.

c. Volume: Volume data was available from the dataset. Option utilization was counted each time the option was used in a quote. For multi vehicle quotes, the option was counted multiple times.

The model, updated to take into account the assumptions described previously, can be observed in the next figure:

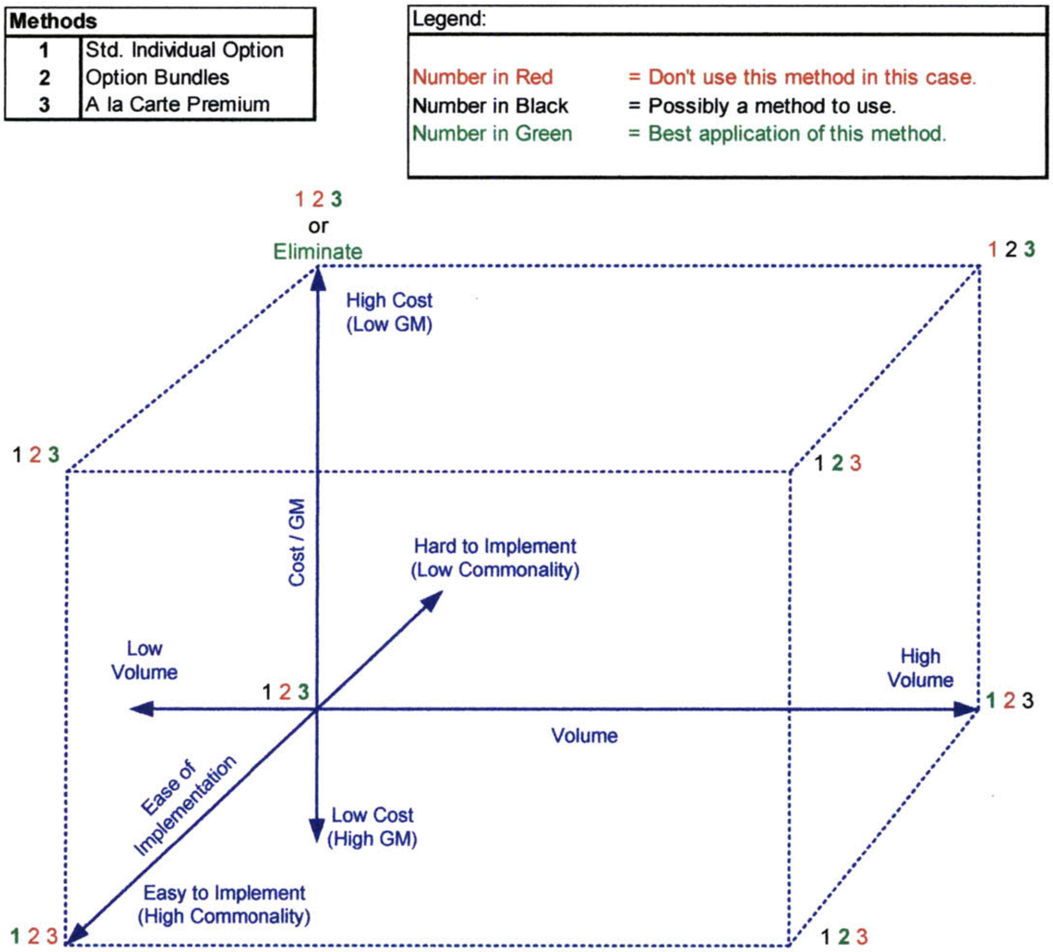


Figure 38: Options Strategy Model and Assumptions

In order to run the model, an Excel spreadsheet was created with the list of all the Pumper related options for which average gross margin data was available (total of 2,931 options). For each one of the options data regarding the commonality (number of Pumpers sharing the option), average gross margin and volume was obtained.

To calculate the values of the axis variables (Cost / Gross Margin, Implementation / Commonality, Volume), an analysis of the option related data was performed using descriptive statistics. The values calculated were the maximum, minimum, median, average, standard deviation and the mode. The maximum and minimum values were utilized as the axis maximum and minimum. The threshold value which is the inflection point where the variable "changes signs" was calculated as follows:

- *Cost / Gross Margin*: For this variable the threshold point was established as 5% which, as described in the previous chapter is the minimum required gross margin for a vehicle. All the values below 5% were considered as low gross margin values (or high cost) and all the values higher than 5% were considered high gross margin (or low cost).
- *Implementation / Commonality*: There are a total of five pumper models in the system (with 4 high volume models). The threshold was established as common to two or more models.
- *Volume*: The threshold for the volume of options was established by using the statistical median of all the values. Any value equal or above the median was considered high volume and the values below the median were considered low volume.

The following table summarizes the threshold and calculated values:

Table 23: Threshold and Values for the Options Strategy Model

Variable	Threshold	Max Value	Min Value	Median	AVG
Commonality	2	5	1	1	1.25
GM	5.0%	33.75%	-21.62%	7.44%	0.05
Volume	2	37	1	2	3.41

Utilizing the spreadsheet built in Ms Excel, each option was characterized based on the established parameters (threshold values) and the result was a suggestion for classifying the option as one of the three types: standard option, bundled option or a la carte premium option (refer to Appendix 10: for the screen shots of the spreadsheet implementation of the model).

A summary of the results of the model are presented in the following table:

Table 24: Options Strategy Model Results Summary Table

Classification	Total # of Options Suggested	# of Options with Margins < 5%	Options with Margins > 5%
Standard Option	592	0	592
Bundled Option	615	185	430
A la Carte Premium	995	325	670
A la Carte / Eliminate	729	729	0
Total Options	2931	1239 510 if the 729 are eliminated	1692

In addition, the distribution of the options that resulted from the application of the model was plotted using Minitab software. This can be observed in Figure 39.

