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Data quality and reliability analysis of U.S. Marine Corps ground vehicle maintenance records

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MONTEREY, CALIFORNIA

THESIS

DATA QUALITY AND RELIABILITY ANALYSIS OF U.S. MARINE CORPS GROUND VEHICLE MAINTENANCE RECORDS

by

Adam T. Foley

June 2015

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We evaluate data quality issues present in Marine Corps maintenance records and develop statistical models to identify the most influential predictor variables to estimate the expected number of failures that cause a vehicle to be non-operational. When a vehicle becomes non-operational, we refer to it as a deadlining event. We analyze data collected from 3,154 Medium Tactical Vehicle Replacement (MTVR) vehicles between January 1, 2011 and December 31, 2013. Data quality issues are present in vehicle serial numbers, maintenance defect codes, regional code, and odometer readings. Due to the high level of inaccuracy in odometer meter readings, vehicle mileage cannot be used as a metric for usage. We build Poisson generalized linear regression models to estimate the expected number of vehicle deadlining events. Without the presence of a true measurement of vehicle usage, the insight gained from fitting regression models to the maintenance data is limited. The number of unscheduled maintenance events acts as a surrogate usage measure within the model. In our model, more than one scheduled maintenance event per year shows evidence of reducing the number of deadlining events. We recommend the improvement of odometer meter reading accuracy in order to provide an effective usage measurement for future studies.

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DATA QUALITY AND RELIABILITY ANALYSIS OF U.S. MARINE CORPS GROUND VEHICLE MAINTENANCE RECORDS

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ABSTRACT

We evaluate data quality issues present in Marine Corps maintenance records and develop statistical models to identify the most influential predictor variables to estimate the expected number of failures that cause a vehicle to be non-operational. When a vehicle becomes non-operational, we refer to it as a deadlining event. We analyze data collected from 3,154 Medium Tactical Vehicle Replacement (MTVR) vehicles between January 1, 2011 and December 31, 2013. Data quality issues are present in vehicle serial numbers, maintenance defect codes, regional code, and odometer readings. Due to the high level of inaccuracy in odometer meter readings, vehicle mileage cannot be used as a metric for usage. We build Poisson generalized linear regression models to estimate the expected number of vehicle deadlining events. Without the presence of a true measurement of vehicle usage, the insight gained from fitting regression models to the maintenance data is limited. The number of unscheduled maintenance events acts as a surrogate usage measure within the model. In our model, more than one scheduled maintenance event per year shows evidence of reducing the number of deadlining events. We recommend the improvement of odometer meter reading accuracy in order to provide an effective usage measurement for future studies.

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LIST OF ACRONYMS AND ABBREVIATIONS

ATLASS	Asset Tracking Logistics and Supply System
BIC	Bayes Information Criterion
CBM+	Condition Based Maintenance Plus
EIC	End item codes
ERO	Equipment repair order
GCSS-MC	Global Combat Support System–Marine Corps
GEMP	Ground Equipment Maintenance Program
HPP	Homogeneous Poisson process
ILSP	Integrated logistics support plan
LOGCOM	Logistics Command
MAS	MTVR armor system
M-ATV	MRAP all-terrain vehicle
NA	Not applicable
MAGTF	Marine Corps Air Ground Task Force
MCF	Mean Cumulative Function
MCO	Marine Corps order
MIMMS	Marine Corps Integrated Maintenance Management System
MRAP	Mine-resistance ambush protected vehicle
MTBF	Mean time between failures
MTVR	Medium Tactical Vehicle Replacement
NMAJ	No major defect
OIF	Operation Iraqi Freedom
ORD	Operational requirement document
RCM	Reliability-Centered Maintenance
SASSY	Supported Activities Supply System
SYSCOM	Systems Command
TAMCN	Table of authorized material control number
TLCM	Total Life Cycle Management
TLCM-OST	Total Life Cycle Management-Operational Support Tool
TRAM	Tractor, rubber tired, articulated steering, multipurpose
UIC	Unit identification code

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EXECUTIVE SUMMARY

In January 2014, the United States Marine Corps introduced the Ground Equipment Maintenance Program (GEMP), Marine Corps Order (MCO) 4790.25, to comply with Department of Defense maintenance requirements and further incorporate the Commandant of the Marine Corps' Total Life Cycle Management (TLCM) policy outlined in MCO 4000.57A. A focus of GEMP is the increased use of Reliability-Centered Maintenance (RCM), which concentrates on conducting and scheduling maintenance only when required rather than following an annual or semi-annual scheduled maintenance plan. This approach to maintenance has two main benefits: reducing cost, and increasing equipment readiness. Currently, maintenance schedules rely on chronological time intervals to conduct preventive maintenance. The Marine Corps Integrated Maintenance Management System (MIMMS) and Global Combat Support System–Marine Corps (GCSS-MC) are the Corps' past and present maintenance systems, respectively, and record information on all maintenance actions.

This research highlights data quality issues, demonstrates modeling techniques, and identifies reliability trends that Marine Corps Logistics Command (LOGCOM) and Marine Corps Systems Command (SYSCOM) can utilize to improve equipment maintenance policies. This thesis evaluates the maintenance records for all Medium Tactical Vehicle Replacement (MTVR) vehicles in the Marine Corps covering a period of three years from 2011 to 2013. We focus on the data obtained from MIMMS because it was implemented more thoroughly than GCSS-MC during the time frame under consideration, resulting in a larger number of available maintenance records. This study begins with an exploratory analysis of maintenance data quality. We specifically focus on vehicle odometer readings to determine their suitability as a metric for vehicle usage. We next build Poisson generalized linear models to evaluate MTVR failure rates. The analysis of the maintenance data provides insights into vehicle reliability and more effective maintenance strategies.

This study answers the following questions:

1. What data quality issues are present in Marine Corps maintenance records?

2. Is vehicle odometer mileage recorded in MIMMS and GCSS-MC a valid metric for evaluating vehicle reliability and preventive maintenance scheduling?

3. Can a Poisson generalized linear model provide insight into future failures that cause a vehicle to be non-operational?

Unfortunately, maintenance records do not always accurately capture a full range of information on the status of the vehicle or on the services being performed. Inaccuracy in maintenance data can be attributed to manual entry errors, improper training, and intentionally erroneous entered data. Areas which demonstrate data quality issues in Marine Corps maintenance records include vehicle odometer readings, inaccurate serial numbers, mission defect codes, and inaccurate regional codes.

Odometer meter readings are of particular importance to any study related to vehicle usage. Time duration between maintenance events is a poor representation of the usage of a vehicle: it does not capture operational intensity and it cannot differentiate between vehicles used frequently and those which sit idle in a motor pool. Odometer recordings for MTVRs obtained from MIMMS and GCSS-MC have several data quality shortfalls:

1. **Non-monotonic entries in odometer readings.** The MTVR odometer records the accumulation of miles driven by a vehicle throughout its lifetime and should contain only non-decreasing values. Over 55 percent of the vehicles in the MIMMS data have non-monotonic odometer readings. While GCSS-MC has significantly less non-monotonic occurrence than MIMMS, non-monotonic odometer readings are still present in over 9 percent of the vehicles.

2. **Recurring entries over an extended length of time.** There are many instances where vehicles have the same odometer readings or very minor increases over several months. In the MIMMS data, 49 percent of the vehicles have a repeated odometer reading after an elapse of 6 months. The GCSS_MC data shows a similar result, with 51 percent of the vehicles having a repeated odometer reading after an elapse of 6 months.

3. **Erroneous or missing meter readings.** MIMMS has a substantial number of meter readings at values such as "123" and "1234." GCSS-MC has limited the occurrence of obviously incorrect entries. Missing entries is a problem in both systems. The most frequent occurrences in MIMMS and GCSS-MC are missing values and zeros.

After evaluating data quality issues, this study gains insight into vehicle failure rates by building regression models. The dependent variable (response) evaluated by this study is the number of deadline maintenance events per vehicle for a three-year period. A vehicle is classified as **deadlined** when critical repairs prevent it from performing its designated mission for over twenty four hours. The number of deadline events is modeled as a Poisson counting process. We use Poisson Generalized Linear Models to estimate the relationship between the number of deadline maintenance events and the other descriptive variables. An aggregate model is created with the dependent variable being the number of deadline events occurring within the three-year period aggregated over all of the vehicle's systems. For the aggregate model, we conclude that the most significant predictor variables are the regional activity code (RAC), Table of Authorized Material Control Numbers (TAMCN), number of unscheduled maintenance events and number of scheduled maintenance events. RAC identifies the geographic location that each vehicle resides. TAMCN describes the specific vehicle variant. The number of expected deadline maintenance events is found to increase as the number of unscheduled maintenance events increase. This can be view as a surrogate usage metric. Vehicles which are used more often will create more unscheduled maintenance events and likewise more deadline maintenance events. In the aggregate model, more than one scheduled maintenance event per year shows evidence of reducing the number of deadline maintenance events. One possible explanation for this is that vehicles that have more than one scheduled maintenance event per year are more efficiently maintained but further research would be needed to confirm this hypothesis. Models evaluating the expected number of deadline events for the electrical system, the expected number of deadline events for the body, and the expected number of deadline events for the axle system are also studied in this thesis.

In conclusion, this thesis demonstrates data quality issues present in Marine Corps maintenance records and demonstrates the use of Poisson generalized linear regression

models to estimate the expected number of deadline events. Vehicle odometer readings, serial numbers, defect codes, and regional codes are all found to contain substantial quality issues which complicate analysis. Vehicle odometer mileage records do not provide a reliable measure of usage. In its current state, the number of errors in the odometer mileage entries precludes its use. The odometer mileage records are shown to suffer from non-monotonic, recurring, erroneous, and missing entries. The degree of inaccuracy within the odometer mileage records hindered imputation. Without the presence of a true measurement of vehicle usage, the insight gained from fitting Poisson generalized linear model to the maintenance data is limited.

Based on the analysis presented in this study, the following future work is suggested to expand this field of research and complement these findings. First, the methodology and models developed in this study should be applied to the GCSS-MC data. This study will provide addition insight into the analytical value of the current state of Marine Corps' maintenance records. Second, a study should be conducted with a subset of the maintenance records where the usage measure is well defined. Defining a set of units in the maintenance data that consistently and accurately record odometer mileage is important to future analysis. Finally, analysis can be conducted on maintenance and usage data downloaded from the vehicle's built in computer. Data quality issues attributed to human errors would be eliminated, providing a more truthful representation of a vehicle's history.

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I. INTRODUCTION

A. MOTIVATION AND OBJECTIVES

In January 2014, the United States Marine Corps introduced the Ground Equipment Maintenance Program (GEMP), Marine Corps Order (MCO) 4790.25, to comply with Department of Defense maintenance requirements and further incorporate the Commandant of the Marine Corps' Total Life Cycle Management (TLCM) policy outlined in MCO 4000.57A. GEMP and TLCM call for the incorporation of Condition Based Maintenance Plus (CBM+) and Reliability-Centered Maintenance (RCM) into maintenance management and sustainment planning. CBM+ and RCM focus on conducting and scheduling maintenance only when required rather than following an annual or semi-annual scheduled maintenance plan (USMC, 2014). This approach to maintenance has two main benefits: reducing cost, and increasing equipment readiness. In 2014 the Marine Corps spent $8,634,900,000 on Operations and Maintenance (DOD, 2015, p. 24). Conducting maintenance only when required eliminates unnecessary maintenance events and as a result is more cost effective. Minor improvements to the maintenance system can have significant impacts to the Marine Corps budget. Additionally, these strategies attempt to preempt equipment failures. Equipment maintenance is highly complex with several component failure models. While some components may benefit from scheduled maintenance, other components may be harmed by such actions. Detailed understanding of each component's life cycle must be known. This requires the effective evaluation of past maintenance data and the study of component failure modes in order to gain accurate insights into equipment reliability.

Currently, maintenance schedules rely on chronological time intervals to conduct preventive maintenance. The Marine Corps Integrated Maintenance Management System (MIMMS) and Global Combat Support System–Marine Corps (GCSS-MC) are the Corps' past and present maintenance systems, respectively, and record information on all maintenance actions. Applying analytical analysis to vehicle maintenance records can provide valuable insights into equipment reliability. This includes the adequacy of current maintenance records practices and vehicle reliability policies. This research demonstrates

the type and quality of information which can be gained from current maintenance records. This helps policy makers develop more efficient maintenance plans and affects future maintenance data collection strategies.

B.   FOCUS OF THE RESEARCH

This research highlights data quality issues, demonstrates modeling techniques, and identifies reliability trends that Marine Corps Logistics Command (LOGCOM) and Marine Corps Systems Command (SYSCOM) can utilize to improve equipment maintenance policies. Data quality issues are identified to emphasize those key areas in which improvement will have the greatest impact on future reliability studies. Parametric modeling emphasizes recurring equipment failures and maintenance trends that may not be evident by viewing summary information or polling subject matter experts.

This thesis evaluates the maintenance records for all Medium Tactical Vehicle Replacement (MTVR) vehicles in the Marine Corps covering a period of three years from 2011 to 2013. The MTVR is widely used throughout the Marine Corps for logistics support and combat operations. The MTVR's frequent and widespread use makes it an ideal vehicle to study. During the observed period, the Marine Corps was transitioning its maintenance records from MIMMS to GCSS-MC. Therefore we must analyze data in each system. Both systems provide key data fields including vehicle type, description of maintenance required, unit, date maintenance began, date maintenance ended, and odometer mileages. While the Marine Corps strives for accurate maintenance records, there exist substantial data quality issues. Missing and erroneous values, particularly with odometer mileage, are prevalent throughout the datasets. Data quality issues are identified and addressed in order to create a usable subset of data. Once the clean data set has been created, statistical models are constructed to estimate the time between vehicle deadlines.

This study begins with an exploratory analysis of maintenance data quality. Missing and erroneous entries are evaluated and removed as necessary. We specifically scrutinized vehicle odometer readings to determine their suitability as a metric for vehicle reliability. Next, we evaluate MTVR failure rates by building Poisson generalized linear

models . The analysis of the maintenance data gives insight into vehicle reliability and influences more effective maintenance strategies. Additional data requirements will be identified to increase potential future studies.

This study answers the following questions:

1.   What data quality issues are present in Marine Corps maintenance records?

Vehicle odometer readings, serial numbers, defect codes, and regional codes all contain quality issues which complicate analysis. Quality issues are present in both MIMMS and GCSS_MC data.

2.   Is vehicle odometer mileage recorded in MIMMS and GCSS-MC a valid metric for evaluating vehicle reliability and preventive maintenance scheduling?

Vehicle odometer mileage records do not provide a reliable measure of usage. In its current state, the number of errors in the odometer mileage entries precludes its use.

3.   Can a Poisson generalized linear model provide insight into future failures that cause a vehicle to be non-operational?

Without the presence of a true measurement of vehicle usage, the insight gained from fitting Poisson generalized linear model to the maintenance data is limited. The absence of a usage term makes our models susceptible to influence of the number of records and the operational tempo of the vehicles observed.

C.   ORGANIZATION OF THIS THESIS

This thesis is divided into five chapters. Chapter II introduces background information on MTVR vehicle characteristics, discusses reliability theory, and provides a literature review of past reliability studies. Chapter III explores the data, data quality issues and the methods used to model the data. We also address the methods used to remove erroneous maintenance entries in the chapter. Chapter IV presents the analysis results from the data modeling in. In Chapter V, we discuss conclusions and recommendations for future study are given.

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II. BACKGROUND

A. MTVR CHARACTERISTICS

The Medium Tactical Vehicle-Replacement was created to replace the aging fleet of M939/M809 5-ton trucks (Marine Corps Gazette, 2001). In 1992, the Marine Corps outlined the requirement for a vehicle capable of operating across the full spectrum of military operations (USMC, 1992). The new vehicle had to be mobile, reliable, and flexible. The 5-ton vehicles were inadequate for the payloads and off-road capabilities the Marine Corps required (USMC, 1992). The MTVR concept intended to increase on-road/off-road capabilities. The requirements for the MTVR were written into an Operational Requirements Document (ORD) in 1994. In 1999, the Oshkosh Corporation began production of the MTVR (Kelly, Peters, Landree, Moore, & Steeb, 2011, p. 45). Fielding of the new vehicle began in 2001 with the Marine Corps initially ordered 6,839 vehicles (*Marine Corps Gazette,* 2001).

The MTVR is a versatile vehicle which is represented throughout the Marine Air-Ground Task Force. "The medium truck is the "workhorse" of the Marine Corps and is called upon to perform a wide range of missions and carry a wide range of loads" (USMC, 1994b, p. 1). It is not only considered an effective, combat proven vehicle but also provides essential logistical support in garrison. Key MTVR functions include troop and equipment transportation, artillery movement, bulk water movement, and recovery operations (USMC, 1994b, p. 4). In 2004, the Marine Corps retrofitted several variants with a permanent MTVR armor system (MAS). MAS provides the MTVR protection against small arms, mines and improvised explosive devices (Kelly et al., 2011, p. 45). In a 2011 report to Congress, the RAND Corporation stated that "Currently, the MTVR consumes 50 percent of all fuels used by Marine Corps vehicles on the battlefield" (Kelly et al., 2011, pp. 45–46).

The MTVR was designed to operate 70 percent off-road and 30 percent on-road (USMC, 1994b, p. 4). Its payload capacity is 7.1 tons off-road and 15 tons on-road (Oshkosh Corporation, 2010). The MTVR design includes effective operate in climates

ranging from -50 degrees Fahrenheit to 125 degrees Fahrenheit. The MTVR is able to travel at 65mph on improved roads and has a range of 300 miles (Oshkosh Corporation, 2010). With its independent suspension system the MTVR is able to negotiate 60% gradients and 30% side slopes off-road (Oshkosh Corporation, 2010). The MTVR was designed with a service life of 22 years (USMC, 2013).

Six variants of the MTVR were originally specified, including a cargo, extended wheel base, dump, wrecker, and tractor variants (USMC, 1994b, p. 3). Currently, there are ten variants designated by Table of Authorized Material Control Numbers (TAMCN). Variants are subdivided into different models depending on if they possess specific equipment such as a winch. There are 30 MTVR models in the Marine Corps inventory. Eight of the most common TAMCNs were studied in this thesis. Table 1 lists the descriptions of the MTVR models used in this study. The table gives the current on hand vehicle quantities from the Marine Corps' Total Life Cycle Management-Operational Support Tool (TLCM-OST) as of April 15, 2015 available at https://lcmi.logcom.usmc.mil/.

Table 1.   The MTVR TAMCN descriptions are listed, along with the current quantities from the TLCM-OST as of April 15, 2015 (after USMC, 2013).

TAMCN	MODEL	DESCRIPTION	QUANTITY
D00037K	AMK23, AMK23A1, AMK25, AMK25A1	Armored, standard bed	2799
D00057K	AMK27, AMK27A1, AMK28, AMK28A1	Armored, extended bed	479
D00077K	AML29, AMK29A1, AMK30, AMK30A1	Armored, dump	274
D00097K	MK31, MK31A1	Tractor	203
D00137K	AMK31, AMK31A1	Armored, tractor	284
D00157K	AMK36	Armored, wrecker	328
D01987K	MK23, MK23A1, MK25, MK25A1	Standard bed	3018
D10627K	MK27, MK28, MK27A1, MK28A1	Extended bed	753
D10737K	MK29, MK29A1, MK30, MK30A1	Dump	205

The MTVR design was required to be maintained within the existing maintenance structure. Table 2 includes the reliability requirements specified within the MTVR ORD.

Table 2.　　　Reliability requirements specified in the MTVR ORD (after USMC, 1994b, pp. 9–10).

PARAMETER	THRESHOLD	OBJECTIVE
Mean miles between operational mission failure	2,000 miles	4,000 miles
Probability of completing a 200 mile mission without a mission failure	0.90	0.95
Achieved availability	0.89	0.90
Mean time to repair: Organizational	< 3 hours	n/a
Mean time to repair: Intermediate	< 5 hours	n/a
Mean miles between preventive maintenance	1,800 miles	3,600 miles
Mean time to perform preventive maintenance	< 3 hours	n/a
Maintenance ratio (hours/operational miles)	0.01375	0.011

An Integrated Logistics Support Plan (ILSP) was established for the MTVR in 1994 (USMC, 1994a). The ILSP describes the methods to support and the logistical steps needed to insure the MTVR performs effectively throughout its lifetime. The maintenance concepts described in the ILSP correspond to maintenance requirements in MCO P4790.2C MIMMS Field Procedure Manual. Marine Corps Maintenance is broken into five echelons of maintenance which are conducted at the organizational, intermediate, and depot levels (USMC, 1994a, pp. 3-1–3-3). Organizational level maintenance is conducted by the equipment operators and maintainers within the owning unit. Intermediate level maintenance is conducted at designated support units. Depot level maintenance usually entails intensive vehicle overhaul and is conducted at specified bases. Additional details concerning echelons of maintenance can be found in Table 3 (USMC, 2012b, pp. 1-3–1-5).

Table 3.   Summarization the Marine Corps' echelons of maintenance from
the MIMMS Field Procedures Manual (after USMC, 2012b, pp. 1-3–1-5).

ECHELON	LEVEL	DESCRIPTION
First	Organizational	Performed by equipment operator. Tasks include proper care, cleaning, lubrication, adjustments, and minor repairs. There is no requirement to collect MIMMS data.
Second	Organizational	Performed by trained maintenance personnel of the owning unit. Tasks include scheduled maintenance, diagnosing easily traceable malfunctions, and replacement of major assemblies which can be readily removed.
Third	Intermediate	Performed by trained maintenance personnel of a designated support unit or owning unit. Tasks include diagnosing malfunctions, repairing and replacing modular components, and minor body work.
Fourth	Intermediate	Performed by trained maintenance personnel of a designated support unit. Tasks includes diagnosis, adjustment, calibration, and repairs to internal piece parts. Components not authorized at lower echelons are replaced and repaired.
Fifth	Depot	Performed trained maintenance personnel at designated depots. Tasks include overhauling or rebuilding of the end item. Repairs exceed the capability of lower echelons and often requiring specialty equipment.

B.   RELIABILITY THEORY

Availability, maintainability, and reliability are the three critical characteristics that comprise equipment performance (Blanchard, 2004, p. 46). Availability measures a vehicle's ability to be operationally ready when required. Availability is a proportion of the time between maintenance to the time between maintenance and the time required for repairs (Blanchard, 2004, pp. 72–73).

Maintainability is an inherent design characteristic describing the ability to efficiently return or keep equipment in an operational state. Maintainability is divided into corrective and preventive maintenance actions (Blanchard, 2004, p. 58). Corrective maintenance actions are conducted after a failure has occurred. Corrective maintenance is unscheduled and is required to return equipment to a specified level of performance. Failures are mitigated through preventive maintenance actions. Preventive maintenance actions are defined as scheduled maintenance actions (Blanchard, 2004, p. 58).

Reliability is defined as the probability that a system will perform in a satisfactory manner for a given period of time. Reliability can be thought of as the probability that equipment will not fail (Blanchard, 2004, pp. 46–48). Availability, maintainability, and reliability are interrelated and have drastic effects on one another. Proper understanding of the reliability characteristics of equipment can improve maintainability and availability. Systems that are more reliable require less corrective maintenance and increase availability. The failure rate is defined as the number of failures divided by the operating time (Blanchard, 2004, p. 48). The inverse of the failure rate is the mean time between failures (MTBF). Equipment with high reliability will have a low failure rate.

The failure rates of equipment or components are not always constant throughout a lifetime. A common failure rate curve applied to equipment lifespan is the bathtub curve (Tobias & Trindade, 1995, pp. 36–37). The bathtub curve, shown in Figure 1, is defined by early failure period near the equipment's inception, a stable failure period through the majority of life, and a wearout failure period at old age. The early failure period has a high failure rate as defective or weak components are weeded out. In the stable failure period, failure events occur at random intervals not directly associated with age. The wearout failure period has an increasing failure rate due to fatigue and deterioration from a long service life (Tobias & Trindade, 1995, pp. 36–37).
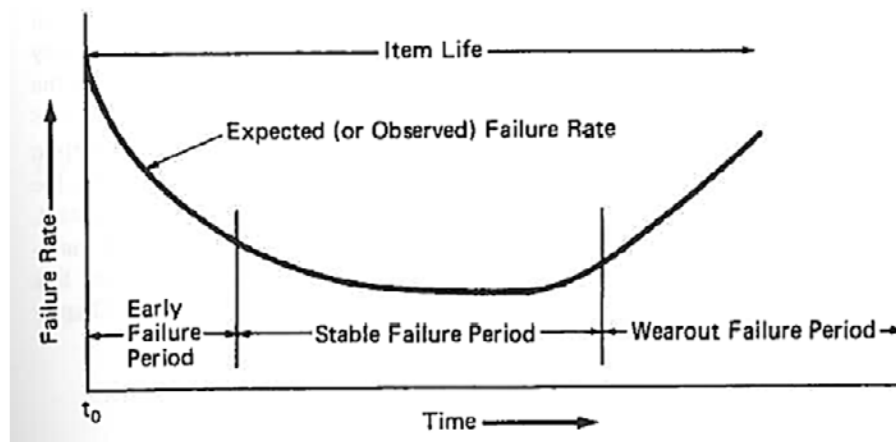
Figure 1.   Bathtub failure rate curve (from Tobias & Trindade, 1995, p. 37).

Not all equipment or components demonstrate the bathtub shaped failure curve. Studies in Reliability Centered Maintenance have identified six commonly found failure curves, shown in Figure 2 (Moubray, 1997, p. 235). The most prevalent failure rate curve from Figure 2 is curve F, which features an early failure period and then stable failure period for the remaining life (Moubray, 1997, p. 246).
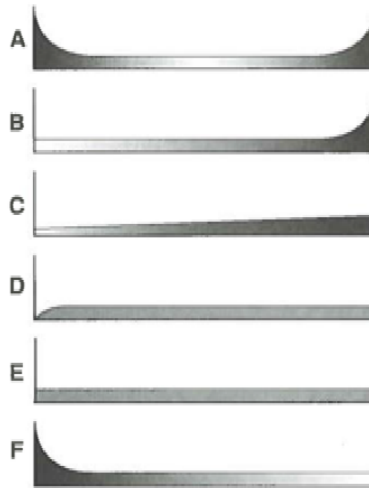
Figure 2.   Six RCM failure rate curves (from Moubray, 1997, p. 235).

Systems are considered to be either repairable or non-repairable. A repairable system is one which can be returned to an acceptable level of performance after a failure (Tobias & Trindade, 1995, p. 304). In order to simplify the analysis of a repairable system, it can be considered a renewal process if we assume that the time between failures is independent and the repair frequency is constant (Tobias & Trindade, 1995, p. 305). When the time between failures can be expressed by an exponential distribution a renewal process is considered a homogeneous Poisson Process (Tobias & Trindade, 1995, pp. 317–318). For a system comprised of several components which can fail, if each of the components is an independent Poisson process then the overall system is a Poisson process. This is called superposition (Tobias & Trindade, 1995, p. 326). The failure rate of the system is the sum of the component failure rates. For simplicity of analysis the MTVR are treated as a Poisson process with its subsystems also being Poisson processes.

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C.   RELIABILITY-CENTERED MAINTENANCE

RCM is a detailed process with the intent to reduce the requirement to perform maintenance while ensuring equipment is operationally capable. The Marine Corps' 2014 GEMP outlines the increased need for RCM (USMC, 2014).

> RCM is a method of analysis that captures and assesses operational and maintenance data to enable decisions that improve design, operational capability and readiness of equipment…In execution, RCM involves performing only those maintenance tasks which will reduce the probability or consequence of a failure, based upon analysis of each failure mode (the specific condition causing the failure) and the consequence of failure (how the failure matters in terms of safety, operational capability of the equipment, etc.). (USMC, 2014, p. 6)

There are seven key questions which RCM attempts to address (Moubray, 1997, p. 7):

1.   What are the operating functions and performance standards of the equipment?

2.   What ways can the equipment fail to complete its functions?

3.   What causes each functional failure?

4.   What happens when each failure occurs?

5.   In what way does each failure matter?

6.   How can each failure be predicted or prevented?

7.   What should be done if a suitable proactive task cannot be found?

RCM requires intimate knowledge of evaluated equipment's operational employment and the equipment repair processes. Detailed understanding of the equipment is gained through the experience and collective knowledge of subject matter experts (Moubray, 1997, pp. 266–267). The subject matter experts gathered to conduct RCM include equipment operators, maintainers, supervisors, and civilian industry experts. Each group reviews current maintenance policies, equipment failures per system component in order to identify any required changes. RCM avoids excessive use of historical due to the complexity and contradiction associated with analyzing the data (Moubray, 1997, pp. 250–254). This study demonstrates simple analysis which can be

applied to existing maintenance data. While this is not intended to replace the RCM review group, this analysis gives insight to guide discussion on equipment maintenance issues and trends.

D.   LITERATURE REVIEW

This section reviews previous studies relating to maintenance management. Studies in the area of military equipment reliability and maintenance data quality are reviewed.

1.   Previous Studies on Equipment Reliability

Reuter (2007) conducts a reliability study of MTVRs deployed to Operation Iraqi Freedom (OIF). Reuter studies 456 MTVRs deployed to Iraq from 2004 to 2007. The focus of the study is to determine the effects on MTVR reliability caused by the installation of MAS. Reuter (2007) evaluates the standard and extended bed MTVRs across the five major units within Marine Corps Air Ground Task Force (MAGTF). The author utilizes nonparametric and parametric statistical methods to evaluate vehicle reliability. Nonparametric techniques focus on the Mean Cumulative Function (MCF). Parametric modeling included the use of a homogeneous Poisson process (HPP) to evaluate reliability.

Reuter (2007) constructs models which considered vehicle type, unit, and accumulated vehicle miles as predictor variables to evaluate deadline failures. By constructing MCF plots the author is able to observe failure trends over time. Comparing the MCF of vehicles before and after the installation of MAS, Reuter (2007) shows a negative effect of the added armor. The author evaluates the reliability of the MTVR's axle/suspension system before and after MAS installation using MCF curves. The author models the mean time between failures using HPP models. Variables used to model MTBF included the major unit, vehicle variant, the interaction between unit and variant, and the presence of armor. Reuter (2007) determines that for all MTVR variants studied the MTBF decreased after the installation of armor kits. The author's study is able to demonstrate the change in vehicle reliability in regards to the presence of MAS, vehicle type, and major unit. Reuter (2007) suggests that his findings be used to influence vehicle

replacement plans and determine areas to focus corrective maintenance actions. The author's evaluation hinges on the ability to identify an appropriate usage factor within the limited data set.

Reuter (2007) evaluates the quality of 456 MTVRs deployed to OIF from 2004 to 2007. The author highlights quality issues relating to the vehicles TAMCN, defect code, odometer meter reading. Only 45.3 percent of the MTVR odometer readings are determined to be useful for the study (Reuter, 2007, p. 24). Errors within the odometer readings are attributed to manual data transfer errors, non-odometer reading entries such as 12345, and recording of the tachometer hour-meter instead of the odometer. Reuter (2007) establishes a set of rules in order to remove erroneous data entries and replace missing values. Imputation and extrapolation are used to replace erroneous data entries in order to create a useable data set. Imputation is critical in allowing Reuter (2007) to employ odometer mileage as his usage measure. Estimations require information beyond what is available in the MIMMS data such as unit daily mean usage rates. We encounter similar issues with the current MIMMS and GCSS-MC data but do not have additional information beyond the maintenance records to reference.

Mimms (1992) applies Bayesian methods and the exponential distribution to simulate future failure and repair times. The author develops an empirically based maintenance forecasting model able to estimate unit operational availability. Mimms (1992) briefly identifies quality issues in the data. Of note, there is no formal requirement or system to check data accuracy. Missing data limits the use of indicator variables in the study (Mimms, 1992, p. 16).

2.   Previous Studies on Data Quality

Hartman (2001) conducts a study on the validity of using German Army maintenance records to support future maintenance predictions. The author studies the maintenance records of a German Army light reconnaissance tank from 1997 to 2000. Hartman (2001) utilizes a Weibull distribution to model vehicle repair times and work order supply times. The author uses data from 1997 to 1999 to build the repair time model while data from 2000 is set aside for validation. Hartman (2001) develops Weibull

repair time models for the overall vehicle and vehicle components such as the electrical, hydraulic and weapon systems. Hartman (2001) also looks into the ability of using maintenance history to model failure rates and scheduled maintenance activities. The author intends to evaluate the MTBF specified in maintenance records against the MTBF calculated from maintenance data. Due to quality issues within German Army maintenance data the author is unable to evaluate the MTBF.

Hartman (2001) experiences data quality issues while evaluating German Army light reconnaissance tank maintenance records from 1997 to 2000. The author determines that data quality issues arise from the data structure and errors from user entries. Twenty percent of the maintenance records are missing repair time entries (Hartman, 2007, pp. 70–71). The author also describes several issues with the vehicle mileage. In 3.9 percent of the maintenance records, there are missing required mileage values (Hartman, 2007, p. 65). "Many vehicles have constant mileages throughout the year and then a huge increase at a certain point, whereas some vehicles toggle between two or three different mileage-levels" (Hartman, 2001, p. 65). The current MIMMS and GCSS-MC data demonstrate similar constant mileage trends. Data quality issues contribute to the author's inability to evaluate MTBF.

In 1996, the RAND Corporation conducted a study on data quality issues present in U. S. Army logistics data (Galway & Hanks, 1996). The study breaks data issues into three categories: operational, conceptual, and organizational problems (Galway & Hanks, 1996). Operational data problems relate to the number of missing or inaccurate data entries. Conceptual data problems result when data is used for purposes it is not originally intended. Organizational data issues stem from a disagreement within an organization on the best methods to implement data quality. In the maintenance data, 62 percent of the end item codes (EIC) are left blank (Galway & Hanks, 1996, p. 26). Missing entries are attributed to an assumed lack of significance of the EIC. The issue is only corrected after mandatory EIC entries were required before receiving repair parts (Galway & Hanks, 1996, p. 27).

E.   CHAPTER SUMMARY

The MTVR is a critical piece of equipment within the Marine Corps fleet of transportation vehicles. Due to its extensive use within the operation forces the MTVR requires maintenance and produces a significant amount of maintenance records. Based on the literature reviewed, there are several potential methods to evaluate the reliability of the MTVR. The evaluation relies heavily on the ability to identify a suitable usage metric. The studies suggest significant data quality issues in all the data reviewed.

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III. DATA AND METHODS

A. THE DATA

This section delves into the data presented in this thesis and outlines the steps taken to prepare the data for analysis. We discuss data quality issues present and methods used to limit their influence.

1. Data Summary

Marine Corps Logistic Command (LOGCOM) maintains the Master Data Repository (MDR). The MDR contains the history of all maintenance requests submitted through the Marine Corps maintenance system. LOGCOM is able to query the MDR and provide maintenance records for specific equipment and time period designated. For this analysis, LOGCOM gathered the records for a five-year period stretching from January 1, 2010 to March 1, 2015. During the time period studied, the Marine Corps was transitioning between MIMMS and GCSS-MC. LOGCOM provides us with records from both systems during the stated time frame.

The Marine Corps first put GCSS-MC into service in 2010, after which the system was incrementally implemented throughout the Marine Corps. The legacy system, MIMMS, has been in service with the Marine Corps for over 40 years (Chandler, 2012). MIMMS instituted uniform management policies in order to improve equipment readiness. The system established maintenance document requirements, provided status updates, and readiness reporting information (USMC, 2012a, p.1–3). GCSS-MC is designed to improve the responsiveness and integration of the Marine Corps' maintenance system and to replace legacy data systems including MIMMS, Supported Activities Supply System (SASSY), and Asset Tracking Logistics and Supply System (ATLASS) (Stone, 2009). SASSY and ATLASS are Marine Corps systems associated with the ordering and supply of parts. Integrating the Marine Corps' maintenance and supply systems is expected to increase the speed and accuracy of repair order fulfillment. GCSS-MC reduces ordered parts status updates from six days to several minutes (Stone, 2009). This thesis focuses on the data obtained from MIMMS because it was more

thoroughly implemented than GCSS-MC during the time frame under consideration, resulting in a larger number of available maintenance records.

LOGCOM provided data, which includes the maintenance actions for all MTVRs, Cougar Mine-Resistance Ambush Protected (MRAP) vehicles, MRAP All-Terrain Vehicles (M-ATV), and Tractor, Rubber Tired, Articulated Steering, Multipurpose (TRAM) vehicles within the Marine Corps inventory. Our study, however, focuses only on the MTVR data. The numbers of MTVR records provided by year are shown in Table 4 and Table 5.

Table 4.   Number of MIMMS records per year.

MIMMS NUMBER OF RECORDS PER YEAR						
YEAR	2009	2010	2011	2012	2013	2014	2015
RECORDS	28	163,819	190,234	159,651	101,812	93,422	9,382

Table 5.   Number of GCSS-MC records per year.

GCSS-MC NUMBER OF RECORDS PER YEAR						
YEAR	2010	2011	2012	2013	2014	2015
RECORDS	62	647	11,501	76,595	146,197	31,284

All maintenance beyond the first echelon (see Table 3) produces maintenance records in MIMMS and GCSS-MC. We classify maintenance actions as **scheduled** or **unscheduled**. Scheduled maintenance encompasses semi-annual, annual, and other preventive maintenance actions intended to preserve equipment capabilities. Unscheduled maintenance events denote a failure which requires repair. Unscheduled maintenance has three levels of severity: non-critical, degraded, or deadlined. Equipment is operational while conducting non-critical maintenance. Degraded equipment requires critical repairs but can still be operated with limited capabilities (USMC, 1995, p. 2-2-9). Equipment is classified as **deadlined** when critical repairs prevent it from performing its designated mission for over twenty four hours (USMC, 2012b, p. 1–7). Because deadlined

equipment is not mission capable, it has a negative effect on equipment availability and readiness.

When a vehicle is entered into the maintenance system one or more records may be created for a single repair order. The MIMMS and GCSS-MC data that we use in our analysis has a substantial number of duplicate records which contain minor changes. For example, two records created for the same maintenance action may only differ in the required repair part number. Maintenance actions often are drawn-out over a long period of time and require multiple actions. When equipment requires repair, there often are multiple actions and varying numbers of parts that must be replaced. Multiple repairs conducted under the same repair order may create numerous records in the data system. The requirement for multiple repair parts also generates multiple records.

Maintenance records provide information on the vehicle itself and on its repair history. Vehicle information includes the vehicle type, TAMCN, serial number, and Unit Identification Code (UIC). Information on services performed on the vehicle include the vehicle status, maintenance category code, echelon of maintenance, the date the vehicle was received for maintenance, defect code, deadlined date, odometer meter reading, maintenance completion date, and repair part numbers. Additional fields included in the data are military labor hours, civilian labor hours, total equipment operational time, and previous maintenance conducted. Table 6 lists data fields that we utilize in this study.