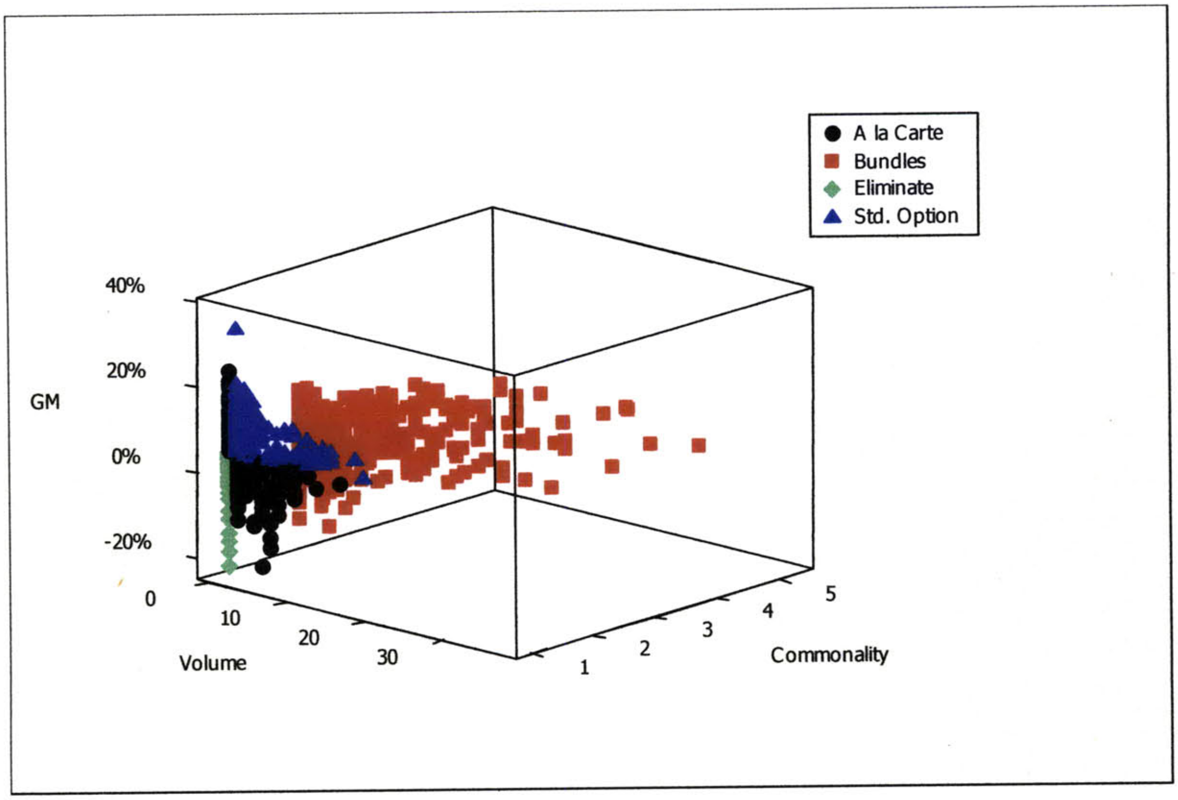


Figure 39: Option Distribution Plot

It can be observed from the results that the model suggested a total of 592 options to be managed as individual standard options and 615 as candidates for bundling. In addition, based on their characterization 995 options are suggested to be managed as premium a la carte options which means that the company could charge higher prices for the implementation of these options. The model also suggests that 729 options be eliminated. These candidates for elimination are options for which the implementation is hard (not shared among models), the cost of implementation is high (gross margins are below the 5% threshold) and the volume is low.

It is interesting to note that after performing the classification, the majority of the options in each classification are related to margins higher than the 5% threshold. In addition, if the 729 options classified as "A la carte / Eliminate" were to be eliminated, the total number of options with low margins (less than 5%) is reduced to 510. The previous results suggest that the model can give useful results to establish a viable options strategy.

Finally, it is important to note that the model suggests a potential option classification. The user of the model should with a more detailed knowledge of the company processes and products be able to make final decisions and form a coherent options strategy.

VI.3 Future Research

In the previous section it was observed that the proposed Options Strategy Model delivered good results. However, it is necessary to perform additional empirical analysis to prove that the model works as required. Specifically, it is necessary to explore the best approach for defining the thresholds for each one of the variables. Also, additional logic and dimensions (more decision variables) could be added to the model in order to account for constraints that may be specific to an organization. Another opportunity for model improvement will be to create mathematical optimization logic to maximize revenue, margins or minimize costs.

Finally, it will be interesting to explore the possibility to implement the model into the SCT, in order to create a dynamic environment in which options could be classified based on the current market conditions and scenarios could be calculated. This will create a more dynamic model that could become a true decision support system for options management. The result will be a dynamic and proactive options strategy that will adapt to changes in the customers' selection patterns and to changes in the internal value chain processes.

Appendix 1: Vehicle Decomposition in SCT Child Subcategories

Parent Category	Child Subcategory	Description
500	501	Base Model
1000	1001	TESTING COMPLIANCE STANDARD
1000	1005	CHASSIS MODEL
1000	1020	CHASSIS PREP
1000	1025	AXLE OPTIONS
1000	1050	WHEEL OPTIONS
1000	1060	TIRE OPTIONS
1000	1070	SUSPENSIONS
1000	1100	BRAKE SYSTEMS
1000	1110	AIR SYSTEM OPTIONS
1000	1125	SECONDARY BRAKING
1000	1150	BUMPER TRAYS
1000	1155	WINCHES
1000	1160	BUMPERS
1000	1200	ENGINES & TRANSMISSIONS
1000	1225	EXHAUST OPTIONS
1000	1250	FRAME ASSEMBLY
1000	1350	FUEL SYSTEMS
1000	1400	BATTERIES
1000	1680	CHASSIS OPTIONS
1000	1700	ALTERNATOR
1000	1800	COOLING PACKAGE
1500	1510	SEATS
1500	1515	HVAC
1500	1520	CAB MODEL
1500	1535	MEDICAL CABINETS
1500	1540	MAP BOXES
1500	1550	CAB DOOR OPTIONS
1500	1610	CAB BADGE PACKAGE
1500	1615	CAB ROOF TYPE
1500	1620	GRILLE
1500	1640	CAB STEP OPTIONS
1500	1670	MIRRORS
1500	1675	MISC EXTERIOR CAB OPTIONS
1500	1685	MISC INTERIOR CAB OPTIONS
1500	1750	CAB ELECTRICAL OPTIONS
3000	3080	BODY MODEL

3000	3090	BODY SPEC
3000	3092	RESCUE BODY LOWER
3000	3094	RESCUE BODY UPPER
3000	3096	RESCUE BODY REAR
3000	3097	RESCUE BODY LIGHT NON WALKIN
3000	3098	RESCUE BODY WALKIN
3000	3100	BODY COMPT LEFT SIDE
3000	3105	BODY COMPT FRONT
3000	3110	BODY COMPT REAR
3000	3120	BODY COMPT RIGHT SIDE
3000	3130	PUMP MODULE
3000	3134	PUMP PANELS
3000	3136	PUMP MODULE OPTIONS
3000	3200	RESCUE BODY INTERIOR
3000	3300	DOORS
3000	3305	COVERS
3000	3310	AERIAL BODY OPTIONS
3000	3315	CASCADE SYSTEM/FILL STATIONS
3000	3320	SCBA BOTTLE STORAGE
3000	3325	HRT SYSTEMS
3000	3330	HANDRAILS / STEPS
3000	3340	MISC BODY OPTIONS
3000	3350	REELS AIR AND HYDRAULIC
3000	3360	RESCUE BODY OPTIONS
3000	3365	LADDER STORAGE / RACKS
3000	3370	SHELVES
3000	3380	TRAYS / TOOLBOARDS
3000	3390	COMPARTMENT DIVIDERS
3000	3395	COMPARTMENTATION INSTRUCTIONS
3000	4010	WATER TANK
3000	4020	WATER TANK OPTIONS
3000	4100	FOAM TANK
3000	4110	FOAM TANK OPTIONS
3000	4450	TANK PLUMBING
3000	4460	MISC PUMP PANEL OPTIONS
4000	4005	PUMPS
4000	4015	PUMP OPTIONS
4000	4030	TURRET
4000	4405	BOOSTER REEL
4000	4410	PLUMBING KITS
4000	4415	DISCHARGES AND PRECONNECTS
4000	4417	DISCHARGE OPTIONS

4000	4420	DRY CHEMICAL /HALOTRON SYSTEMS
4000	4430	FOAM SYSTEMS
4000	4432	FOAM SYSTEM OPTIONS
4000	4435	GAUGES
4000	4440	INTAKES
4000	4445	INTAKE OPTIONS
4000	4455	WINTERIZATION
4000	4465	PRESSURE GOVERNORS
4000	4475	PUMP CERTIFICATION
3986	4628	RESCUE BODY LOWER
5000	5050	MISC ELECTRICAL 110V
5000	5100	CONTROLS / SWITCHES
5000	5110	MISC ELECTRICAL
5000	5130	ELECTRIC CORD REELS
5000	5150	DOT LIGHTING
5000	5200	BREAKER BOXES
5000	5250	GENERATOR
5000	5255	GENERATOR TEST
5000	5260	GENERATOR OPTIONS
5000	5300	LIGHT BARS
5000	5310	DIRECTIONAL LIGHT BARS
5000	5350	CAMERAS / INTERCOM
5000	5380	LIGHTS - COMPARTMENT, STEP & GROUND
5000	5390	LIGHTS - DECK AND SCENE
5000	5400	LIGHTS - NON-WARNING
5000	5450	LIGHTS - QUARTZ
5000	5460	LIGHT TOWERS
5000	5470	RECEPTACLES
5000	5500	SIRENS
5000	5510	SPEAKERS
5000	5550	WARNING LIGHT PACKAGES
5000	5600	WARNING LIGHTS
5000	5900	ARFF RADIO EQUIPMENT
6000	6100	AERIAL MODEL
6000	6150	AERIAL HYDRAULIC SYSTEM OPTIONS
6000	6200	ARFF AERIAL
6000	6300	MONITORS
6000	6350	WATERWAY OPTIONS
6000	6400	BREATHING AIR
6000	6500	AERIAL EQUIPMENT
6000	6550	AERIAL WARNING LIGHTS
6000	6560	AERIAL LIGHTING

6000	6570	MISC AERIAL ELECTRICAL
6000	6600	AERIAL LADDER BRACKETS
6000	6700	BRONTO OPTIONS
6000	6750	SIGN PLATES
6000	6850	AERIAL CONTROLS
6000	6900	AERIAL TESTING
7000	7200	ADAPTERS
7000	7300	REDUCERS
7000	7400	ELBOWS
7000	7500	SCBA BOTTLE BRACKETS
7000	7550	EXTINGUISHERS
7000	7600	HAND TOOLS
7000	7700	HOSE / NOZZLES
7000	7800	GROUND LADDERS
7000	7900	MISC LOOSE EQUIPMENT
7000	7950	LOOSE EQUIPMENT PKGS
8000	8100	EXTERIOR PAINT
8000	8150	INTERIOR PAINT
8000	8200	LETTERING
8000	8300	STRIPING
8000	8400	GRAPHICS
9000	9100	WARRANTY / STANDARD & EXTENDED
9000	9300	SUPPORT, DELIVERY, INSPECTIONS AND MANUALS