Table 6. List of important variables (USMC, 1995, pp. 2-2-2 – 2-2-24)

DATA FIELD	DESCRIPTION
TAMCN	The table of authorized material control number describes the vehicle variant.
Serial number	Serial number identifies the vehicle in maintenance
Unit Identification code	UIC specifies which unit owns the vehicle
Regional activity code	RAC identifies the geographic region the vehicle is located
Equipment repair order number	A reference number assigned to a maintenance action
Defect code	Describes the component which failed
Echelon of maintenance	Describes the echelon of maintenance, one through four
Maintenance category code	Describes the type of equipment under repair and the severity of the repairs required
Deadline control date	This is the date a vehicle was identified as deadlined
Category M days deadlined	The number of days a vehicle has been deadlined
Date closed	Date that maintenance has been completed
Date received in shop	Date the vehicle was accepted for maintenance
Meter reading	Odometer readings of the vehicle entering maintenance

2. Data Quality

The Marine Corps performs equipment maintenance to ensure it is capable of performing all required missions for which it is called upon. Unfortunately, maintenance records do not always accurately capture a full range of information on the status of the vehicle or on the services being performed. Previous research has noted data quality shortfalls with Marine Corps maintenance records (Reuter, 2007). Inaccuracy in maintenance data can be attributed to manual entry errors, improper training, and intentionally erroneous entered data. When maintainers are required to physically type data into a system there is a chance that errors will occur. Inadequate training may result in inaccurate data. Improperly trained Marines can enter erroneous data without knowing their fault. For example, the tachometer is located next to the odometer on the MTVR instrument panel which creates an opportunity for confusion (Reuter, 2007, pp. 24–25). Intentionally erroneous entries are an issue in the maintenance data. Marines taking shortcuts to increase their own work productivity may enter false data or duplicate

previous data entries. Areas which demonstrate data quality issues in Marine Corps maintenance records include vehicle odometer readings, inaccurate serial numbers, mission defect codes, and inaccurate regional codes.

Odometer meter readings are of particular importance to any study based on vehicle usage. Time duration between maintenance events is a poor representation of the usage of a vehicle: it does not capture operational intensity and it cannot differentiate between vehicles used frequently and those which sit idle in a motor pool. Odometer recordings for MTVRs obtained from MIMMS and GCSS-MC have several data quality shortfalls:

1. **Non-monotonic entries in odometer readings.** The MTVR odometer records the accumulation of miles driven by a vehicle throughout its lifetime and should contain only non-decreasing values. Over 55 percent of the vehicles in the MIMMS data have non-monotonic odometer readings. While GCSS-MC has significantly less non-monotonic occurrence than MIMMS, non-monotonic odometer readings are still present in over 9 percent of the vehicles.

2. **Recurring entries over an extended length of time.** There are many instances where vehicles have the same odometer readings or very minor increases over several months. In the MIMMS data, 49 percent of the vehicles have a repeated odometer reading after an elapse of 6 months. The GCSS_MC data shows a similar result, with 51 percent of the vehicles having a repeated odometer reading after an elapse of 6 months. This suggests two possibilities: either infrequent use of the equipment or maintainers duplicating previous odometer readings on new service requests. Without being able to observe the dispatch records for a particular unit there is no way of knowing if recurring meter entries are legitimate.

3. **Erroneous or missing meter readings.** Table 7 and Table 8 show the top ten occurrences of meter readings for MIMMS and GCSS-MC. MIMMS has a substantial number of meter readings at values such as "123" and "1234". GCSS-MC has limited the occurrence of obviously incorrect entries. Missing entries is a problem in both systems. The more frequent occurrences in MIMMS and GCSS-MC are missing values and zeros.

Table 7.   Most frequent odometer readings in the MIMMS data.

MIMMS TOP TEN ODOMETER ENTRIES		
ODOMETER ENTRY	NUMBER OF ENTRIES	PERCENTAGE OF RECORDS
Missing	193316	26.91%
0	61967	8.63%
1	61020	8.49%
123	9804	1.36%
1234	7616	1.06%
1212	5832	0.81%
22	3043	0.42%
100	2827	0.39%
333	2661	0.37%
2	2115	0.29%

Table 8.   Most frequent odometer readings in the GCSS-MC data.

GCSS-MC TOP TEN ODOMETER ENTRIES		
ODOMETER ENTRY	NUMBER OF ENTRIES	PERCENTAGE OF RECORDS
0	33,835	12.71%
Missing	22,655	8.51%
1	942	0.35%
939	718	0.27%
17286	598	0.22%
22999	572	0.21%
15825	542	0.20%
23387	520	0.20%
64161	486	0.18%
6833	478	0.18%

When infrequent errors are present in data, imputation can be used to replace the missing or erroneous with reasonable estimates. The combination of non-monotonic data, reoccurring entries, and numerous missing values makes effective imputation unlikely. After extensive attempts to remedy errors in the data, we conclude that the inaccuracies present in the MTVR odometer data make it an unreliable vehicle usage metric.

MIMMS and GCSS-MC use vehicle serial numbers to track the maintenance history of a specific vehicle. The inaccuracy of vehicle serial numbers can have an effect on this analysis because data associated with one vehicle can falsely be represented as multiple vehicles. The Marine Corps TLCM-OST as of April 15, 2015, reported 8,343 MTVRs on hand but also reported 9,206 serial numbers. The MIMMS data provided contains 8790 unique serial number of which 680 are not listed on TLCM-OST. The GCSS-MC data has 5929 unique serial numbers with 37 not present in TLCM-OST.

Defect codes are comprised of two parts, the major system and the defective component of the system. Vehicles are broken into 32 major systems such as engine, transmission, body, hydraulic, and electrical systems. The defective component can be placed into 71 categories which give additional details on the repairs that are required. Examples of defective components include: hose, tubing, and fittings; packing, seals, or gaskets; inoperative; and adjust. A listing of the major systems and the defective components can be found in UM 4790-5 MIMMS (AIS) Field Maintenance Procedures (USMC, 1988, pp. 24-5–24-6). There are instances in the data sets where the major system, defective component or both are missing from the defect code. A list of the defect codes found in the data appears in Appendix A. Table 9 and Table 10 show the most frequent defect codes and displays the incompleteness present in the records.

Table 9.   Most frequent defect codes recorded in MIMMS. Note that SL-3 describes auxiliary equipment assigned to the vehicle such as chains and binders to secure cargo.

	MIMMS TOP TEN DEFECT CODES			
DEFECT CODE	REPORT PRINT		NUMBER OF ENTRIES	PERCENTAGE OF RECORDS
	MAJOR SYSTEM	COMPONENT		
64	No Major Defect	SL-3 Application	143,678	20.00%
52	No Major Defect	Annual Scheduled Preventive Maintenance	44,425	6.18%
Missing	Missing	Missing	33,165	4.62%
56	No Major Defect	Minor	26,489	3.69%
E16	Axle System	Packing, Seals, or Gaskets	25,820	3.59%
H34	Body, Frame, or Hull	Replace	21,690	3.02%
K55	Electrical System	Inoperative	19,340	2.69%
K34	Electrical System	Replace	19,314	2.69%
H48	Body, Frame, or Hull	Cracked, Broken, or Bent	17,329	2.41%
E34	Axle System	Replace	11,313	1.57%

Table 10.   Most frequent defect codes recorded in GCSS-MC. Note that SL-3 describes auxiliary equipment assigned to the vehicle such as chains and binders to secure cargo.

	GCSS-MC TOP TEN DEFECT CODES			
DEFECT CODE	REPORT PRINT		NUMBER OF ENTRIES	PERCENTAGE OF RECORDS
	MAJOR SYSTEM	COMPONENT		
NMAJ.SL3AP	No Major Defect	SL-3 Application	72,374	27.18%
.	Missing	Missing	11,273	4.23%
NMAJ.MINR	No Major Defect	Minor	8,091	3.04%
ELEC.INOP	Electrical System	Inoperative	8,042	3.02%
NMAJ.	No Major Defect	Missing	6,076	2.28%
BODY.CBB	Body, Frame, or Hull	Cracked, Broken, or Bent	5,774	2.17%
AXLE.SEAL	Axle System	Packing, Seals, or Gaskets	5,603	2.10%
COMP.RPLC	Component	Replace	4,685	1.76%
COMP.SL3AP	Component	SL-3 Application	4,454	1.67%
ELEC.RPLC	Electrical System	Replace	4,084	1.53%

3.   Data Formatting

Our analysis of the MIMMS data makes use of the following fields: TAMCN, serial number, equipment repair order (ERO), defect code, echelon of maintenance, maintenance category, deadline control date, number of days deadlined, date closed, date received in shop, regional code, and owner unit. The data formatting requires adjustments in order for the data to be analyzed.

a.   *Observation Removal, Variable Substitution*

To analyze the MIMMS maintenance records, accuracy and completeness of the entries is paramount. When pertinent information was missing or invalid, we removed the record from the data. We adopt the assumption that all maintenance actions within the time period of our study have concluded by the end date of the data provided, which is March 1, 2015. All maintenance recorders which do not have a recorded close date are removed from the study.

We limit our analysis to MTVRs that have a record of usage over the entire time frame of our study, which is January 1, 2011 to December 31, 2013. For this reason, we only use those vehicles for which there is at least one MIMMS record prior to the start of this time period and at least one record after the end of this time period. Of the 8790 MTVRs present in the original data, 5091 MTVRs or 57.9 percent of the vehicles are removed by this requirement.

As we mentioned in Section 1, the MIMMS data may contain multiple records for a single maintenance event. For the purpose of our analysis, we reduce such occurrences to one record per maintenance action.

We removed records with erroneous serial numbers from the study data. We cross-reference serial numbers found in the provided data with a list of known serial numbers obtained from TLCM-OST on April 15, 2015, available at https://lcmi.logcom.usmc.mil/. Serial numbers not present in the TLCM-OST list are removed as invalid entries. 7.8 percent (680 serial numbers) of the MTVRs in the MIMMS data have invalid serial numbers and are removed.

b.   *Grouping of Categorical Data*

Categorical variables derived from the MIMMS data as possible variables for our study include TAMCN, UIC, regional code, defect code, and type of maintenance. In order to effectively conduct regression on the data, the categorical factor must be of a sufficient size. Categorical factors that contain a negligible number of observations are consolidated into larger groups when appropriate. In other situations, the removal of records is appropriate to reduce the number of categorical levels. We give a brief description of each categorical variable and its treatment in the paragraphs below.

The MIMMS data comprise 451 distinct UICs. In order to reduce the number of categorical variables within the data, we removed all UICs with less than 10 vehicle serial numbers from the study. 140 UICs, associated with 523 vehicle serial numbers, are removed from the data.

The regional codes listed in the data are a mix of MIMMS and SASSY codes. In order to reduce the number of duplicate categorical variables, all SASSY regional codes are converted to their equivalent code in MIMMS. A list of SASSY and MIMMS regional codes can be found in Appendix B. Five hundred sixty-one records are removed from the data due to missing regional codes.

Our study uses information only on major component systems such as Electrical, Body, Axle, etc. and not on the defective component associated with the system. By removing the defective component, we reduce the possible values of defect codes from 2,274 to 32. When the major system was missing from the defect code, the defective component was used to deduce the correct system. If the defect code could not be interpreted No Major Defect (NMAJ) was used as the major system. When both the major system and component are missing, Not Applicable (NA) is used in place of an actual system code. Figure 3 shows the major component systems in decreasing order of frequency in the data that we consider. We classify defect codes as either scheduled or unscheduled maintenance. While not specifically designated in the MIMMS data, the level of maintenance and defect code is used to classify a maintenance action as scheduled or unscheduled. Scheduled maintenance events primarily relate to annual,

semi-annual, paint, or calibration maintenance events. Appendix A lists the scheduling classification of each defect code.

Frequency of Major System Defect Code
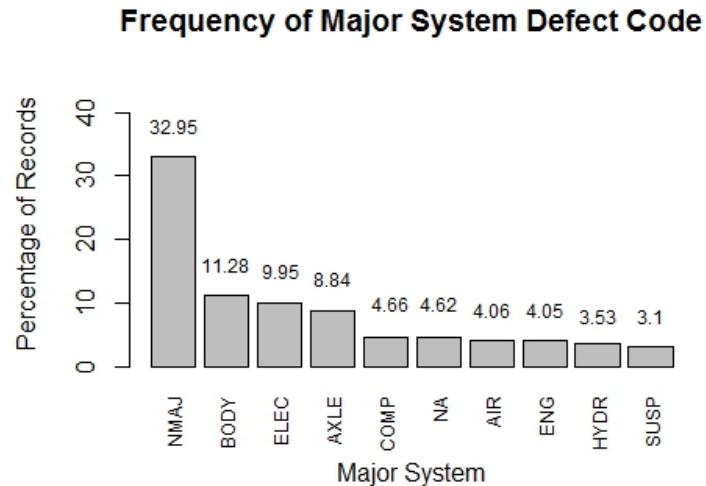
Figure 3.   Ten most frequent major systems recorded in MIMMS defect codes.

Data screening and aggregation resulted in a data set with 3154 observations, consisting of one record per MTVR. Of the original 8790 vehicle serial numbers present in the MIMMS data, we use only 3154 serial numbers for analysis. The majority of the data reduction can be attributed to the removal of duplicate repair order entries, the restriction of vehicles observed from 2011 to 2013, and the summarization of maintenance events by vehicle for the three-year period.

4.   Assumptions and Limitations of the Data

One purpose of this study is to evaluate maintenance data quality and consider modeling techniques suitable for the data currently available. While the focus of this study has been on the MTVR, each Marine Corps vehicle provides a varying state of maintenance record accuracy. Techniques used to evaluate the MTVR may not be appropriate for other vehicles which possesses differing degrees of records accuracy.

The data quality issues present in MTVR odometer meter reading preclude it from being used as an accurate representation of vehicle usage. Therefore, we analyze the maintenance data by using the number, type, and duration between maintenance events.

While time duration is a poor representation of vehicle usage, important insights and trends relating to the maintenance data can still be found but will not hold the same significance.

B.   VARIABLE DESCRIPTIONS

This section describes the variables utilized in analysis. In order to evaluate the MTVR MIMMS maintenance records, we created summary information for each vehicle maintenance records from 2011 to 2013. Deadlined equipment is considered not mission capable and as such has an adverse effect on a unit's vehicle availability and overall readiness. The intent of Marine Corps maintenance policy is to increase equipment readiness by reducing the number of deadline events. The number of deadline maintenance events will be the focus of our modeling. We evaluate additional maintenance data to gain insight into what variables are the most influential to the number of vehicle deadlines. The abbreviations for the dependent and independent variables are listed in Table 11 along with variable descriptions. These variable names are used throughout the remainder of this thesis for clarity.

Table 11.   Variable abbreviations and descriptions used for
modeling and analysis.

Variable	Description
Dependent Variable	
DEADLINES	The number of deadline maintenance events which occur per vehicle during the three-year period. The estimated mean number of deadline events will be calculated in the regression model. The number of deadline maintenance events attributed to a vehicle system is noted by the addition of a system abbreviation such as DEADLINES_ELEC, DEADLINES_BODY, and DEADLINES_AXLE for the electrical, body, and axle systems, respectively.
Independent Variables	
SCHED	The number of scheduled maintenance events which occur per vehicle during the three-year period. The number of scheduled maintenance events attributed to a vehicle system is noted by the addition of a system abbreviation such as SCHED_ELEC, SCHED_BODY, and SCHED_AXLE for the electrical, body, and axle systems, respectively.
UNSCHED	The number of unscheduled maintenance events which occur per vehicle during the three-year period. The number of unscheduled maintenance events attributed to a vehicle system is noted by the addition of a system abbreviation such as UNSCHED_ELEC, UNSCHED_BODY, and UNSCHED_AXLE for the electrical, body, and axle systems, respectively.
REGACT_CODE	The regional activity code is a categorical variable with seven levels describing the geographical location of the vehicle. The default factor level not assigned an indicator variable is MIM001 (Camp Pendleton- West coast). Indicator variables are listed below: RGACT_CODEMIM002 (Camp Lejeune- East coast) RGACT_CODEMIM003 (Okinawa, Japan and Hawaii) RGACT_CODEMIM004 (Marine Corps Reserve) RGACT_CODEMIM007 (VII Marine Expeditionary Unit) RGACT_CODEMIM008 (Bases, Posts, and stations) RGACT_CODEMIMMPS (Maritime prepositioned ships)
TAMCN	The table of authorized material control number describes the vehicle variant. Variant descriptions are given in Table 1. It is a categorical variable with eight levels. The default level is D00037K. The seven indicator variables are listed below: TAMCND0005 (D00057K) TAMCND0007 (D00077K) TAMCND0013 (D00137K) TAMCND0015 (D00157K) TAMCND0198 (D01987K) TAMCND1062 (D10627K) TAMCND1073 (D10737K)
OWNER_CODE	The Unit Identification Code. This is a categorical variable with 256 levels. UICs appear in specific regional codes. The indicator variables are the combination of the regional code and UIC. (Note: 11001 is the default for the model since MIM001 is also a model default) Each region has a default unit which is listed below: MIM001 (11001) MIM002 (12001) MIM003 (11170) MIM004 (01149) MIM007 (94000) MIM008 (30300) MIMMPS (38222)

1. Dependent Variable

The dependent variable considered for this study is the number of deadline maintenance events per vehicle (DEADLINES), which occurred from 2011 to 2013. The number of deadline events is a non-negative count of major maintenance issues. The MTVR is a system composed of many subsystems. The number of deadline events for the entire vehicle is an aggregation across all subsystems. We also evaluate separately the number of deadlines for the major subsystems to gain insight into the failures of individual systems.

2. Independent Variables

We consider the independent variables for analysis to be the following: the number of scheduled maintenance events (SCHED), the number of unscheduled maintenance events (UNSCHED), regional activity code (REGACT_CODE), UIC (OWNER_CODE), and vehicle variant (TAMCN). SCHED and UNSCHED are non-negative counts of the number respective maintenance events which occur per vehicle during the three-year period studied. Similarly to DEADLINES, SCHED and UNSCHED per vehicle are aggregated across the vehicle subsystems. REGACT_CODE is a categorical variable which specifies the geographic location (out of seven possibilities) of the vehicle. The OWNER_CODE is a categorical variable which identified the unit that owns the vehicle. There are 256 OWNER_CODEs present in the data. TAMCN is a categorical variable denoting one of the nine MTVR variants. To incorporate categorical variables into a regression model the categorical levels are represented as indicator variables, taking a value of one if the level is present or zero if it is absent (Faraway, 2005b, pp. 177–189). There is one less indicator variable than the number of categorical levels (Faraway, 2005b, pp. 177–189). The missing categorical level is accounted for in the model intercept.

C.   METHODOLOGY

1.   Poisson Generalized Linear Regression

The dependent variable (response) evaluated by this study is the number of deadline maintenance occurrences per vehicle for a three-year period from 2011 to 2013. The number of deadlines can be estimated as a Poisson counting process. A Poisson process has three key characteristics (Ross, 2010, p. 313):

1. $N(0) = 0$ The number of occurrences at time zero is zero.

2.   The process has independent increments.

3.   The number of events in an interval of length t is Poisson distributed with mean λt. That is, for all s, $t \geq 0$

$$P\{N(t+s) - N(s) = n\} = e^{-\lambda t}\frac{(\lambda t)^n}{n!}$$

Poisson Generalized Linear Models can be used estimate the relationship between the mean response and the linear predictors. The link function, η, describes how the mean response, $\mu = \lambda t$, is related to the p independent variables $\{x_1, x_2, x_3, ...x_p\}$ (Faraway, 2005, pp. 113–115):

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_p x_p$$
$$\eta = \log(\mu)$$

2.   Variable Selection

Variable selection is the process of choosing a subset of the independent variables to use in a statistical model. A good model will accurately represent the response variable with the smallest number of independent variables possible (Faraway, 2005b, p. 130). We use criterion-based techniques to identify a reasonable subset of independent variable to use for predicting DEADLINES. The prospective models are evaluated with the Bayes Information Criterion (BIC). BIC evaluates the log-likelihood for a given set of independent variables in the model and apply a penalty based on the number of independent variables used. This criterion is as follows (Faraway, 2005b, pp. 134–135):

$$BIC = -2 * \log likelihood + p \log n$$

Increasing the number of variables improves the apparent model fit by increasing the likelihood, but also may lead to unnecessary complication and overfitted models that is reflected in the penalty term of BIC based on the number of independent variables used (p) and the sample size (n).