Appendix 2: List of High Degree Nodes (number of connections) for the Option to Option Network

a. Nodes with more than 1000 connections:

Option	Degree
1001-0000	2669
1001-0001	1538
1001-0009	1075

b. Nodes with more than 500 connections but less than 1000 connections

Option	Degree
1001-0010	808
1001-0011	639
1001-0012	544

c. Nodes with more than 200 connections but less than 500 connections

Option	Degree
1001-0013	475
1001-0015	378
10012	330
1005-0018	284
1005-0090	273
10075	221
10081	222
10082	214
10083	206
1025-0004	207
1025-0017	206
1050-0007	205
1100-0011	204
1160-0000	203
1160-0010	202
11898	201

d. Nodes with more than 100 connections but less than 200 connections: 246 total

e. Nodes with more than 50 connections but less than 100 connections: 777 total

Appendix 3: List of Isolated Nodes (Categories) of the Category Network

There are 36 isolated categories (not connected to any other categories, through a quote).

Following is the list of these categories:

Parent Category	Child Subcategory	Description
1000	1070	SUSPENSIONS
1000	1125	SECONDARY BRAKING
1000	1150	BUMPER TRAYS
1000	1155	WINCHES
1000	1225	EXHAUST OPTIONS
1000	1400	BATTERIES
1500	1620	GRILLE
1500	1640	CAB STEP OPTIONS
1500	1670	MIRRORS
3000	3090	BODY SPEC
3000	3320	SCBA BOTTLE STORAGE
3000	3330	HANDRAILS / STEPS
3000	4020	WATER TANK OPTIONS
3000	4100	FOAM TANK
3000	4110	FOAM TANK OPTIONS
4000	4410	PLUMBING KITS
4000	4455	WINTERIZATION
5000	5150	DOT LIGHTING
5000	5200	BREAKER BOXES
5000	5255	GENERATOR TEST
5000	5390	LIGHTS - DECK AND SCENE
5000	5900	ARFF RADIO EQUIPMENT
6000	6200	ARFF AERIAL
6000	6300	MONITORS
6000	6400	BREATHING AIR
6000	6600	AERIAL LADDER BRACKETS
6000	6700	BRONTO OPTIONS
7000	7200	ADAPTERS
7000	7300	REDUCERS
7000	7400	ELBOWS
7000	7550	EXTINGUISHERS
7000	7700	HOSE / NOZZLES
7000	7950	LOOSE EQUIPMENT PKGS

8000	8150	INTERIOR PAINT
8000	8200	LETTERING
9000	9100	WARRANTY / STANDARD & EXTENDED
4000	4015	PUMP OPTIONS
4000	4405	BOOSTER REEL
4000	4415	DISCHARGES AND PRECONNECTS
4000	4417	DISCHARGE OPTIONS
4000	4430	FOAM SYSTEMS
4000	4432	FOAM SYSTEM OPTIONS
4000	4435	GAUGES
4000	4440	INTAKES
4000	4445	INTAKE OPTIONS
4000	4465	PRESSURE GOVERNORS
5000	5010	
5000	5100	CONTROLS / SWITCHES
5000	5110	MISC ELECTRICAL
5000	5130	ELECTRIC CORD REELS
5000	5150	DOT LIGHTING
5000	5200	BREAKER BOXES
5000	5250	GENERATOR
5000	5260	GENERATOR OPTIONS
5000	5300	LIGHT BARS
5000	5310	DIRECTIONAL LIGHT BARS
5000	5350	CAMERAS / INTERCOM
5000	5380	LIGHTS - COMPARTMENT, STEP & GROUND
5000	5390	LIGHTS - DECK AND SCENE
5000	5400	LIGHTS - NON-WARNING
5000	5450	LIGHTS - QUARTZ
5000	5460	LIGHT TOWERS
5000	5470	RECEPTACLES
5000	5500	SIRENS
5000	5550	WARNING LIGHT PACKAGES
5000	5600	WARNING LIGHTS
7000	7200	ADAPTERS
7000	7800	GROUND LADDERS
7000	7900	MISC LOOSE EQUIPMENT
8000	8100	EXTERIOR PAINT
8000	8200	LETTERING
8000	8300	STRIPING
9000	9300	SUPPORT, DELIVERY, INSPECTIONS AND MANUALS

Appendix 4: Summary of Quote, Order and Option data per Model

	Vehicle Model	# of Quotes	# of Orders (ORDERSUBMITTED QUOTES)	% of Order Success per Model	# of Different Options Used per Model
Pumper	Pumper 1	391	96	24.6%	2275
	Pumper 2	366	82	22.4%	3706
	Pumper 3	230	31	13.5%	1527
	Pumper 4	105	24	22.9%	1475
	Pumper 5	1	1	100.0%	49
	Pumper 6	5	2	40.0%	6
Aerials	AERIAL 1	31	10	32.3%	240
	AERIAL 2	15	4	26.7%	191
	AERIAL 3	16	7	43.8%	149
	AERIAL 4	18	3	16.7%	341
	AERIAL 5	46	12	26.1%	802
	AERIAL 6	39	12	30.8%	700
	AERIAL 7	3	0	0.0%	140
	AERIAL 8	38	13	34.2%	555
	AERIAL 9	17	2	11.8%	261
	AERIAL 10	1	0	0.0%	33
	AERIAL 11	8	2	25.0%	119
	AERIAL 12	16	6	37.5%	353
	AERIAL 13	2	0	0.0%	4
	AERIAL 14	1	0	0.0%	0
	AERIAL 15	7	2	28.6%	327
ARFF	ARFF 1	53	6	11.3%	454
	ARFF 2	16	1	6.3%	200
	ARFF 3	3	1	33.3%	24
	ARFF 4	1	1	100.0%	10
	ARFF 5	1	0	0.0%	8
	ARFF 6	17	4	23.5%	203
	ARFF 7	1	0	0.0%	51
	ARFF 8	8	3	37.5%	181
Rescue	Rescue 1	25	3	12.0%	417
	Rescue 2	18	1	5.6%	413
	Rescue 3	2	0	0.0%	95
	Rescue 4	15	0	0.0%	77
Other	Other 1	2	0	0.0%	0
	Other 2	2	1	50.0%	7
	Other 3	1	0	0.0%	0
	N/A	1	0	0.0%	0

Appendix 5: Common Options for all Pumper Models

1001-0015	3136-0031
1110-0026	3136-0032
1150-0103	3300-0007-003
1160-0014	3300-0008-004
1750-0059-277-04	3300-0008-016
3100-0057	3300-0010-027
3100-0112	3300-0011-004
3100-0115	3300-0011-007
3110-0004	3300-0011-016
3110-0005	3300-0017-004
3110-0015	3300-0017-016
3110-0017	3300-0017-027
3110-0024	3300-0019-003
3110-0033	3300-0019-005
3110-0034	3300-0019-015
3120-0237	3300-0019-017
3130-0003	3300-0019-027
3130-0004	3300-0019-203
3130-0005	3300-0019-864
3130-0008	3300-0030-003
3130-0009	3300-0030-005
3130-0010	3300-0062-003
3130-0011	3300-0062-004
3130-0012	3300-0062-005
3130-0014	3300-0062-015
3130-0015	3300-0062-016
3130-0017	3300-0062-017
3130-0020	3300-0066-027
3130-0023	3300-0103-027
3130-0024	3305-0069
3130-0083	3320-0007
3130-0093	3330-0007-060
3130-0097	3330-0024
3130-0099	3330-0025
3130-0102	3340-0035

3130-0103	3340-0045
3130-0110	3340-0049
3130-0167	3340-0063
3130-0202	3340-0074
3134-0012	3340-0075
3134-0013	3340-0076
3134-0014	3340-0083
3134-0026	3340-0121
3136-0003-202	3340-0198
3136-0014	3340-0241
3136-0017	3350-0018-382
3136-0018	3365-0003
3365-0004	4415-0058-655
3365-0008	4415-0058-853
3365-0011-005	4417-0026-573
3365-0018	4417-0058-350
3365-0022	4417-0058-573
3365-0025-516	4417-0058-574
3365-0028	4430-0020
3365-0030	4435-0015-352
3365-0033-052	4435-0015-356
3365-0034-515	4435-0015-357
3365-0086-B99	4435-0015-581
3365-0087-C57	4435-0015-583
3370-0023-003	4435-0092-356
3370-0023-005	4435-0094
3370-0023-017	4440-0015
3370-0025-099	4450-0023
3370-0025-102	5100-0001-952
3370-0026-003	5100-0001-953
3370-0026-005	5100-0001-963
3370-0026-016	5100-0001-B44
3370-0026-017	5100-0006-198
3370-0027-069	5100-0011-423
3370-0027-073	5100-0011-424
3370-0027-075	5110-0010
3370-0027-077	5110-0017

3370-0028-072	5150-0017
3370-0028-074	5200-0001-394
3370-0028-088	5260-0000
3380-0019-135	5300-0021
3380-0019-136	5300-0055
3380-0021	5300-0100
3380-0022-016	5390-0000-395
3380-0022-017	5390-0001
3380-0023-016	5390-0002
3380-0036-004	5390-0020-396
3380-0049-135	5400-0003
3380-0049-136	5400-0006
4010-0016	5400-0037
4010-0017	5450-0049-063
4010-0037	5450-0049-064
4010-0057	5550-0059-535
4015-0045	5600-0034-479-08
4100-0009-590	5600-0080-479-06
4405-0020	5600-0118-742
4405-0045-121	8100-0077-000-18
4415-0012-654	8100-0079-000-17
4415-0012-655	

Appendix 6: Common Categories for all Pumper Models

Parent Category	Child Subcategory	Description
1000	1001	TESTING COMPLIANCE STANDARD
1000	1025	AXLE OPTIONS
1000	1060	TIRE OPTIONS
1000	1110	AIR SYSTEM OPTIONS
1000	1150	BUMPER TRAYS
1000	1160	BUMPERS
1000	1200	ENGINES & TRANSMISSIONS
1000	1225	EXHAUST OPTIONS
1000	1350	FUEL SYSTEMS
1000	1400	BATTERIES
1500	1510	SEATS
1500	1520	CAB MODEL
1500	1535	MEDICAL CABINETS
1500	1540	MAP BOXES
1500	1675	MISC EXTERIOR CAB OPTIONS
1500	1680	
1500	1685	MISC INTERIOR CAB OPTIONS
1500	1750	CAB ELECTRICAL OPTIONS
3000	3100	BODY COMPT LEFT SIDE
3000	3110	BODY COMPT REAR
3000	3120	BODY COMPT RIGHT SIDE
3000	3130	PUMP MODULE
3000	3134	PUMP PANELS
3000	3136	PUMP MODULE OPTIONS
3000	3300	DOORS
3000	3305	COVERS
3000	3320	SCBA BOTTLE STORAGE
3000	3330	HANDRAILS / STEPS
3000	3340	MISC BODY OPTIONS
3000	3350	REELS AIR AND HYDRAULIC
3000	3365	LADDER STORAGE / RACKS
3000	3370	SHELVES
3000	3380	TRAYS / TOOLBOARDS
3000	3390	COMPARTMENT DIVIDERS
3000	4010	WATER TANK
3000	4020	WATER TANK OPTIONS
3000	4100	FOAM TANK
3000	4110	FOAM TANK OPTIONS
3000	4450	TANK PLUMBING
3000	4460	MISC PUMP PANEL OPTIONS
4000	4005	PUMPS