We express the log likelihood for a Poisson general linear regression model by the following equation (Faraway, 2005a, p. 55):

$$l(\beta) = \sum_{i=1}^{n} (y_i x_i^T \beta - \exp(x_i^T \beta) - \log(y_i!))$$

$y_i =$ number of deadline events for vehicle i

$x_i^T = (1, x_{i1}, \ldots, x_{ip}) =$ vector of independent
variables for vehicle i

$\beta^T = (\beta_0, \beta_1, \ldots, \beta_p) =$ vector of Poisson
regression coefficients

BIC places a heavier penalty on the number of independent variables included in the model and favors smaller, more succinct models (Faraway, 2005b, p. 134). BIC is used to evaluate potential models for this study.

3.   Model Validation

We evaluated the models developed in this study to ensure that they provide meaningful results. We conducted regression diagnostics to ensure that model structure is sensible and to identify any influential observations that may be present (Faraway, 2005b, p. 69).

We use partial residual plots to assess the adequacy of modeling of the independent variables and the need for nonlinear transformations, as explained in Faraway (2005a, p.126). Partial residual plots show the influence of the variable of interest while making allowance for the effect of the other predictors (Faraway, 2005a, p. 126).

We use a piecewise linear spline with three internal knots to determine the need for a non-linear transformation of the independent variables. A piecewise linear function allows the independent variable to enter the model in a more flexible manner than by including it as it is. Observing the shape of the partial residual plot and the 95 percent confidence interval bands based on a piecewise-linear function often suggests a more appropriate and interpretable transformation.

Upon reviewing the partial residual plots, the need for a transformation may be confirmed by using a chi-square test. The chi-square test is used as a model comparison test in generalized linear models (Faraway, 2005a, pp. 117–120). The model with a variable transformation is compared to the same model without a transformation. The difference in the model deviances is evaluated against the chi-square distribution with the degrees of freedom equal the difference in the number of parameters in the two models (Faraway, 2005a, pp. 117–120). Deviance is a measure of model fit in an absolute sense (Faraway, 2005a, p. 8). For a Poisson regression, the deviance is defined as follows (Faraway, 2005a, p. 58):

$$D = 2\sum_{i=1}^{n}(y_i \log(y_i / \hat{\mu}_i) - (y_i - \hat{\mu}_i))$$

$y_i =$ number of deadline events for vehicle i

$\hat{\mu}_i =$ estimated mean deadline events for vehicle i

$\quad = \exp(\hat{\eta}_i)$

$n =$ number of observations (vehicles)

4.   Software Used for Analysis

The R program language and statistical computing environment was utilized throughout this analysis (R Core Team, 2014). RSudio, an integrated development environment, was used as an interface to R (Rstudio, 2012). Functions from the [R] MASS package (Venables & Ripley, 2002) were utilized for variable selection.

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IV. RESULTS AND ANALYSIS

In this chapter, we present the results from fitting Poisson generalized linear regression models to the MIMMS data for MTVRs covering the years 2011 to 2013. We define model variables in Chapter III and the abbreviations located in Table 11. We develop four models to consider the aggregate number of deadlines (DEADLINES), the number of deadlines only attributed to the electrical system (DEADLINES_ELEC), the number of deadlines attributed to the body system (DEADLINES_BODY), and the number of deadlines attributed to the axle system (DEADLINES_AXLE).

A. AGGREGATED MODEL ANALYSIS

In this section, we discuss the results of fitting Poisson generalized linear regression model to predict DEADLINES from the MIMMS data. The five independent variables evaluated in this regression are REGACT_CODE, OWNER_CODE, TAMCN, SCHED, and UNSCHED.

1. Variable Relationship Exploration

In order to gain a basic understanding the relationship between DEADLINES and the independent variables we created the plots in Figure 4. Only the 20 most frequent OWNER_CODEs are shown to simplify the plot. The variations between the boxplots associated with the categorical variables suggest a possible relationship with DEADLINES. The REGACT_CODEs MIM001, MIM002, and MIM003 show very similar boxplots compared to the remaining codes. There are large variations also between the OWNER_CODEs. SCHED and UNSCHED plots show an increase in DEADLINES until roughly four SCHED or UNSCHED events and then decreases. Descriptive statics for independent variables is given in Table 12 and Table 13.
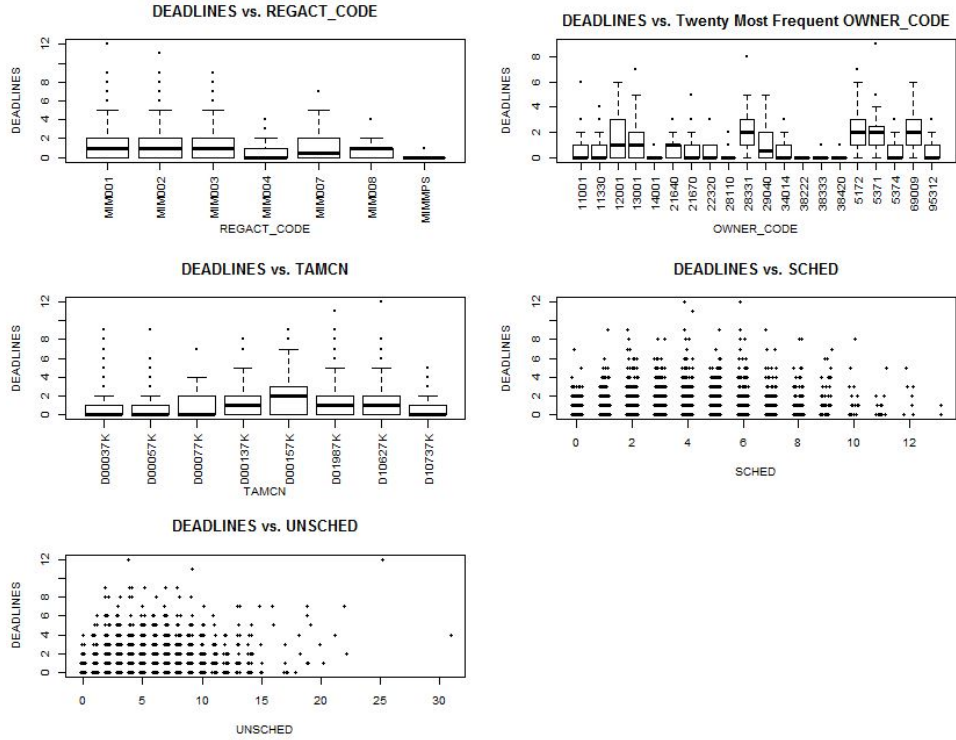
Figure 4.   Plots showing the relationship of DEADLINES to the five independent variables from the MIMMS data. Note that only the 20 most frequent OWNER_CODEs are displayed.

Table 12.   Descriptive statistics for REGACT_CODE and TAMCN.

REGACT_CODE Number of Observations	MIM001 1119	MIM002 732	MIM003 467	MIM004 325	MIM007 210	MIM008 34	MIMMPS 267	
TAMCN Number of Observations	D00037K 756	D00057K 140	D00077K 29	D00137K 137	D00157K 142	D01987K 1432	D10627K 379	D10737K 139

Table 13.   Descriptive statistics for SCHED and UNSCHED.

Variable	Minimum	1st Quantile	Median	Mean	3rd Quantile	Maximum
SCHED	0	1	3	3.2	5	13
UNSCHED	0	2	4	4.7	6	31

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2.   Estimation of the Poisson Regression Model

We use subset selection based on the BIC criterion discussed in Chapter III to identify a subset of the five independent variables to use in a Poisson regression model for estimating DEADLINES. Models with and without variable interactions are considered. The model which minimizes BIC has the following four predictor variables: REGACT_CODE, TAMCN, SCHED, and UNSCHED. The results of fitting the model are summarized in Figure 5. The p-value for each variable is given in the column with heading "$\Pr(>|t|)$." A p-value less than 0.05 suggests that the corresponding explanatory variable is a significant predictor of DEADLINES. Although the model does not find evidence that TAMCND0007 and TAMCND1073 are significant for predicting DEADLINES, categorical levels are not removed individually from the model in order to facilitate comparisons across the different levels of TAMCN.

The column labeled "Estimate" provides the estimated regression coefficients $\hat{\beta}_j$ in a function that takes the form

$$\hat{\eta} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + ... + \hat{\beta}_p x_p$$

where $E(Y \mid X_1 = x_1, \ldots, X_p = x_p)$ is estimated by $\exp(\hat{\eta})$. Here, Y denotes DEADLINES for a particular MTVR and $X_1, \ldots, X_p$ denote the explanatory variables, where $p = 15$. Applying the exponential function to the estimated regression coefficients provides an estimate of the relative effect of each variable on the estimated mean DEADLINES. We provide these estimates in Table 14. For example, the mean of DEADLINES for vehicles with regional activity code MIM002 (REGACT_CODEMIM002 = 1) is 1.46 times as large as that for vehicles with regional activity code MIM001. Another way of stating this is that, all other things being equal, on average vehicles in MIM002 have about 46 percent more DEADLINES than those in MIN001. Similarly, SCHED and UNSCHED have the effects of increasing the estimated mean of DEADLINES by approximately 5 percent and 4 percent, respectively.

```
Call:
glm(formula = DEADLINED ~ REGACT_CODE + TAMCN + SCHED + UNSCHED,
    family = "poisson", data = BB3c_vic)

Deviance Residuals:
    Min      1Q   Median      3Q      Max
-2.5172  -1.2911  -0.3401  0.4457   5.5876

Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)          -0.495899   0.058113  -8.533  < 2e-16 ***
REGACT_CODEMIM002     0.379545   0.042557   8.919  < 2e-16 ***
REGACT_CODEMIM003     0.422907   0.046298   9.134  < 2e-16 ***
REGACT_CODEMIM004    -0.947604   0.101254  -9.359  < 2e-16 ***
REGACT_CODEMIM007    -0.159620   0.083829  -1.904 0.056895 .
REGACT_CODEMIM008    -0.629397   0.205235  -3.067 0.002164 **
REGACT_CODEMIMMPS    -2.707213   0.261805 -10.341  < 2e-16 ***
TAMCND0005            0.156674   0.093735   1.671 0.094630 .
TAMCND0007            0.199555   0.190600   1.047 0.295107
TAMCND0013            0.298321   0.089503   3.333 0.000859 ***
TAMCND0015            0.612953   0.072112   8.500  < 2e-16 ***
TAMCND0198            0.095656   0.047347   2.020 0.043350 *
TAMCND1062            0.441409   0.059416   7.429 1.09e-13 ***
TAMCND1073           -0.036152   0.104721  -0.345 0.729924
SCHED                 0.044621   0.006922   6.446 1.14e-10 ***
UNSCHED               0.043023   0.005290   8.133 4.20e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 5773.4  on 3153  degrees of freedom
Residual deviance: 4536.0  on 3138  degrees of freedom
AIC: 8716.6

Number of Fisher Scoring iterations: 6
```

Figure 5.   Results of fitting a Poisson regression using DEADLINES as the
dependent variable.

Table 14.   Relative effect on DEADLINES per variable derived from raising
the exponential function by the estimated regression coefficients.

Variable	Effect
(Intercept)	0.61
REGACT_CODEMIM002	1.46
REGACT_CODEMIM003	1.53
REGACT_CODEMIM004	0.39
REGACT_CODEMIM007	0.85
REGACT_CODEMIM008	0.53
REGACT_CODEMIMMPS	0.07
TAMCND0005	1.17
TAMCND0007	1.22
TAMCND0013	1.35
TAMCND0015	1.85
TAMCND0198	1.10
TAMCND1062	1.55
TAMCND1073	0.96
SCHED	1.05
UNSCHED	1.04

The previous results are for non-transformed predictor variables SCHED and UNSCHED. We now examine the partial residual plots as explained in Chapter III, to assess the need for non-linear transformations of these two variables. The partial residual plots for the aggregate DEADLINES model are shown in Figure 6. The prominent curve in the SCHED and the sharp bend in UNSCHED partial residual plots suggest the need for a non-linear transformation. The need for a transformation is further gauged by comparing the deviance of models with and without the transformation using the chi-square test. SCHED results in a p-value less than 0.001 with 3 degrees of freedom. For a significance level of 0.05, the comparison indicates the transformed SCHED model is significantly better than the model without transforming SCHED. The SCHED is transformed by a piecewise linear transform with a bend point at four. The partial residual plot for SCHED after the transformation is showing in Figure 7. To incorporate a stepwise function into the model, SCHED is broken into two linear functions denoted as Upper Function (UF) and Lower Function (LF). Comparing the model with UNSCHED transformed against the model without the transformation results in a p-value of 0.002

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with 3 degrees of freedom. This indicates transforming UNSCHED is significantly better than not transforming UNSCHED. A piecewise linear transform is also applied to UNSCHED but with two bend points at four and six. UNSCHED is broken into three linear functions: Upper UNSCHED Function (UUF), middle UNSCHED Function (MUF), Lower UNSCHED Function (LUF).

$$\text{Upper Function } UF = \begin{cases} x - x_0 & x > x_0 \\ 0 & x \le x_0 \end{cases}$$

$$\text{Upper UNSCHED Function } UUF = \begin{cases} z - 6 & z > 6 \\ 0 & z \le 6 \end{cases}$$

$$\text{Lower Function } LF = \begin{cases} 0 & x \ge x_0 \\ x - x_0 & x < x_0 \end{cases}$$

$$\text{Middle UNSCHED Function } MUF = \begin{cases} 0 & z \ge 6 \\ z - 6 & z < 6 \end{cases}$$

$$x_0 = 4$$

$$\text{Lower UNSCHED Function } LUF = \begin{cases} 0 & z \ge 4 \\ z - 4 & z < 4 \end{cases}$$

$$x = \text{SCHED}$$

$$z = \text{UNSCHED}$$

The updated model summary incorporating the transformation of SCHED and UNSCHED is presented in Figure 8. This model is studied in more detail in Section 3.
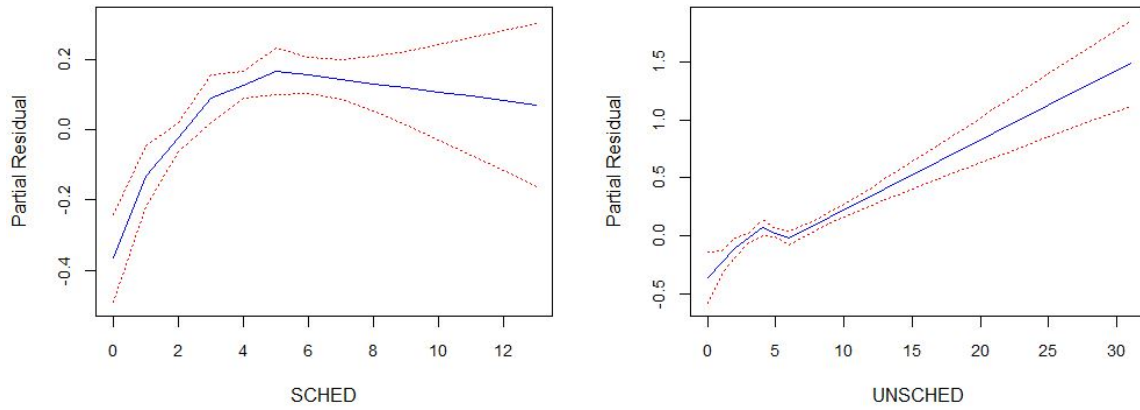
Figure 6.   Partial residual plots for SCHED and UNSCHED. The blue line is the residual plot. The red dotted lines are 95 percent confidence bounds. A piecewise-linear spline is used for SCHED and UNSCHED.
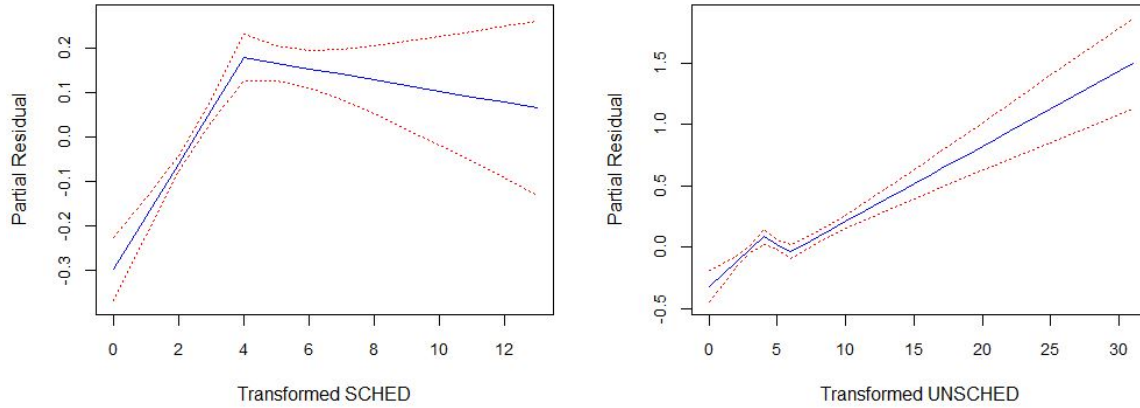
Figure 7. Partial residual plot for SCHED and UNSCHED. A piecewise linear transformation with a bend point at four is applied to SCHED. A piecewise linear transformation with bend points at four and six is used for UNSCHED.

```
Call:
glm(formula = DEADLINED ~ REGACT_CODE + TAMCN + LF(SCHED) + UF(SCHED) +
    UUF(UNSCHED) + MUF(UNSCHED) + LUF(UNSCHED), family = "poisson",
    data = BB3c_vic)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.5809  -1.2584  -0.3452   0.4310   5.2532

Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)         -0.006958   0.058834  -0.118 0.905859
REGACT_CODEMIM002    0.359867   0.042691   8.429  < 2e-16 ***
REGACT_CODEMIM003    0.413756   0.046419   8.914  < 2e-16 ***
REGACT_CODEMIM004   -0.948336   0.101579  -9.336  < 2e-16 ***
REGACT_CODEMIM007   -0.175164   0.083717  -2.092 0.036409 *
REGACT_CODEMIM008   -0.696398   0.205809  -3.384 0.000715 ***
REGACT_CODEMIMMPS   -2.605940   0.263193  -9.901  < 2e-16 ***
TAMCND0005           0.125355   0.093675   1.338 0.180831
TAMCND0007           0.198991   0.190352   1.045 0.295846
TAMCND0013           0.263716   0.089921   2.933 0.003360 **
TAMCND0015           0.596097   0.072330   8.241  < 2e-16 ***
TAMCND0198           0.092798   0.047395   1.958 0.050230 .
TAMCND1062           0.436069   0.059667   7.308 2.70e-13 ***
TAMCND1073          -0.071138   0.104928  -0.678 0.497793
LF(SCHED)            0.115375   0.015107   7.637 2.22e-14 ***
UF(SCHED)           -0.012029   0.012621  -0.953 0.340549
UUF(UNSCHED)         0.060884   0.007964   7.645 2.08e-14 ***
MUF(UNSCHED)        -0.051885   0.025257  -2.054 0.039954 *
LUF(UNSCHED)         0.148085   0.041823   3.541 0.000399 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 5773.4  on 3153  degrees of freedom
Residual deviance: 4488.6  on 3135  degrees of freedom
AIC: 8675.2

Number of Fisher Scoring iterations: 6
```

Figure 8. Aggregated DEADLINES model output after SCHED and UNSCHED are transformed using piecewise linear functions.