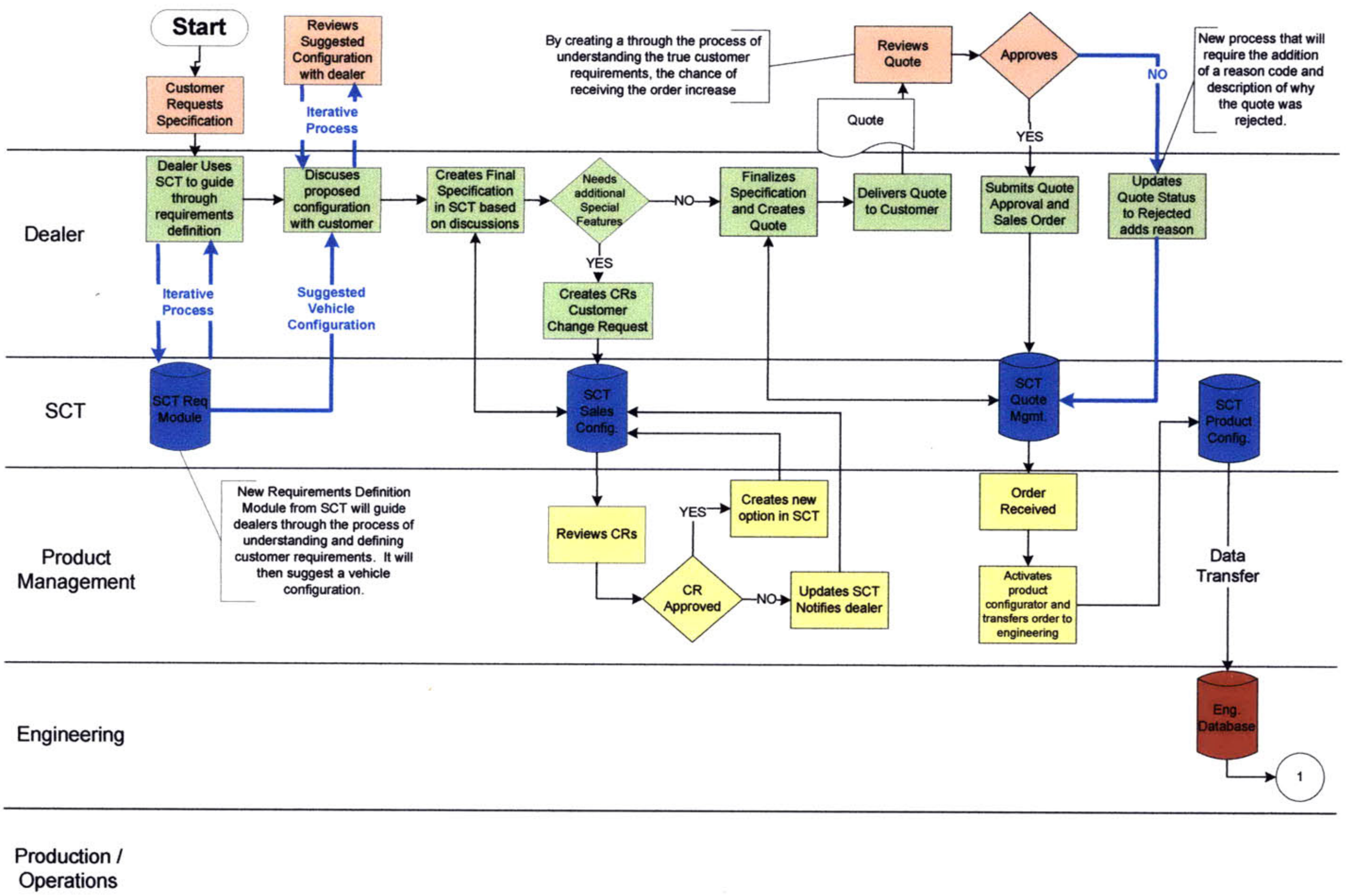
Appendix 7: Common Options for the high volume Aerial Models