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3. Explanation of the Model Results

For the model that uses aggregate number of deadline events (DEADLINES) as an outcome variable, we conclude that REGACT_CODE, TAMCN, SCHED and UNSCHED are significant predictor variables. The relative effects on DEADLINES for each coefficient in Figure 8 are shown in Table 15. The base case used to further evaluate the model results utilizes the default independent variable values. The default independent variable values are as follows: REGACT_CODE = MIM001, TAMCN = D00037K, SCHED = 0 and UNSCHED = 0.

Table 15.   Relative effect on DEADLINES per variable derived from raising the exponential function by the estimated regression coefficients after transforming SCHED.

Variable	Deadline Multiplier
(Intercept)	0.99
REGACT_CODEMIM002	1.43
REGACT_CODEMIM003	1.51
REGACT_CODEMIM004	0.39
REGACT_CODEMIM007	0.84
REGACT_CODEMIM008	0.50
REGACT_CODEMIMMPS	0.07
TAMCND0005	1.13
TAMCND0007	1.22
TAMCND0013	1.30
TAMCND0015	1.82
TAMCND0198	1.10
TAMCND1062	1.55
TAMCND1073	0.93
LF(SCHED)	1.12
UF(SCHED)	0.99
UUF(UNSCHED)	1.06
MUF(UNSCHED)	0.95
LUF(UNSCHED)	1.16

Figure 9 shows the relative change in the estimated expected DEADLINES for the REGACT_CODE values relative to MIM001when all other variables are held to their

default values. Compared to REGACT_CODE MIM001, a D00037K in MIM003 will have 1.5 times or 50 percent more expected DEADLINES.
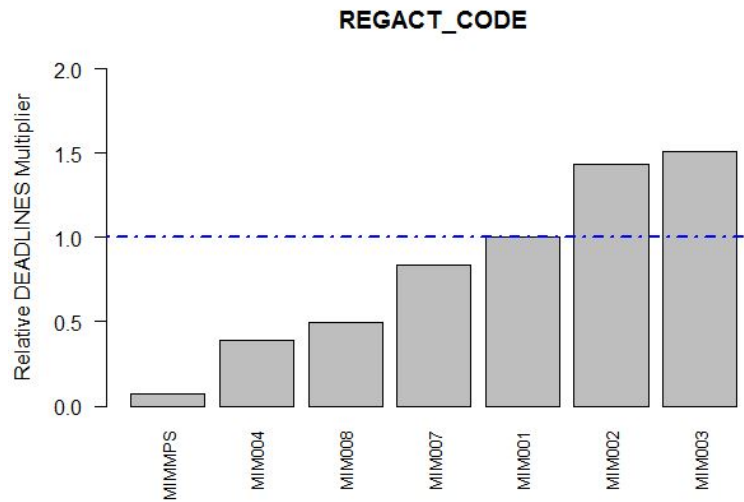
REGACT_CODE

Figure 9. Relative change in the estimated expected DEADLINES due to REGACT_CODE compared to region MIM001 given that all other variables are held constant.

Figure 10 shows the relative change in DEADLINES due to the TAMCN when all other variables are held to their default values. Compared to D00037K, a D00157K in MIM001 will have over 80 percent more estimated expected DEADLINES during the three-year time period.
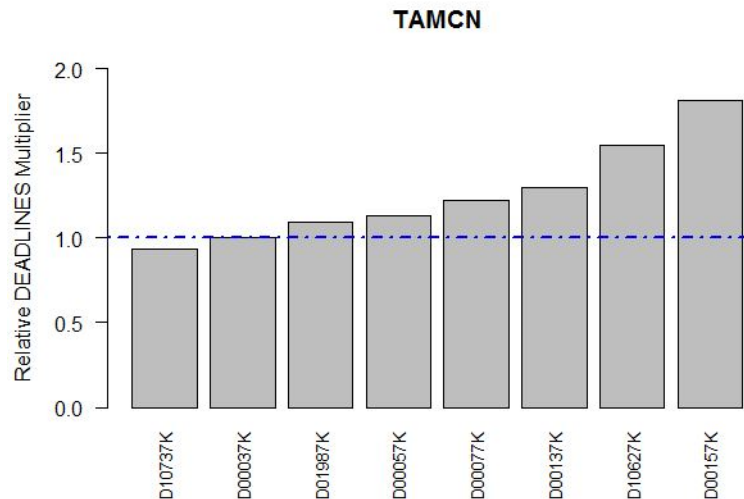
TAMCN

Figure 10. Relative changes in the estimated expected DEADLINES due to TAMCN compared to TAMCN D00037K given that all other variables are held constant.

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Figure 11 shows the relative change in the estimated expected DEADLINES when the SCHED range from 0 to 15 and all other variables are held to their default values. Below four SCHED, the estimated expected DEADLINES increases as the number of SCHED increases. After four maintenance events, the estimated expected DEADLINES gradually decreases as SCHED increases. This suggests when more than one scheduled maintenance events per year is conducted the number of deadline maintenance events may decrease. One possible explanation for this is that vehicles that have more than one scheduled maintenance event per year are more efficiently maintained, but further research would be needed to confirm this hypothesis.
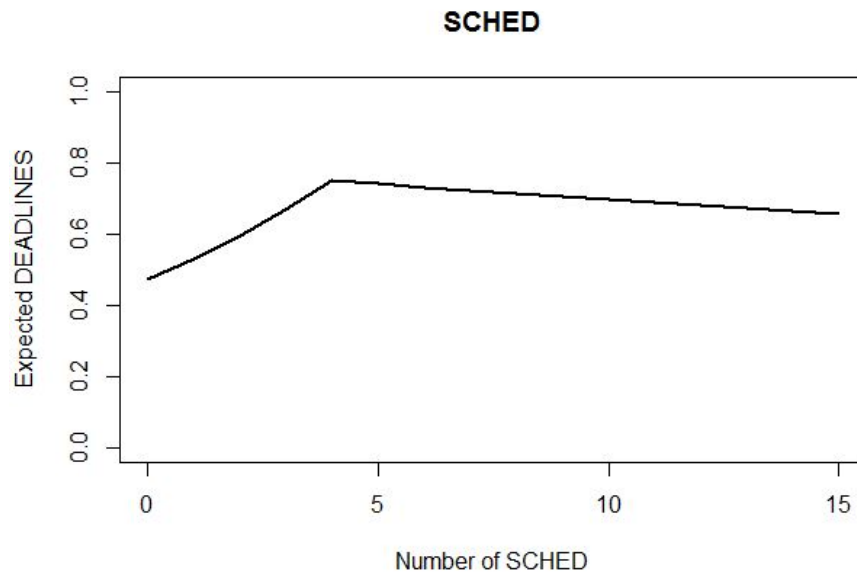
SCHED

Figure 11.   Change in the estimated expected DEADLINES due to SCHED given that all other variables are held constant.

Figure 12 illustrates the relative change in the estimated expected DEADLINES when UNSCHED range from 0 to 15 and all other variables are held to their default values. An overall trend shows the estimated expected DEADLINES increasing as the number of UNSCHED increases. UNSCHED between 4 and 6 is inconsistent with the overall trend and cannot be easily explained. Figure 4 shows that a large portion on the observations has UNSCHED between 2 and 8. Further study is required to determine the inconsistency in the trend between DEADLINES and UNSCHED. We focus on the overall trend and view UNSCHED as a surrogate usage metric. Vehicles which are used

more often will create more unscheduled maintenance events and similarly more deadline maintenance events.
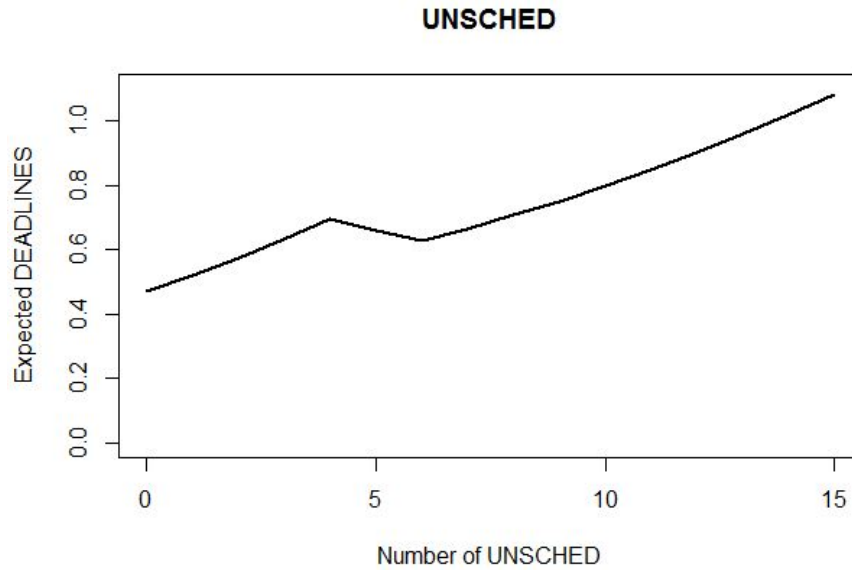
UNSCHED

Figure 12.   Changes in the estimated expected DEADLINES due to UNSCHED
given that all other variables are held constant.

B.   MAJOR SYSTEM MODELS

In this section we discuss the results of fitting three Poisson generalized linear regression model to predict DEADLINES_ELEC, DEADLINES_BODY, and DEADLINES_AXLE for the electrical, body, and axle systems, respectively. Similar analysis as conducted for the aggregate model is performed on each system. Additional information for the analysis of each model can be found in appendixes C through E.

1.   Electrical System Model Analysis

In this model, we evaluate only the deadline maintenance events attributed to the electrical system (DEADLINE_ELEC) while all other deadline maintenance events are removed. The scheduled and unscheduled maintenance events attributed to the electrical system are considered as additional independent variables in this model and labeled as SCHED_ELEC and UNSCHED_ELEC, respectively. The seven independent variables evaluated in this regression are REGACT_CODE, OWNER_CODE, TAMCN, SCHED, UNSCHED, SCHED_ELEC, and UNSCHED_ELEC. The relationship between

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DEADLINES_ELEC and independent variables are explored through the plots found in Appendix C.

Figure 13 shows optimal model containing two variables: REGACT_CODE, and UNSCHED. The partial residual plots do not suggest the need for nonlinear transformation of UNSCHED. This is confirmed through a chi-square test. Comparing the deviance of models with and without transforming UNSCHED produces a p-value of 0.17 with 3 degrees of freedom. This indicates a transformation of UNSCHED is not significant to the model.

```
Call:
glm(formula = DEAD_ELEC ~ REGACT_CODE + UNSCHED, family = "poisson",
    data = BB3c_elec)

Deviance Residuals:
    Min      1Q   Median      3Q      Max
-0.9697  -0.6518  -0.5768  -0.3949   4.2158

Coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -2.03824    0.10426 -19.550  < 2e-16 ***
REGACT_CODEMIM002   0.29484    0.10522   2.802  0.00508 **
REGACT_CODEMIM003   0.35982    0.11397   3.157  0.00159 **
REGACT_CODEMIM004  -0.53082    0.19898  -2.668  0.00764 **
REGACT_CODEMIM007  -0.75786    0.23174  -3.270  0.00107 **
REGACT_CODEMIM008  -0.06390    0.41415  -0.154  0.87738
REGACT_CODEMIMMPS  -1.87069    0.41752  -4.480 7.45e-06 ***
UNSCHED             0.06112    0.01275   4.793 1.65e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 2262.9  on 3153  degrees of freedom
Residual deviance: 2131.5  on 3146  degrees of freedom
AIC: 3114.8

Number of Fisher Scoring iterations: 6
```

Figure 13.   Electrical system model output.

We evaluate the model using the default values of all the independent variables listed in section A. The default value for both SCHED_ELEC and UNSCHED_ELEC is zero. Figure 14 shows the relative change in estimated expected DEADLINES_ELEC due to REGACT_CODE and UNSCHED when all other variables are held constant. Similar to the aggregate model, UNSCHED can be view as a surrogate usage metric. The

model fails to provide evidence that scheduled maintenance events is a significant predictor of the number of electrical system deadline maintenance events. More research is needed to better understand the relationship between scheduled maintenance events and electrical system deadline maintenance events.
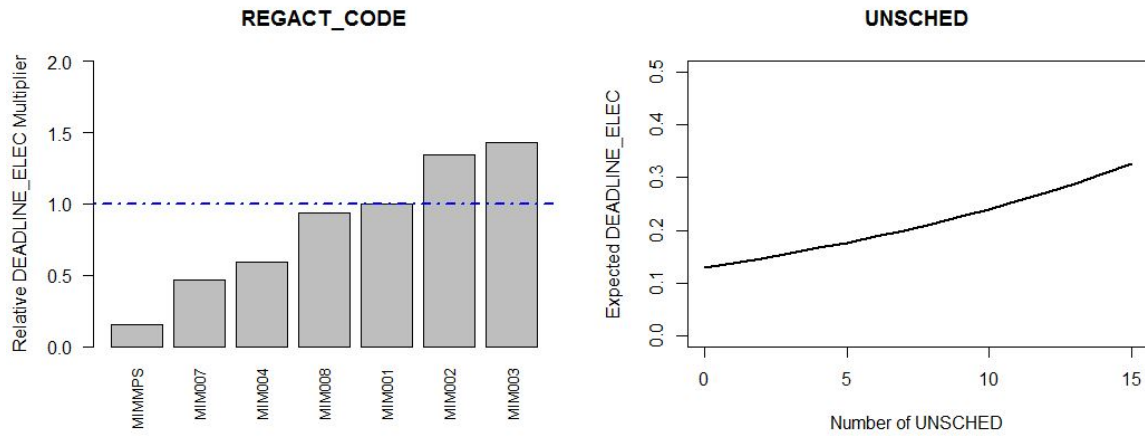
Figure 14.   Changes in the estimated expected DEADLINES_ELEC due to the REGACT_CODE and UNSCHED given that all other variables are held constant.

2.   Body System Model Analysis

In this section, the number of deadline maintenance events attributed to the body system (DEADLINES_BODY) is assessed while all other deadline maintenance events are removed. The independent variables evaluated in this regression are REGACT_CODE, OWNER_CODE, TAMCN, SCHED, UNSCHED, SCHED_BODY, and UNSCHED_BODY. Using BIC, the only indicator variable found to be significant is REGACT_CODE. Figure 15 summarizes the model results.

```
Call:
glm(formula = DEAD_BODY ~ REGACT_CODE, family = "poisson", data = BB3c_body)

Deviance Residuals:
    Min      1Q   Median      3Q      Max
-0.5345  -0.4310  -0.3247  -0.2602   3.8775

Coefficients:
                   Estimate Std. Error z value Pr(>|z|)
(Intercept)        -2.9427      0.1302 -22.603  < 2e-16 ***
REGACT_CODEMIM002    0.5664      0.1779   3.183  0.00146 **
REGACT_CODEMIM003    0.7666      0.1893   4.051 5.11e-05 ***
REGACT_CODEMIM004   -0.4433      0.3284  -1.350  0.17710
REGACT_CODEMIM007    0.9967      0.2242   4.445 8.79e-06 ***
REGACT_CODEMIM008   -0.5837      1.0084  -0.579  0.56271
REGACT_CODEMIMMPS   -2.6446      1.0083  -2.623  0.00872 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 1256.8  on 3153  degrees of freedom
Residual deviance: 1185.8  on 3147  degrees of freedom
AIC: 1609

Number of Fisher Scoring iterations: 7
```

Figure 15.   Body system model output.

Figure 16 shows the relative change in estimated expected DEADLINES_BODY due to the REGACT_CODE. Compared to regional activity code MIM001, a D00037K in MIM007 will have over 2.5 times more estimated expected DEADLINES_BODY. These results show no evidence that deadline maintenance events attributed to the body system is dependent on scheduled or unscheduled maintenance events. Without knowing a date the vehicle was fielded or having a usage metric, it cannot be inferred that body system deadline maintenance events are due to age.
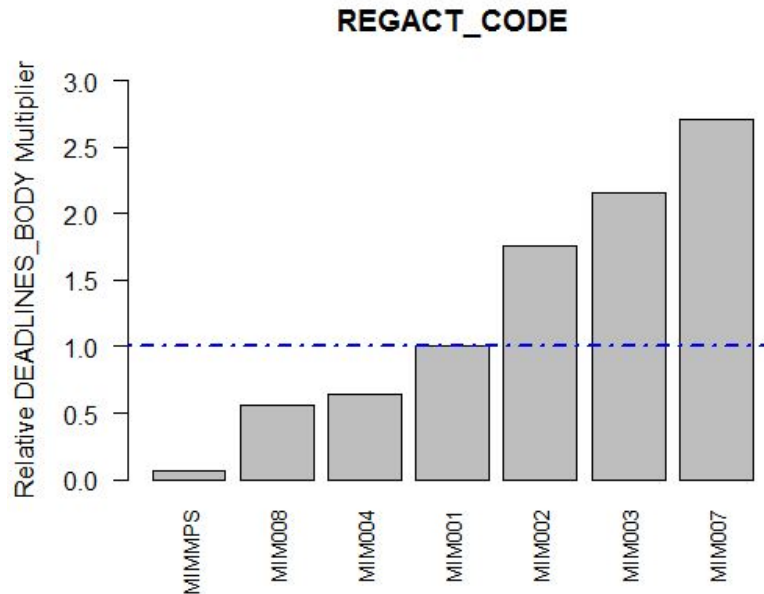
Figure 16.   Relative change in the estimated expected DEADLINES_BODY due
to REGACT_CODE compared to region MIM001.

3.   Axle System Model Analysis

This model only evaluates the deadline maintenance events attributed to the axle system (DEADLINES_AXLE). The independent variables evaluated in this regression are   REGACT_CODE,   OWNER_CODE,   TAMCN,   SCHED,   UNSCHED, SCHED_AXLE,   and   UNSCHED_AXLE.   The   relationship   between DEADLINES_AXLE and independent variables are explored with the plots in Appendix E.   The   initial   model   found   the   REGACT_CODE,   SCHED,   UNSCHED, UNSCHED_AXLE, and the interaction between UNSCHED and UNSCHED_AXLE to be significant. Examining the partial residual plots in Appendix E, SCHED requires nonlinear transformation. The chi-square test evaluating the transform of SCHED results in a p-value less than 0.001 with 3 degrees of freedom. The transformation of SCHED is significant to the model. A piecewise linear transformation with a bend point at five is applied to the SCHED. As done in section A, SCHED is broken into two linear functions denoted as Upper Function (UF) and Lower Function (LF). With p-values of 0.12 and 0.13, respectively, UNSCHED and UNSCHED_AXLE do not require transformation. Figure 17 summarizes the model.