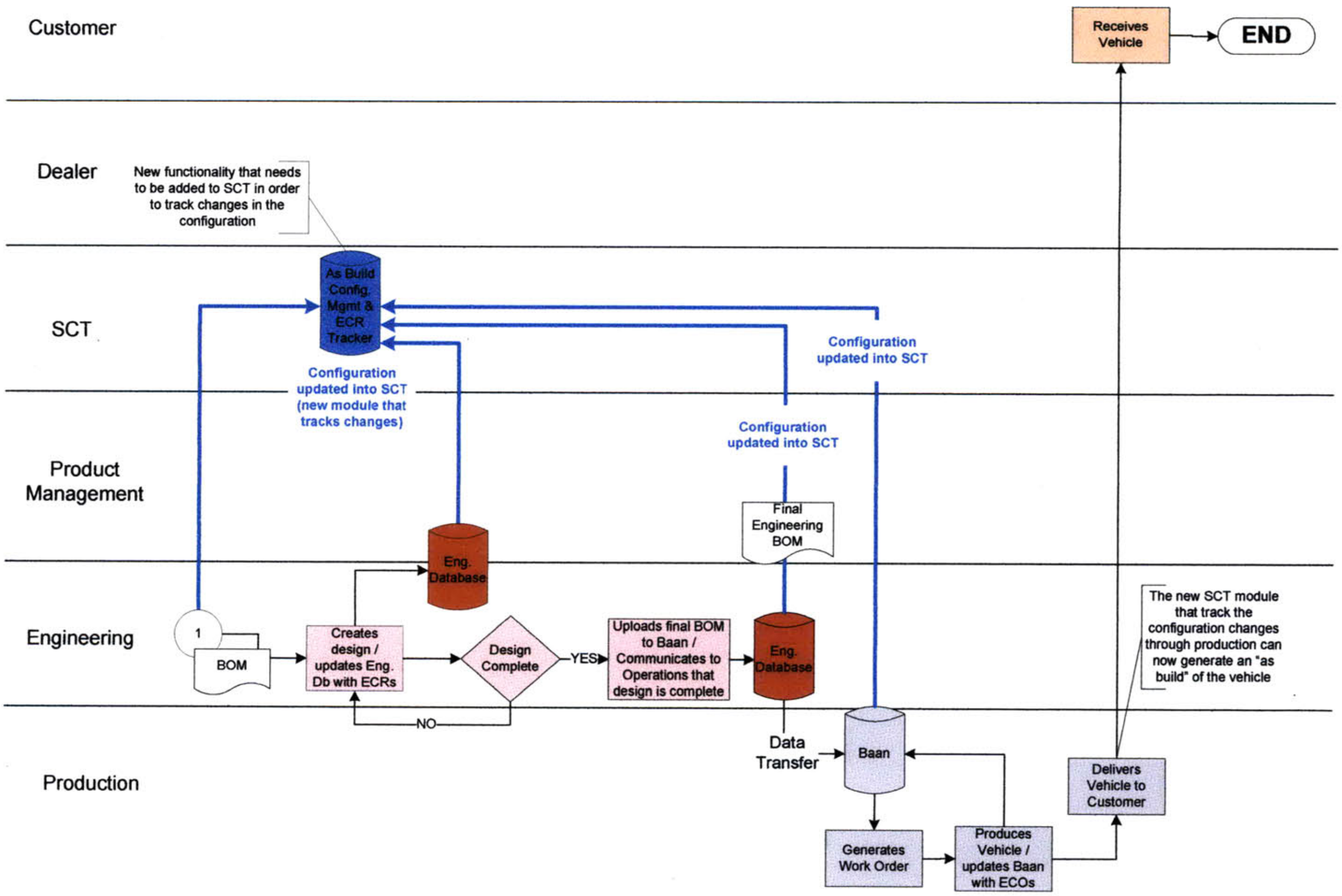
5130-0028	4417-0058-573
5130-0024-392	1550-0059-000-71
5130-0024-203	3310-0037
5130-0022-821	

Appendix 8: Common Categories for all Aerial Models

Parent Category	Child Subcategory	Description
1000	1025	AXLE OPTIONS
1000	1050	WHEEL OPTIONS
1000	1060	TIRE OPTIONS
1000	1150	BUMPER TRAYS
1500	1510	SEATS
1500	1550	CAB DOOR OPTIONS
1500	1675	MISC EXTERIOR CAB OPTIONS
1500	1685	MISC INTERIOR CAB OPTIONS
1500	1750	CAB ELECTRICAL OPTIONS
3000	3080	BODY MODEL
3000	3300	DOORS
3000	3305	COVERS
3000	3310	AERIAL BODY OPTIONS
3000	3340	MISC BODY OPTIONS
3000	3365	LADDER STORAGE / RACKS
3000	3370	SHELVES
3000	3380	TRAYS / TOOLBOARDS
3000	3390	COMPARTMENT DIVIDERS
4000	4415	DISCHARGES AND PRECONNECTS
4000	4417	DISCHARGE OPTIONS
4000	4432	FOAM SYSTEM OPTIONS
4000	4435	GAUGES
5000	5100	CONTROLS / SWITCHES
5000	5110	MISC ELECTRICAL
5000	5130	ELECTRIC CORD REELS
5000	5200	BREAKER BOXES
5000	5300	LIGHT BARS
5000	5350	CAMERAS / INTERCOM
5000	5380	LIGHTS - COMPARTMENT, STEP & GROUND
5000	5450	LIGHTS - QUARTZ
5000	5600	WARNING LIGHTS
6000	6300	MONITORS
6000	6350	WATERWAY OPTIONS
6000	6500	AERIAL EQUIPMENT
6000	6570	MISC AERIAL ELECTRICAL
6000	6850	AERIAL CONTROLS
8000	8100	EXTERIOR PAINT
8000	8300	STRIPING

Appendix 9: Proposed Future State Workflow for SCT





Customer
Receives Vehicle
END
Dealer
New functionality that needs to be added to SCT in order to track changes in the configuration
SCT
As Build Config. Mgmt & ECR Tracker
Configuration updated into SCT
Configuration updated into SCT (new module that tracks changes)
Product Management
Configuration updated into SCT
Final Engineering BOM
Eng. Database
Engineering
1
BOM
Creates design / updates Eng. Db with ECRs
Design Complete
YES
NO
Uploads final BOM to Baan / Communicates to Operations that design is complete
Eng. Database
The new SCT module that track the configuration changes through production can now generate an "as build" of the vehicle
Production
Data Transfer
Baan
Generates Work Order
Produces Vehicle / updates Baan with ECOs
Delivers Vehicle to Customer

Appendix 10: Microsoft Excel Implementation of the Suggested Options Strategy Model

Main Table: Contains the option list, variable values, the characterization based on the thresholds and the suggestion for the option classification.

					CLASSIFICATION		
Option #	**Commonality**	**GM**	**Volume**	**Implementation**	**Cost (GM)**	**Volume**	**Suggestion**
3330-0007-062	5	6.35%	20	Easy	Low	High	Bundles
5390-0001	4	13.99%	28	Easy	Low	High	Bundles
5300-0055	4	12.89%	12	Easy	Low	High	Bundles
3330-0025	4	12.77%	17	Easy	Low	High	Bundles
5390-0005	4	11.84%	25	Easy	Low	High	Bundles
3370-0026-027	4	11.23%	12	Easy	Low	High	Bundles
3130-0003	4	10.62%	14	Easy	Low	High	Bundles
3330-0024	4	9.56%	37	Easy	Low	High	Bundles
3330-0007-060	4	7.62%	31	Easy	Low	High	Bundles
3380-0019-135	4	7.56%	14	Easy	Low	High	Bundles
3130-0024	4	7.45%	20	Easy	Low	High	Bundles
3365-0086-B99	4	6.71%	10	Easy	Low	High	Bundles
3130-0010	4	5.95%	7	Easy	Low	High	Bundles
3340-0063	4	5.21%	14	Easy	Low	High	Bundles
3136-0014	4	4.79%	8	Easy	High	High	Bundles
5150-0017	4	4.76%	10	Easy	High	High	Bundles
3300-0011-016	4	4.28%	13	Easy	High	High	Bundles
3365-0018	4	2.25%	19	Easy	High	High	Bundles
3130-0015	4	1.04%	7	Easy	High	High	Bundles
3370-0028-070	3	15.57%	12	Easy	Low	High	Bundles
4415-0039-351	3	15.29%	9	Easy	Low	High	Bundles
3370-0027-027	3	15.12%	10	Easy	Low	High	Bundles
3340-0005	3	14.58%	10	Easy	Low	High	Bundles
5150-0011	3	14.22%	11	Easy	Low	High	Bundles
3370-0026-015	3	14.20%	10	Easy	Low	High	Bundles
1200-0024	3	13.73%	11	Easy	Low	High	Bundles
5600-0099-464	3	13.71%	11	Easy	Low	High	Bundles
3340-0015	3	13.62%	16	Easy	Low	High	Bundles
1750-0019	3	12.72%	14	Easy	Low	High	Bundles
4015-0053-198	3	12.70%	13	Easy	Low	High	Bundles
5400-0037	3	12.54%	11	Easy	Low	High	Bundles
3365-0020	3	12.52%	10	Easy	Low	High	Bundles
3370-0026-003	3	12.52%	13	Easy	Low	High	Bundles
1070-0001	3	12.46%	11	Easy	Low	High	Bundles
3130-0018	3	12.29%	13	Easy	Low	High	Bundles
9300-0012	3	12.00%	13	Easy	Low	High	Bundles
3370-0027-073	3	11.84%	6	Easy	Low	High	Bundles
3370-0028-072	3	11.82%	13	Easy	Low	High	Bundles
3300-0062-003	3	11.80%	5	Easy	Low	High	Bundles
3380-0024-003	3	11.30%	9	Easy	Low	High	Bundles
4010-0016	3	11.12%	15	Easy	Low	High	Bundles
3340-0080	3	11.11%	28	Easy	Low	High	Bundles
3110-0034	3	10.67%	18	Easy	Low	High	Bundles
3370-0028-088	3	10.63%	15	Easy	Low	High	Bundles
3305-0007-000-02	3	10.59%	24	Easy	Low	High	Bundles
5110-0010	3	10.33%	3	Easy	Low	High	Bundles
5110-0004	3	10.32%	10	Easy	Low	High	Bundles
3370-0027-075	3	10.30%	5	Easy	Low	High	Bundles
5550-0059-535	3	9.90%	5	Easy	Low	High	Bundles
3305-0017-135	3	9.80%	8	Easy	Low	High	Bundles
5510-0013-209	3	9.76%	8	Easy	Low	High	Bundles
5470-0014-671	3	9.65%	6	Easy	Low	High	Bundles
3380-0019-136	3	9.47%	14	Easy	Low	High	Bundles
5550-0010-534	3	9.21%	28	Easy	Low	High	Bundles
5450-0049-063	3	9.09%	4	Easy	Low	High	Bundles
5450-0049-064	3	9.09%	4	Easy	Low	High	Bundles

Threshold Table: Definition of the threshold values and calculation of the descriptive statistics values.

Variable	Threshold	Max Value	Min Value	Median	AVG
Commonality	2	5	1	1	1.25
GM	5.0%	33.75%	-21.62%	7.44%	0.05
Volume	2	37	1	2	3.41

Classification Table: This is the table representation of the graphical option strategy model.

CLASSIFICATION						
Implementation	**Cost (GM)**	**Volume**	**Std. Indiv Option**	**Bundles**	**A la Carte**	**Suggestion**
Easy	Low	Low	Best	Don't	Don't	Std. Option
Easy	High	Low	Possibly	Don't	Best	A la Carte
Easy	Low	High	Possibly	Best	Don't	Bundles
Easy	High	High	Possibly	Best	Don't	Bundles
Hard	Low	Low	Possibly	Don't	Best	A la Carte
Hard	High	Low	Don't	Don't	Best	A la Carte / Eliminate
Hard	Low	High	Best	Don't	Possibly	Std. Option
Hard	High	High	Don't	Possibly	Best	A la Carte

Summary Table: Presents the summary of the results

Classification	# of Options
Standard Option	592
Bundled Option	615
A la Carte Premium	995
A la Carte / Eliminate	729
Total Options	2931

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