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```
Call:
glm(formula = DEAD_AXLE ~ REGACT_CODE + LF(SCHED) + UF(SCHED) +
    UNSCHED + UNSCHED_AXLE + UNSCHED:UNSCHED_AXLE, family = "poisson",
    data = BB3c_axle)

Deviance Residuals:
    Min      1Q   Median      3Q      Max
-1.4524  -0.5693  -0.4423  -0.2182   5.3474

Coefficients:
                       Estimate Std. Error z value Pr(>|z|)
(Intercept)            -1.81000    0.14372 -12.594  < 2e-16 ***
REGACT_CODEMIM002        0.03598    0.11232   0.320 0.748713
REGACT_CODEMIM003       -0.61134    0.17107  -3.574 0.000352 ***
REGACT_CODEMIM004       -1.81780    0.38779  -4.688 2.76e-06 ***
REGACT_CODEMIM007       -0.82201    0.25578  -3.214 0.001310 **
REGACT_CODEMIM008       -1.95220    1.00301  -1.946 0.051615 .
REGACT_CODEMIMMPS       -3.11761    1.00734  -3.095 0.001969 **
LF(SCHED)                0.19781    0.03473   5.696 1.23e-08 ***
UF(SCHED)               -0.13324    0.05101  -2.612 0.009004 **
UNSCHED                  0.04374    0.01841   2.377 0.017470 *
UNSCHED_AXLE             0.72388    0.10672   6.783 1.17e-11 ***
UNSCHED:UNSCHED_AXLE    -0.05073    0.01374  -3.693 0.000222 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 2071.9  on 3153  degrees of freedom
Residual deviance: 1805.1  on 3142  degrees of freedom
AIC: 2478.5

Number of Fisher Scoring iterations: 7
```

Figure 17.   Axle system model output after transforming SCEHD using a
piecewise linear function with a bend point at five.

Figure 18 shows the relative change in estimated expected DEADLINES_AXLE when the independent variables are altered. SCHED shows an increase in estimated expected DEADLINES_AXLE up until five scheduled events, after which the estimated expected DEADLINES_AXLE decreases. This suggests similar results as the aggregate model, when more than the one scheduled maintenance events per year is conducted the number of axle deadline maintenance events decreases. The number of axle deadline maintenance events increases with axle unscheduled maintenance events. This suggests a greater number of unscheduled maintenance events attributed to the axle system indicate a faulty axle system which is more likely to fail.
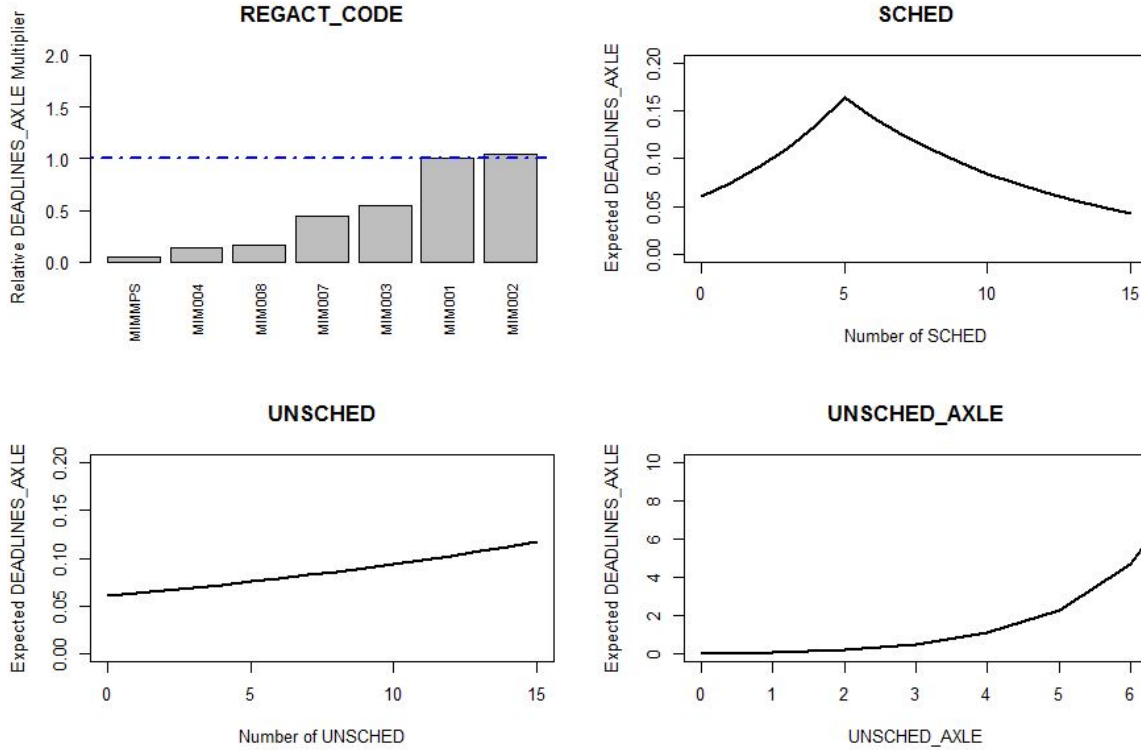
Figure 18.   Changes in the estimated expected DEADLINES_AXLE due to the independent variable given that all other variables are held constant.

C.   CHAPTER SUMMARY

In this chapter, we developed four Poisson generalized linear regression models to estimate the number of deadline maintenance events for a vehicle within the three-year period. The aggregate model found REGACT_CODE, TAMCN, SCHED, and UNSCHED to be statistically significant predictors for the expected DEADLINES. UNSCHED acts as a surrogate usage term within the model. The estimated expected DEADLINES increases with SCHED, until SCHED reaches four, after which the estimated mean number of deadline events decreases. Without the presence of a true measurement of vehicle usage, the insight gained from this chapter is limited. The absence of a usage term makes our models susceptible to the influence of the number of records and the operational tempo of the vehicles observed.

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V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

This thesis evaluates the data quality issues present in Marine Corps maintenance records and develops Poisson generalized linear regression model to identify the most influential predictor variables for the expected number of deadline events. We do not intend to provide a forecasting tool for future deadline events but rather examine trends within the data. Specifically, we consider three questions in our analysis, which we present in this section with our findings.

1. What data quality issues exist in Marine Corps maintenance records?

Vehicle odometer readings, serial numbers, defect codes, and regional codes all contain quality issues which complicate analysis. This finding is consistent with past studies on Marine Corps maintenance records (Reuter, 2007). Quality issues are present in both MIMMS and GCSS_MC data.

2. Is vehicle odometer mileage recorded in MIMMS and GCSS-MC a valid metric for evaluating vehicle reliability and preventive maintenance scheduling?

As shown in Chapter III, vehicle odometer mileage records do not provide a reliable measure of usage. In its current state, the number of errors in the odometer mileage entries precludes its use. The odometer mileage records are shown to suffer from non-monotonic, recurring, erroneous, and missing entries. The degree of inaccuracy within the odometer mileage records hinders imputation.

3. Can a Poisson generalized linear model provide insight into future failures that cause a vehicle to be non-operational?

Without the presence of a true measurement of vehicle usage, the insight gained from fitting Poisson generalized linear model to the maintenance data is limited. Models developed from the aggregation of all MTVR systems found REGACT_CODE, TAMCN, SCHED, and UNSCHED to be significant predictors. UNSCHED acts as a surrogate usage term within the model, increasing the estimated mean number of deadline

events as the number of UNSCHED increase. The estimated expected number of deadline events increases with SCHED, until SCHED reaches four, after which the estimated mean number of deadline events decreases. The absence of a usage term makes our models susceptible to influence of the number of records and the operational tempo of the vehicles observed.

B.   RECOMMENDATIONS FOR FUTURE WORK

Based on the analysis presented in this study, we suggest the following future work to expand this field of research and complement these findings. First, the methodology and models developed in this study should be applied to the GCSS-MC data. GCSS-MC is the current maintenance management system and the models developed using GCSS-MC can be compared to those we developed. This study will provide addition insight into the analytical value of the current state of Marine Corps' maintenance records. Second, a study should be conducted with a subset of the maintenance records where the usage measure is well defined. Defining a set of units in the maintenance data that consistently and accurately record odometer mileage is important to future analysis. If a valid subset of the current maintenance records cannot be found, then a study must be performed to collect the appropriate information. An accurate usage measure will allow for the estimation of vehicle and system mean time between failures. Finally, analysis can be conducted on the maintenance and usage data downloaded from the vehicle's built in computer. Data quality issues attributed to human errors would be eliminated, providing a more truthful representation of a vehicle's history.

APPENDIX A. DEFECT CODES PRESENT IN THE MIMMS DATA

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
111	ANEW	N	7	1	ANEW	ANCILLARY EQUIPMENT/WIRING	11	HOSE	HOSE, TUBING, AND FITTINGS
116	ANEW	N	44	1	ANEW	ANCILLARY EQUIPMENT/WIRING	16	SEAL	PACKING, SEALS, AND GASKETS
117	ANEW	N	3	1	ANEW	ANCILLARY EQUIPMENT/WIRING	17	PUMP	PUMPS AND COMPONENTS
134	ANEW	N	89	1	ANEW	ANCILLARY EQUIPMENT/WIRING	34	RPLC	REPLACE
148	ANEW	N	4	1	ANEW	ANCILLARY EQUIPMENT/WIRING	48	CBB	CRACKED, BROKEN, OR BENT
155	ANEW	N	29	1	ANEW	ANCILLARY EQUIPMENT/WIRING	55	INOP	INOPERATIVE
156	ANEW	N	11	1	ANEW	ANCILLARY EQUIPMENT/WIRING	56	MINR	MINOR
160	ANEW	N	4	1	ANEW	ANCILLARY EQUIPMENT/WIRING	60	SAFDL	SAFETY DEADLINE
163	ANEW	N	19	1	ANEW	ANCILLARY EQUIPMENT/WIRING	63	EXSYS	EXHUAST SYSTEM
164	ANEW	Y	7	1	ANEW	ANCILLARY EQUIPMENT/WIRING	64	SL3AP	SL-3 APPLICATION
165	ANEW	N	1	1	ANEW	ANCILLARY EQUIPMENT/WIRING	65	SEW	SEWING RIPS/TORN AREAS
171	ANEW	N	3	1	ANEW	ANCILLARY EQUIPMENT/WIRING	71	RPR	REPAIR
1	ANEW	N	21	1	ANEW	ANCILLARY EQUIPMENT/WIRING			NOT GIVEN
222	TEDD	N	54	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	22	STEER	STEERING COMPONENTS
223	TEDD	N	17	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	23	VALV	VALVES AND VALVE COMPONENTS
227	TEDD	N	27	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	27	UNK	UNKNOWN
234	TEDD	N	29	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	34	RPLC	REPLACE
244	TEDD	N	598	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	44	ALGN	SYSTEM ALIGNMENT
248	TEDD	N	4	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	48	CBB	CRACKED, BROKEN, OR BENT
250	TEDD	N	29	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	50	COTO	COMPONENTS OUT OF TOLERANCE
252	TEDD	Y	65	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
255	TEDD	N	3	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	55	INOP	INOPERATIVE
256	TEDD	N	8	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	56	MINR	MINOR
257	TEDD	N	156	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	57	ADJS	ADJUST
260	TEDD	N	1	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	60	SAFDL	SAFETY DEADLINE
268	TEDD	Y	263	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	68	CAL	CALIBRATION
269	TEDD	Y	21	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	69	SPM	SCHEDULED PREVENTIVE MAINTENANCE
271	TEDD	N	26	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES	71	RPR	REPAIR
2	TEDD	N	83	2	TEDD	TEST EQUIPMENT/DISPLAY DEVICES			NOT GIVEN
305	A/C	N	42	3	A/C	AIR CONDITIONERS	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
306	A/C	N	71	3	A/C	AIR CONDITIONERS	6	CONT	CONTROL MECHANISMS
308	A/C	N	62	3	A/C	AIR CONDITIONERS	8	DIST	DISTRIBUTION SYSTEMS
311	A/C	N	54	3	A/C	AIR CONDITIONERS	11	HOSE	HOSE, TUBING, AND FITTINGS
314	A/C	N	53	3	A/C	AIR CONDITIONERS	14	MDRV	MECHANICAL DRIVE SYSTEMS
317	A/C	N	255	3	A/C	AIR CONDITIONERS	17	PUMP	PUMPS AND COMPONENTS
319	A/C	N	7	3	A/C	AIR CONDITIONERS	19	REG	REGULATOR MECHANISMS
321	A/C	N	25	3	A/C	AIR CONDITIONERS	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
323	A/C	N	3	3	A/C	AIR CONDITIONERS	23	VALV	VALVES AND VALVE COMPONENTS
327	A/C	N	205	3	A/C	AIR CONDITIONERS	27	UNK	UNKNOWN
330	A/C	N	31	3	A/C	AIR CONDITIONERS	30	AUX	AUXILIARY
333	A/C	N	1	3	A/C	AIR CONDITIONERS	33	HVSWR	HIGH VOLTAGE STANDING WAVE RATIO
334	A/C	N	1404	3	A/C	AIR CONDITIONERS	34	RPLC	REPLACE
335	A/C	N	63	3	A/C	AIR CONDITIONERS	35	FREQ	FREQUENCY SHIFT/STABILITY
337	A/C	N	25	3	A/C	AIR CONDITIONERS	37	CABL	CABLING MALFUNCTION
341	A/C	N	9	3	A/C	AIR CONDITIONERS	41	SHORT	SHORTED/LOW RESISTIVE CIRCUITRY
342	A/C	N	27	3	A/C	AIR CONDITIONERS	42	MECH	MECHANICAL/LINKAGE OR DRIVE
344	A/C	N	1	3	A/C	AIR CONDITIONERS	44	ALGN	SYSTEM ALIGNMENT
348	A/C	N	296	3	A/C	AIR CONDITIONERS	48	CBB	CRACKED, BROKEN, OR BENT
350	A/C	N	254	3	A/C	AIR CONDITIONERS	50	COTO	COMPONENTS OUT OF TOLERANCE
352	A/C	Y	2	3	A/C	AIR CONDITIONERS	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
353	A/C	Y	2	3	A/C	AIR CONDITIONERS	53	SAPM	SEMIANNUAL SCHEDULED PREVENTIVE MAINTENANCE
354	A/C	N	1	3	A/C	AIR CONDITIONERS	54	N/A	NOT APPLICABLE
355	A/C	N	10775	3	A/C	AIR CONDITIONERS	55	INOP	INOPERATIVE
356	A/C	N	197	3	A/C	AIR CONDITIONERS	56	MINR	MINOR
357	A/C	N	248	3	A/C	AIR CONDITIONERS	57	ADJS	ADJUST
358	A/C	N	16	3	A/C	AIR CONDITIONERS	58	MOIST	MOISTURE FOUND
359	A/C	N	1	3	A/C	AIR CONDITIONERS	59	ARCB	ARCING/BURNT COMPONENTS
360	A/C	N	8	3	A/C	AIR CONDITIONERS	60	SAFDL	SAFETY DEADLINE
362	A/C	N	1	3	A/C	AIR CONDITIONERS	62	BTRY	BATTERY
367	A/C	Y	3	3	A/C	AIR CONDITIONERS	67	MODAP	MODIFICATION APPLICATION
369	A/C	Y	5	3	A/C	AIR CONDITIONERS	69	SPM	SCHEDULED PREVENTIVE MAINTENANCE
371	A/C	N	572	3	A/C	AIR CONDITIONERS	71	RPR	REPAIR
3	A/C	N	53	3	A/C	AIR CONDITIONERS			NOT GIVEN
401	COMP	N	201	4	COMP	COMPONENT	1	ALGEN	ALTERNATOR, GENERATOR MECHANISM
402	COMP	N	280	4	COMP	COMPONENT	2	BRK	BRAKE SYSTEMS AND COMPONENTS
404	COMP	N	236	4	COMP	COMPONENT	4	CARR	CARRIAGE AND MOUNT MECHANISM
405	COMP	N	1	4	COMP	COMPONENT	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
406	COMP	N	116	4	COMP	COMPONENT	6	CONT	CONTROL MECHANISMS
407	COMP	N	45	4	COMP	COMPONENT	7	CYL	CYLINDERS, ACCUMULATORS, AND REPLENISHERS
411	COMP	N	38	4	COMP	COMPONENT	11	HOSE	HOSE, TUBING, AND FITTINGS
412	COMP	N	82	4	COMP	COMPONENT	12	HOUS	HOUSING AND CASTINGS
414	COMP	N	126	4	COMP	COMPONENT	14	MDRV	MECHANICAL DRIVE SYSTEMS
416	COMP	N	113	4	COMP	COMPONENT	16	SEAL	PACKING, SEALS, AND GASKETS
417	COMP	N	84	4	COMP	COMPONENT	17	PUMP	PUMPS AND COMPONENTS

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
418	COMP	N	7	4	COMP	COMPONENT	18	RECL	RECOIL MECHANISM
419	COMP	N	31	4	COMP	COMPONENT	19	REG	REGULATOR MECHANISMS
420	COMP	N	7	4	COMP	COMPONENT	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
422	COMP	N	809	4	COMP	COMPONENT	22	STEER	STEERING COMPONENTS
423	COMP	N	13	4	COMP	COMPONENT	23	VALV	VALVES AND VALVE COMPONENTS
425	COMP	N	1239	4	COMP	COMPONENT	25	GLASS	GLASS REPLACEMENT
426	COMP	Y	4	4	COMP	COMPONENT	26	PAINT	PAINTING, BODY WORK
427	COMP	N	32	4	COMP	COMPONENT	27	UNK	UNKNOWN
430	COMP	N	48	4	COMP	COMPONENT	30	AUX	AUXILIARY
431	COMP	N	10	4	COMP	COMPONENT	31	OVRHL	OVERHAUL
434	COMP	N	8825	4	COMP	COMPONENT	34	RPLC	REPLACE
436	COMP	N	1	4	COMP	COMPONENT	36	ADJS	SUBASSEMBLY ADJUSTMENT
437	COMP	N	26	4	COMP	COMPONENT	37	CABL	CABLING MALFUNCTION
440	COMP	N	21	4	COMP	COMPONENT	40	OPEN	OPEN/HIGH RESISTIVE CIRCUITRY
442	COMP	N	110	4	COMP	COMPONENT	42	MECH	MECHANICAL/LINKAGE OR DRIVE
444	COMP	N	49	4	COMP	COMPONENT	44	ALGN	SYSTEM ALIGNMENT
446	COMP	N	0	4	COMP	COMPONENT	46	LVPS	LOW VOLTAGE POWER SUPPLY
448	COMP	N	2556	4	COMP	COMPONENT	48	CBB	CRACKED, BROKEN, OR BENT
450	COMP	N	44	4	COMP	COMPONENT	50	COTO	COMPONENTS OUT OF TOLERANCE
452	COMP	Y	2	4	COMP	COMPONENT	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
454	COMP	N	8	4	COMP	COMPONENT	54	N/A	NOT APPLICABLE
455	COMP	N	1891	4	COMP	COMPONENT	55	INOP	INOPERATIVE
456	COMP	N	193	4	COMP	COMPONENT	56	MINR	MINOR
457	COMP	N	203	4	COMP	COMPONENT	57	ADJS	ADJUST
458	COMP	N	104	4	COMP	COMPONENT	58	MOIST	MOISTURE FOUND
460	COMP	N	420	4	COMP	COMPONENT	60	SAFDL	SAFETY DEADLINE
461	COMP	N	33	4	COMP	COMPONENT	61	START	STARTER
462	COMP	N	38	4	COMP	COMPONENT	62	BTRY	BATTERY
463	COMP	N	77	4	COMP	COMPONENT	63	EXSYS	EXHUAST SYSTEM
464	COMP	Y	1829	4	COMP	COMPONENT	64	SL3AP	SL-3 APPLICATION
465	COMP	N	234	4	COMP	COMPONENT	65	SEW	SEWING RIPS/TORN AREAS
466	COMP	Y	15	4	COMP	COMPONENT	66	FAB	FABRICATION
467	COMP	Y	566	4	COMP	COMPONENT	67	MODAP	MODIFICATION APPLICATION
470	COMP	Y	63	4	COMP	COMPONENT	70	LTI	ACCEPTANCE/LIMITED TECHNICAL INSPECTION
471	COMP	N	448	4	COMP	COMPONENT	71	RPR	REPAIR
4	COMP	N	432	4	COMP	COMPONENT			NOT GIVEN
524	TEXT	N	4	5	TEXT	TEXTILES	24	TORS	TORSION COMPONENTS
534	TEXT	N	28	5	TEXT	TEXTILES	34	RPLC	REPLACE
548	TEXT	N	1	5	TEXT	TEXTILES	48	CBB	CRACKED, BROKEN, OR BENT
556	TEXT	N	1	5	TEXT	TEXTILES	56	MINR	MINOR
565	TEXT	N	81	5	TEXT	TEXTILES	65	SEW	SEWING RIPS/TORN AREAS
571	TEXT	N	2	5	TEXT	TEXTILES	71	RPR	REPAIR
614	CANV	N	30	6	CANV	CANVAS	14	MDRV	MECHANICAL DRIVE SYSTEMS
626	CANV	Y	38	6	CANV	CANVAS	26	PAINT	PAINTING, BODY WORK
634	CANV	N	1353	6	CANV	CANVAS	34	RPLC	REPLACE
638	CANV	N	1	6	CANV	CANVAS	38	LPO	LOW POWER OUT
648	CANV	N	47	6	CANV	CANVAS	48	CBB	CRACKED, BROKEN, OR BENT
654	CANV	N	7	6	CANV	CANVAS	54	N/A	NOT APPLICABLE
656	CANV	N	98	6	CANV	CANVAS	56	MINR	MINOR
664	CANV	Y	247	6	CANV	CANVAS	64	SL3AP	SL-3 APPLICATION
665	CANV	N	203	6	CANV	CANVAS	65	SEW	SEWING RIPS/TORN AREAS
666	CANV	Y	1	6	CANV	CANVAS	66	FAB	FABRICATION
6	CANV	N	173	6	CANV	CANVAS			NOT GIVEN
722	AXLE	N	5	7		UNKNOWN	22	STEER	STEERING COMPONENTS
726	BODY	Y	843	7		UNKNOWN	26	PAINT	PAINTING, BODY WORK
748	BODY	N	27	7		UNKNOWN	48	CBB	CRACKED, BROKEN, OR BENT
A01	ENG	N	122	A	ENG	ENGINE	1	ALGEN	ALTERNATOR, GENERATOR MECHANISM
A02	ENG	N	1	A	ENG	ENGINE	2	BRK	BRAKE SYSTEMS AND COMPONENTS
A04	ENG	N	24	A	ENG	ENGINE	4	CARR	CARRIAGE AND MOUNT MECHANISM
A05	ENG	N	44	A	ENG	ENGINE	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
A06	ENG	N	187	A	ENG	ENGINE	6	CONT	CONTROL MECHANISMS
A07	ENG	N	12	A	ENG	ENGINE	7	CYL	CYLINDERS, ACCUMULATORS, AND REPLENISHERS
A08	ENG	N	89	A	ENG	ENGINE	8	DIST	DISTRIBUTION SYSTEMS
A09	ENG	N	6	A	ENG	ENGINE	9	ELTR	ELEVATION AND TRAVERSING MECHANISMS
A11	ENG	N	3143	A	ENG	ENGINE	11	HOSE	HOSE, TUBING, AND FITTINGS
A12	ENG	N	204	A	ENG	ENGINE	12	HOUS	HOUSING AND CASTINGS
A13	ENG	N	297	A	ENG	ENGINE	13	INJEC	INJECTOR SYSTEMS
A14	ENG	N	1579	A	ENG	ENGINE	14	MDRV	MECHANICAL DRIVE SYSTEMS
A16	ENG	N	3054	A	ENG	ENGINE	16	SEAL	PACKING, SEALS, AND GASKETS
A17	ENG	N	363	A	ENG	ENGINE	17	PUMP	PUMPS AND COMPONENTS
A19	ENG	N	30	A	ENG	ENGINE	19	REG	REGULATOR MECHANISMS
A21	ENG	N	489	A	ENG	ENGINE	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
A22	ENG	N	89	A	ENG	ENGINE	22	STEER	STEERING COMPONENTS
A23	ENG	N	138	A	ENG	ENGINE	23	VALV	VALVES AND VALVE COMPONENTS
A24	ENG	N	26	A	ENG	ENGINE	24	TORS	TORSION COMPONENTS
A27	ENG	N	469	A	ENG	ENGINE	27	UNK	UNKNOWN
A29	ENG	N	38	A	ENG	ENGINE	29	UNAUT	ABUSE/UNAUTHORIZED MAINTENANCE
A30	ENG	N	117	A	ENG	ENGINE	30	AUX	AUXILIARY
A31	ENG	N	4	A	ENG	ENGINE	31	OVRHL	OVERHAUL
A33	ENG	N	7	A	ENG	ENGINE	33	HVSWR	HIGH VOLTAGE STANDING WAVE RATIO
A34	ENG	N	4797	A	ENG	ENGINE	34	RPLC	REPLACE
A36	ENG	N	21	A	ENG	ENGINE	36	ADJS	SUBASSEMBLY ADJUSTMENT
A37	ENG	N	69	A	ENG	ENGINE	37	CABL	CABLING MALFUNCTION
A38	ENG	N	117	A	ENG	ENGINE	38	LPO	LOW POWER OUT

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
C52	PWRP	Y	1	C	PWRP	POWER PACK	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
C56	PWRP	N	4	C	PWRP	POWER PACK	56	MINR	MINOR
C58	PWRP	N	29	C	PWRP	POWER PACK	58	MOIST	MOISTURE FOUND
C62	PWRP	N	16	C	PWRP	POWER PACK	62	BTRY	BATTERY
D02	PWRT	N	258	D	PWRT	POWER TRAIN	2	BRK	BRAKE SYSTEMS AND COMPONENTS
D05	PWRT	N	28	D	PWRT	POWER TRAIN	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
D08	PWRT	N	36	D	PWRT	POWER TRAIN	8	DIST	DISTRIBUTION SYSTEMS
D11	PWRT	N	156	D	PWRT	POWER TRAIN	11	HOSE	HOSE, TUBING, AND FITTINGS
D12	PWRT	N	7	D	PWRT	POWER TRAIN	12	HOUS	HOUSING AND CASTINGS
D13	PWRT	N	38	D	PWRT	POWER TRAIN	13	INJEC	INJECTOR SYSTEMS
D14	PWRT	N	636	D	PWRT	POWER TRAIN	14	MDRV	MECHANICAL DRIVE SYSTEMS
D16	PWRT	N	3137	D	PWRT	POWER TRAIN	16	SEAL	PACKING, SEALS, AND GASKETS
D17	PWRT	N	103	D	PWRT	POWER TRAIN	17	PUMP	PUMPS AND COMPONENTS
D21	PWRT	N	618	D	PWRT	POWER TRAIN	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
D22	PWRT	N	230	D	PWRT	POWER TRAIN	22	STEER	STEERING COMPONENTS
D23	PWRT	N	29	D	PWRT	POWER TRAIN	23	VALV	VALVES AND VALVE COMPONENTS
D24	PWRT	N	46	D	PWRT	POWER TRAIN	24	TORS	TORSION COMPONENTS
D27	PWRT	N	1	D	PWRT	POWER TRAIN	27	UNK	UNKNOWN
D30	PWRT	N	48	D	PWRT	POWER TRAIN	30	AUX	AUXILIARY
D31	PWRT	N	7	D	PWRT	POWER TRAIN	31	OVRHL	OVERHAUL
D34	PWRT	N	1860	D	PWRT	POWER TRAIN	34	RPLC	REPLACE
D35	PWRT	N	57	D	PWRT	POWER TRAIN	35	FREQ	FREQUENCY SHIFT/STABILITY
D39	PWRT	N	4	D	PWRT	POWER TRAIN	39	CORR	CORRODED/RUSTED
D42	PWRT	N	72	D	PWRT	POWER TRAIN	42	MECH	MECHANICAL/LINKAGE OR DRIVE
D43	PWRT	N	7	D	PWRT	POWER TRAIN	43	ACDCS	ALTERNATING CURRENT/DIRECT CURRENT SOURCE
D48	PWRT	N	633	D	PWRT	POWER TRAIN	48	CBB	CRACKED, BROKEN, OR BENT
D50	PWRT	N	2	D	PWRT	POWER TRAIN	50	COTO	COMPONENTS OUT OF TOLERANCE
D51	PWRT	Y	15	D	PWRT	POWER TRAIN	51	QSPM	QUARTERLY SCHEDULED PREVENTIVE MAINTENANCE
D52	PWRT	Y	127	D	PWRT	POWER TRAIN	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
D53	PWRT	Y	16	D	PWRT	POWER TRAIN	53	SAPM	SEMIANNUAL SCHEDULED PREVENTIVE MAINTENANCE
D54	PWRT	N	13	D	PWRT	POWER TRAIN	54	N/A	NOT APPLICABLE
D55	PWRT	N	276	D	PWRT	POWER TRAIN	55	INOP	INOPERATIVE
D56	PWRT	N	6	D	PWRT	POWER TRAIN	56	MINR	MINOR
D57	PWRT	N	34	D	PWRT	POWER TRAIN	57	ADJS	ADJUST
D58	PWRT	N	438	D	PWRT	POWER TRAIN	58	MOIST	MOISTURE FOUND
D71	PWRT	N	76	D	PWRT	POWER TRAIN	71	RPR	REPAIR
D	PWRT	N	127	D	PWRT	POWER TRAIN			NOT GIVEN
E01	AXLE	N	17	E	AXLE	AXLE SYSTEM	1	ALGEN	ALTERNATOR, GENERATOR MECHANISM
E02	AXLE	N	2939	E	AXLE	AXLE SYSTEM	2	BRK	BRAKE SYSTEMS AND COMPONENTS
E03	AXLE	N	13	E	AXLE	AXLE SYSTEM	3	CARB	CARBURETION SYSTEM
E04	AXLE	N	95	E	AXLE	AXLE SYSTEM	4	CARR	CARRIAGE AND MOUNT MECHANISM
E06	AXLE	N	111	E	AXLE	AXLE SYSTEM	6	CONT	CONTROL MECHANISMS
E08	AXLE	N	15	E	AXLE	AXLE SYSTEM	8	DIST	DISTRIBUTION SYSTEMS
E10	AXLE	N	1	E	AXLE	AXLE SYSTEM	10	GUN	GUN TUBE, BREECH, AND FIRING MECHANISMS
E11	AXLE	N	251	E	AXLE	AXLE SYSTEM	11	HOSE	HOSE, TUBING, AND FITTINGS
E12	AXLE	N	655	E	AXLE	AXLE SYSTEM	12	HOUS	HOUSING AND CASTINGS
E14	AXLE	N	1243	E	AXLE	AXLE SYSTEM	14	MDRV	MECHANICAL DRIVE SYSTEMS
E15	AXLE	N	5	E	AXLE	AXLE SYSTEM	15	OPTIC	OPTICS SYSTEMS AND COMPONENTS
E16	AXLE	N	22335	E	AXLE	AXLE SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
E17	AXLE	N	198	E	AXLE	AXLE SYSTEM	17	PUMP	PUMPS AND COMPONENTS
E19	AXLE	N	6	E	AXLE	AXLE SYSTEM	19	REG	REGULATOR MECHANISMS
E20	AXLE	N	1143	E	AXLE	AXLE SYSTEM	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
E21	AXLE	N	606	E	AXLE	AXLE SYSTEM	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
E22	AXLE	N	4887	E	AXLE	AXLE SYSTEM	22	STEER	STEERING COMPONENTS
E23	AXLE	N	70	E	AXLE	AXLE SYSTEM	23	VALV	VALVES AND VALVE COMPONENTS
E27	AXLE	N	84	E	AXLE	AXLE SYSTEM	27	UNK	UNKNOWN
E28	AXLE	N	1	E	AXLE	AXLE SYSTEM	28	LKPM	LACK OF PREVENTIVE MAINTENANCE
E31	AXLE	N	30	E	AXLE	AXLE SYSTEM	31	OVRHL	OVERHAUL
E32	AXLE	N	7	E	AXLE	AXLE SYSTEM	32	REFP	REFLECTED POWER
E34	AXLE	N	9807	E	AXLE	AXLE SYSTEM	34	RPLC	REPLACE
E35	AXLE	N	1	E	AXLE	AXLE SYSTEM	35	FREQ	FREQUENCY SHIFT/STABILITY
E38	AXLE	N	6	E	AXLE	AXLE SYSTEM	38	LPO	LOW POWER OUT
E39	AXLE	N	18	E	AXLE	AXLE SYSTEM	39	CORR	CORRODED/RUSTED
E42	AXLE	N	286	E	AXLE	AXLE SYSTEM	42	MECH	MECHANICAL/LINKAGE OR DRIVE
E44	AXLE	N	36	E	AXLE	AXLE SYSTEM	44	ALGN	SYSTEM ALIGNMENT
E45	AXLE	N	5	E	AXLE	AXLE SYSTEM	45	MODUL	MODULATOR
E46	AXLE	N	2	E	AXLE	AXLE SYSTEM	46	LVPS	LOW VOLTAGE POWER SUPPLY
E48	AXLE	N	4420	E	AXLE	AXLE SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
E50	AXLE	N	34	E	AXLE	AXLE SYSTEM	50	COTO	COMPONENTS OUT OF TOLERANCE
E51	AXLE	Y	1	E	AXLE	AXLE SYSTEM	51	QSPM	QUARTERLY SCHEDULED PREVENTIVE MAINTENANCE
E54	AXLE	N	203	E	AXLE	AXLE SYSTEM	54	N/A	NOT APPLICABLE
E55	AXLE	N	629	E	AXLE	AXLE SYSTEM	55	INOP	INOPERATIVE
E56	AXLE	N	499	E	AXLE	AXLE SYSTEM	56	MINR	MINOR
E57	AXLE	N	63	E	AXLE	AXLE SYSTEM	57	ADJS	ADJUST
E58	AXLE	N	1083	E	AXLE	AXLE SYSTEM	58	MOIST	MOISTURE FOUND
E60	AXLE	N	128	E	AXLE	AXLE SYSTEM	60	SAFDL	SAFETY DEADLINE
E62	AXLE	N	1	E	AXLE	AXLE SYSTEM	62	BTRY	BATTERY
E64	AXLE	Y	2	E	AXLE	AXLE SYSTEM	64	SL3AP	SL-3 APPLICATION
E65	AXLE	N	110	E	AXLE	AXLE SYSTEM	65	SEW	SEWING RIPS/TORN AREAS
E67	AXLE	Y	18	E	AXLE	AXLE SYSTEM	67	MODAP	MODIFICATION APPLICATION
E71	AXLE	N	900	E	AXLE	AXLE SYSTEM	71	RPR	REPAIR
E	AXLE	N	836	E	AXLE	AXLE SYSTEM			NOT GIVEN
F02	SUSP	N	57	F	SUSP	SUSPENSION SYSTEM	2	BRK	BRAKE SYSTEMS AND COMPONENTS
F04	SUSP	N	38	F	SUSP	SUSPENSION SYSTEM	4	CARR	CARRIAGE AND MOUNT MECHANISM

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
F06	SUSP	N	163	F	SUSP	SUSPENSION SYSTEM	6	CONT	CONTROL MECHANISMS
F07	SUSP	N	22	F	SUSP	SUSPENSION SYSTEM	7	CYL	CYLINDERS, ACCUMULATORS, AND REPLENISHERS
F08	SUSP	N	74	F	SUSP	SUSPENSION SYSTEM	8	DIST	DISTRIBUTION SYSTEMS
F11	SUSP	N	90	F	SUSP	SUSPENSION SYSTEM	11	HOSE	HOSE, TUBING, AND FITTINGS
F12	SUSP	N	233	F	SUSP	SUSPENSION SYSTEM	12	HOUS	HOUSING AND CASTINGS
F14	SUSP	N	71	F	SUSP	SUSPENSION SYSTEM	14	MDRV	MECHANICAL DRIVE SYSTEMS
F16	SUSP	N	3160	F	SUSP	SUSPENSION SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
F17	SUSP	N	65	F	SUSP	SUSPENSION SYSTEM	17	PUMP	PUMPS AND COMPONENTS
F18	SUSP	N	18	F	SUSP	SUSPENSION SYSTEM	18	RECL	RECOIL MECHANISM
F19	SUSP	N	1	F	SUSP	SUSPENSION SYSTEM	19	REG	REGULATOR MECHANISMS
F20	SUSP	N	4412	F	SUSP	SUSPENSION SYSTEM	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
F21	SUSP	N	55	F	SUSP	SUSPENSION SYSTEM	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
F22	SUSP	N	1832	F	SUSP	SUSPENSION SYSTEM	22	STEER	STEERING COMPONENTS
F24	SUSP	N	25	F	SUSP	SUSPENSION SYSTEM	24	TORS	TORSION COMPONENTS
F27	SUSP	N	8	F	SUSP	SUSPENSION SYSTEM	27	UNK	UNKNOWN
F31	SUSP	N	13	F	SUSP	SUSPENSION SYSTEM	31	OVRHL	OVERHAUL
F34	SUSP	N	4500	F	SUSP	SUSPENSION SYSTEM	34	RPLC	REPLACE
F42	SUSP	N	40	F	SUSP	SUSPENSION SYSTEM	42	MECH	MECHANICAL/LINKAGE OR DRIVE
F44	SUSP	N	9	F	SUSP	SUSPENSION SYSTEM	44	ALGN	SYSTEM ALIGNMENT
F48	SUSP	N	1926	F	SUSP	SUSPENSION SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
F50	SUSP	N	18	F	SUSP	SUSPENSION SYSTEM	50	COTO	COMPONENTS OUT OF TOLERANCE
F52	SUSP	Y	13	F	SUSP	SUSPENSION SYSTEM	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
F54	SUSP	N	33	F	SUSP	SUSPENSION SYSTEM	54	N/A	NOT APPLICABLE
F55	SUSP	N	1857	F	SUSP	SUSPENSION SYSTEM	55	INOP	INOPERATIVE
F56	SUSP	N	137	F	SUSP	SUSPENSION SYSTEM	56	MINR	MINOR
F57	SUSP	N	41	F	SUSP	SUSPENSION SYSTEM	57	ADJS	ADJUST
F58	SUSP	N	40	F	SUSP	SUSPENSION SYSTEM	58	MOIST	MOISTURE FOUND
F60	SUSP	N	73	F	SUSP	SUSPENSION SYSTEM	60	SAFDL	SAFETY DEADLINE
F62	SUSP	N	12	F	SUSP	SUSPENSION SYSTEM	62	BTRY	BATTERY
F65	SUSP	N	52	F	SUSP	SUSPENSION SYSTEM	65	SEW	SEWING RIPS/TORN AREAS
F66	SUSP	Y	5	F	SUSP	SUSPENSION SYSTEM	66	FAB	FABRICATION
F67	SUSP	Y	17	F	SUSP	SUSPENSION SYSTEM	67	MODAP	MODIFICATION APPLICATION
F71	SUSP	N	230	F	SUSP	SUSPENSION SYSTEM	71	RPR	REPAIR
F	SUSP	N	260	F	SUSP	SUSPENSION SYSTEM			NOT GIVEN
G02	TRAC	N	67	G	TRAC	TRACK CRAWLER SYSTEM	2	BRK	BRAKE SYSTEMS AND COMPONENTS
G16	TRAC	N	5	G	TRAC	TRACK CRAWLER SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
G34	TRAC	N	43	G	TRAC	TRACK CRAWLER SYSTEM	34	RPLC	REPLACE
G48	TRAC	N	10	G	TRAC	TRACK CRAWLER SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
G71	TRAC	N	55	G	TRAC	TRACK CRAWLER SYSTEM	71	RPR	REPAIR
H02	BODY	N	4	H	BODY	BODY, FRAME, OR HULL	2	BRK	BRAKE SYSTEMS AND COMPONENTS
H04	BODY	N	910	H	BODY	BODY, FRAME, OR HULL	4	CARR	CARRIAGE AND MOUNT MECHANISM
H05	BODY	N	33	H	BODY	BODY, FRAME, OR HULL	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
H06	BODY	N	230	H	BODY	BODY, FRAME, OR HULL	6	CONT	CONTROL MECHANISMS
H08	BODY	N	20	H	BODY	BODY, FRAME, OR HULL	8	DIST	DISTRIBUTION SYSTEMS
H09	BODY	N	165	H	BODY	BODY, FRAME, OR HULL	9	ELTR	ELEVATION AND TRAVERSING MECHANISMS
H11	BODY	N	36	H	BODY	BODY, FRAME, OR HULL	11	HOSE	HOSE, TUBING, AND FITTINGS
H12	BODY	N	145	H	BODY	BODY, FRAME, OR HULL	12	HOUS	HOUSING AND CASTINGS
H14	BODY	N	10	H	BODY	BODY, FRAME, OR HULL	14	MDRV	MECHANICAL DRIVE SYSTEMS
H16	BODY	N	185	H	BODY	BODY, FRAME, OR HULL	16	SEAL	PACKING, SEALS, AND GASKETS
H17	BODY	N	28	H	BODY	BODY, FRAME, OR HULL	17	PUMP	PUMPS AND COMPONENTS
H18	BODY	N	107	H	BODY	BODY, FRAME, OR HULL	18	RECL	RECOIL MECHANISM
H19	BODY	N	1	H	BODY	BODY, FRAME, OR HULL	19	REG	REGULATOR MECHANISMS
H20	BODY	N	354	H	BODY	BODY, FRAME, OR HULL	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
H21	BODY	N	15	H	BODY	BODY, FRAME, OR HULL	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
H22	BODY	N	243	H	BODY	BODY, FRAME, OR HULL	22	STEER	STEERING COMPONENTS
H23	BODY	N	21	H	BODY	BODY, FRAME, OR HULL	23	VALV	VALVES AND VALVE COMPONENTS
H25	BODY	N	6457	H	BODY	BODY, FRAME, OR HULL	25	GLASS	GLASS REPLACEMENT
H26	BODY	Y	3460	H	BODY	BODY, FRAME, OR HULL	26	PAINT	PAINTING, BODY WORK
H27	BODY	N	85	H	BODY	BODY, FRAME, OR HULL	27	UNK	UNKNOWN
H28	BODY	N	24	H	BODY	BODY, FRAME, OR HULL	28	LKPM	LACK OF PREVENTIVE MAINTENANCE
H29	BODY	N	48	H	BODY	BODY, FRAME, OR HULL	29	UNAUT	ABUSE/UNAUTHORIZED MAINTENANCE
H30	BODY	N	11	H	BODY	BODY, FRAME, OR HULL	30	AUX	AUXILIARY
H31	BODY	N	5334	H	BODY	BODY, FRAME, OR HULL	31	OVRHL	OVERHAUL
H32	BODY	N	78	H	BODY	BODY, FRAME, OR HULL	32	REFP	REFLECTED POWER
H34	BODY	N	19860	H	BODY	BODY, FRAME, OR HULL	34	RPLC	REPLACE
H35	BODY	N	68	H	BODY	BODY, FRAME, OR HULL	35	FREQ	FREQUENCY SHIFT/STABILITY
H36	BODY	N	52	H	BODY	BODY, FRAME, OR HULL	36	ADJS	SUBASSEMBLY ADJUSTMENT
H37	BODY	N	3	H	BODY	BODY, FRAME, OR HULL	37	CABL	CABLING MALFUNCTION
H38	BODY	N	30	H	BODY	BODY, FRAME, OR HULL	38	LPO	LOW POWER OUT
H39	BODY	N	475	H	BODY	BODY, FRAME, OR HULL	39	CORR	CORRODED/RUSTED
H40	BODY	N	22	H	BODY	BODY, FRAME, OR HULL	40	OPEN	OPEN/HIGH RESISTIVE CIRCUITRY
H41	BODY	N	3	H	BODY	BODY, FRAME, OR HULL	41	SHORT	SHORTED/LOW RESISTIVE CIRCUITRY
H42	BODY	N	449	H	BODY	BODY, FRAME, OR HULL	42	MECH	MECHANICAL/LINKAGE OR DRIVE
H44	BODY	N	5	H	BODY	BODY, FRAME, OR HULL	44	ALGN	SYSTEM ALIGNMENT
H48	BODY	N	14037	H	BODY	BODY, FRAME, OR HULL	48	CBB	CRACKED, BROKEN, OR BENT
H50	BODY	N	154	H	BODY	BODY, FRAME, OR HULL	50	COTO	COMPONENTS OUT OF TOLERANCE
H51	BODY	Y	1	H	BODY	BODY, FRAME, OR HULL	51	QSPM	QUARTERLY SCHEDULED PREVENTIVE MAINTENANCE
H52	BODY	Y	23	H	BODY	BODY, FRAME, OR HULL	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
H54	BODY	N	56	H	BODY	BODY, FRAME, OR HULL	54	N/A	NOT APPLICABLE
H55	BODY	N	875	H	BODY	BODY, FRAME, OR HULL	55	INOP	INOPERATIVE
H56	BODY	N	8948	H	BODY	BODY, FRAME, OR HULL	56	MINR	MINOR
H57	BODY	N	359	H	BODY	BODY, FRAME, OR HULL	57	ADJS	ADJUST
H58	BODY	N	11	H	BODY	BODY, FRAME, OR HULL	58	MOIST	MOISTURE FOUND
H59	BODY	N	29	H	BODY	BODY, FRAME, OR HULL	59	ARCB	ARCING/BURNT COMPONENTS

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
H60	BODY	N	547	H	BODY	BODY, FRAME, OR HULL	60	SAFDL	SAFETY DEADLINE
H62	BODY	N	129	H	BODY	BODY, FRAME, OR HULL	62	BTRY	BATTERY
H63	BODY	N	188	H	BODY	BODY, FRAME, OR HULL	63	EXSYS	EXHAUST SYSTEM
H64	BODY	Y	171	H	BODY	BODY, FRAME, OR HULL	64	SL3AP	SL-3 APPLICATION
H65	BODY	N	97	H	BODY	BODY, FRAME, OR HULL	65	SEW	SEWING RIPS/TORN AREAS
H66	BODY	Y	287	H	BODY	BODY, FRAME, OR HULL	66	FAB	FABRICATION
H67	BODY	Y	3694	H	BODY	BODY, FRAME, OR HULL	67	MODAP	MODIFICATION APPLICATION
H71	BODY	N	373	H	BODY	BODY, FRAME, OR HULL	71	RPR	REPAIR
H	BODY	N	997	H	BODY	BODY, FRAME, OR HULL			NOT GIVEN
I04	ARMT	N	281	I	ARMT	ARMAMENT	4	CARR	CARRIAGE AND MOUNT MECHANISM
I11	ARMT	N	2	I	ARMT	ARMAMENT	11	HOSE	HOSE, TUBING, AND FITTINGS
I12	ARMT	N	152	I	ARMT	ARMAMENT	12	HOUS	HOUSING AND CASTINGS
I16	ARMT	N	1	I	ARMT	ARMAMENT	16	SEAL	PACKING, SEALS, AND GASKETS
I20	ARMT	N	35	I	ARMT	ARMAMENT	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
I25	ARMT	N	766	I	ARMT	ARMAMENT	25	GLASS	GLASS REPLACEMENT
I26	ARMT	Y	169	I	ARMT	ARMAMENT	26	PAINT	PAINTING, BODY WORK
I27	ARMT	N	51	I	ARMT	ARMAMENT	27	UNK	UNKNOWN
I31	ARMT	N	7	I	ARMT	ARMAMENT	31	OVRHL	OVERHAUL
I34	ARMT	N	2351	I	ARMT	ARMAMENT	34	RPLC	REPLACE
I42	ARMT	N	15	I	ARMT	ARMAMENT	42	MECH	MECHANICAL/LINKAGE OR DRIVE
I48	ARMT	N	386	I	ARMT	ARMAMENT	48	CBB	CRACKED, BROKEN, OR BENT
I49	ARMT	N	7	I	ARMT	ARMAMENT	49	GRND	GROUNDED
I50	ARMT	N	57	I	ARMT	ARMAMENT	50	COTO	COMPONENTS OUT OF TOLERANCE
I55	ARMT	N	106	I	ARMT	ARMAMENT	55	INOP	INOPERATIVE
I56	ARMT	N	135	I	ARMT	ARMAMENT	56	MINR	MINOR
I57	ARMT	N	315	I	ARMT	ARMAMENT	57	ADJS	ADJUST
I60	ARMT	N	15	I	ARMT	ARMAMENT	60	SAFDL	SAFETY DEADLINE
I66	ARMT	Y	5	I	ARMT	ARMAMENT	66	FAB	FABRICATION
I67	ARMT	Y	3627	I	ARMT	ARMAMENT	67	MODAP	MODIFICATION APPLICATION
I71	ARMT	N	207	I	ARMT	ARMAMENT	71	RPR	REPAIR
I	ARMT	N	124	I	ARMT	ARMAMENT			NOT GIVEN
J03	COOL	N	1	J	COOL	COOLING SYSTEM	3	CARB	CARBURETION SYSTEM
J04	COOL	N	3	J	COOL	COOLING SYSTEM	4	CARR	CARRIAGE AND MOUNT MECHANISM
J05	COOL	N	464	J	COOL	COOLING SYSTEM	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
J06	COOL	N	275	J	COOL	COOLING SYSTEM	6	CONT	CONTROL MECHANISMS
J07	COOL	N	18	J	COOL	COOLING SYSTEM	7	CYL	CYLINDERS, ACCUMULATORS, AND REPLENISHERS
J11	COOL	N	1468	J	COOL	COOLING SYSTEM	11	HOSE	HOSE, TUBING, AND FITTINGS
J12	COOL	N	96	J	COOL	COOLING SYSTEM	12	HOUS	HOUSING AND CASTINGS
J14	COOL	N	190	J	COOL	COOLING SYSTEM	14	MDRV	MECHANICAL DRIVE SYSTEMS
J16	COOL	N	695	J	COOL	COOLING SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
J17	COOL	N	474	J	COOL	COOLING SYSTEM	17	PUMP	PUMPS AND COMPONENTS
J18	COOL	N	2	J	COOL	COOLING SYSTEM	18	RECL	RECOIL MECHANISM
J19	COOL	N	29	J	COOL	COOLING SYSTEM	19	REG	REGULATOR MECHANISMS
J21	COOL	N	9	J	COOL	COOLING SYSTEM	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
J22	COOL	N	2	J	COOL	COOLING SYSTEM	22	STEER	STEERING COMPONENTS
J27	COOL	N	123	J	COOL	COOLING SYSTEM	27	UNK	UNKNOWN
J28	COOL	N	1	J	COOL	COOLING SYSTEM	28	LKPM	LACK OF PREVENTIVE MAINTENANCE
J31	COOL	N	5	J	COOL	COOLING SYSTEM	31	OVRHL	OVERHAUL
J34	COOL	N	1801	J	COOL	COOLING SYSTEM	34	RPLC	REPLACE
J39	COOL	N	126	J	COOL	COOLING SYSTEM	39	CORR	CORRODED/RUSTED
J41	COOL	N	10	J	COOL	COOLING SYSTEM	41	SHORT	SHORTED/LOW RESISTIVE CIRCUITRY
J42	COOL	N	18	J	COOL	COOLING SYSTEM	42	MECH	MECHANICAL/LINKAGE OR DRIVE
J48	COOL	N	846	J	COOL	COOLING SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
J50	COOL	N	28	J	COOL	COOLING SYSTEM	50	COTO	COMPONENTS OUT OF TOLERANCE
J51	COOL	Y	1	J	COOL	COOLING SYSTEM	51	QSPM	QUARTERLY SCHEDULED PREVENTIVE MAINTENANCE
J53	COOL	Y	31	J	COOL	COOLING SYSTEM	53	SAPM	SEMIANNUAL SCHEDULED PREVENTIVE MAINTENANCE
J55	COOL	N	807	J	COOL	COOLING SYSTEM	55	INOP	INOPERATIVE
J56	COOL	N	62	J	COOL	COOLING SYSTEM	56	MINR	MINOR
J57	COOL	N	169	J	COOL	COOLING SYSTEM	57	ADJS	ADJUST
J58	COOL	N	230	J	COOL	COOLING SYSTEM	58	MOIST	MOISTURE FOUND
J63	COOL	N	4	J	COOL	COOLING SYSTEM	63	EXSYS	EXHUAST SYSTEM
J71	COOL	N	161	J	COOL	COOLING SYSTEM	71	RPR	REPAIR
J	COOL	N	199	J	COOL	COOLING SYSTEM			NOT GIVEN
K01	ELEC	N	1288	K	ELEC	ELECTRICAL SYSTEM	1	ALGEN	ALTERNATOR, GENERATOR MECHANISM
K02	ELEC	N	849	K	ELEC	ELECTRICAL SYSTEM	2	BRK	BRAKE SYSTEMS AND COMPONENTS
K04	ELEC	N	9	K	ELEC	ELECTRICAL SYSTEM	4	CARR	CARRIAGE AND MOUNT MECHANISM
K06	ELEC	N	1622	K	ELEC	ELECTRICAL SYSTEM	6	CONT	CONTROL MECHANISMS
K08	ELEC	N	71	K	ELEC	ELECTRICAL SYSTEM	8	DIST	DISTRIBUTION SYSTEMS
K09	ELEC	N	46	K	ELEC	ELECTRICAL SYSTEM	9	ELTR	ELEVATION AND TRAVERSING MECHANISMS
K10	ELEC	N	12	K	ELEC	ELECTRICAL SYSTEM	10	GUN	GUN TUBE, BREECH, AND FIRING MECHANISMS
K11	ELEC	N	5	K	ELEC	ELECTRICAL SYSTEM	11	HOSE	HOSE, TUBING, AND FITTINGS
K12	ELEC	N	60	K	ELEC	ELECTRICAL SYSTEM	12	HOUS	HOUSING AND CASTINGS
K14	ELEC	N	52	K	ELEC	ELECTRICAL SYSTEM	14	MDRV	MECHANICAL DRIVE SYSTEMS
K15	ELEC	N	2	K	ELEC	ELECTRICAL SYSTEM	15	OPTIC	OPTICS SYSTEMS AND COMPONENTS
K16	ELEC	N	39	K	ELEC	ELECTRICAL SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
K17	ELEC	N	92	K	ELEC	ELECTRICAL SYSTEM	17	PUMP	PUMPS AND COMPONENTS
K19	ELEC	N	123	K	ELEC	ELECTRICAL SYSTEM	19	REG	REGULATOR MECHANISMS
K20	ELEC	N	7	K	ELEC	ELECTRICAL SYSTEM	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
K21	ELEC	N	1	K	ELEC	ELECTRICAL SYSTEM	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
K22	ELEC	N	92	K	ELEC	ELECTRICAL SYSTEM	22	STEER	STEERING COMPONENTS
K23	ELEC	N	27	K	ELEC	ELECTRICAL SYSTEM	23	VALV	VALVES AND VALVE COMPONENTS
K27	ELEC	N	1317	K	ELEC	ELECTRICAL SYSTEM	27	UNK	UNKNOWN
K29	ELEC	N	12	K	ELEC	ELECTRICAL SYSTEM	29	UNAUT	ABUSE/UNAUTHORIZED MAINTENANCE
K30	ELEC	N	72	K	ELEC	ELECTRICAL SYSTEM	30	AUX	AUXILIARY

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
K31	ELEC	N	13	K	ELEC	ELECTRICAL SYSTEM	31	OVRHL	OVERHAUL
K32	ELEC	N	20	K	ELEC	ELECTRICAL SYSTEM	32	REFP	REFLECTED POWER
K34	ELEC	N	17322	K	ELEC	ELECTRICAL SYSTEM	34	RPLC	REPLACE
K35	ELEC	N	123	K	ELEC	ELECTRICAL SYSTEM	35	FREQ	FREQUENCY SHIFT/STABILITY
K36	ELEC	N	123	K	ELEC	ELECTRICAL SYSTEM	36	ADJS	SUBASSEMBLY ADJUSTMENT
K37	ELEC	N	127	K	ELEC	ELECTRICAL SYSTEM	37	CABL	CABLING MALFUNCTION
K38	ELEC	N	87	K	ELEC	ELECTRICAL SYSTEM	38	LPO	LOW POWER OUT
K39	ELEC	N	772	K	ELEC	ELECTRICAL SYSTEM	39	CORR	CORRODED/RUSTED
K40	ELEC	N	1517	K	ELEC	ELECTRICAL SYSTEM	40	OPEN	OPEN/HIGH RESISTIVE CIRCUITRY
K41	ELEC	N	1907	K	ELEC	ELECTRICAL SYSTEM	41	SHORT	SHORTED/LOW RESISTIVE CIRCUITRY
K42	ELEC	N	87	K	ELEC	ELECTRICAL SYSTEM	42	MECH	MECHANICAL/LINKAGE OR DRIVE
K43	ELEC	N	68	K	ELEC	ELECTRICAL SYSTEM	43	ACDCS	ALTERNATING CURRENT/DIRECT CURRENT SOURCE
K45	ELEC	N	217	K	ELEC	ELECTRICAL SYSTEM	45	MODUL	MODULATOR
K46	ELEC	N	144	K	ELEC	ELECTRICAL SYSTEM	46	LVPS	LOW VOLTAGE POWER SUPPLY
K47	ELEC	N	56	K	ELEC	ELECTRICAL SYSTEM	47	HVPS	HIGH VOLTAGE POWER SUPPLY
K48	ELEC	N	1327	K	ELEC	ELECTRICAL SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
K49	ELEC	N	225	K	ELEC	ELECTRICAL SYSTEM	49	GRND	GROUNDED
K50	ELEC	N	377	K	ELEC	ELECTRICAL SYSTEM	50	COTO	COMPONENTS OUT OF TOLERANCE
K52	ELEC	Y	9	K	ELEC	ELECTRICAL SYSTEM	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
K54	ELEC	N	31	K	ELEC	ELECTRICAL SYSTEM	54	N/A	NOT APPLICABLE
K55	ELEC	N	15778	K	ELEC	ELECTRICAL SYSTEM	55	INOP	INOPERATIVE
K56	ELEC	N	2240	K	ELEC	ELECTRICAL SYSTEM	56	MINR	MINOR
K57	ELEC	N	94	K	ELEC	ELECTRICAL SYSTEM	57	ADJS	ADJUST
K58	ELEC	N	2	K	ELEC	ELECTRICAL SYSTEM	58	MOIST	MOISTURE FOUND
K59	ELEC	N	416	K	ELEC	ELECTRICAL SYSTEM	59	ARCB	ARCING/BURNT COMPONENTS
K60	ELEC	N	870	K	ELEC	ELECTRICAL SYSTEM	60	SAFDL	SAFETY DEADLINE
K61	ELEC	N	2511	K	ELEC	ELECTRICAL SYSTEM	61	START	STARTER
K62	ELEC	N	4200	K	ELEC	ELECTRICAL SYSTEM	62	BTRY	BATTERY
K63	ELEC	N	4	K	ELEC	ELECTRICAL SYSTEM	63	EXSYS	EXHUAST SYSTEM
K65	ELEC	N	14	K	ELEC	ELECTRICAL SYSTEM	65	SEW	SEWING RIPS/TORN AREAS
K67	ELEC	Y	206	K	ELEC	ELECTRICAL SYSTEM	67	MODAP	MODIFICATION APPLICATION
K71	ELEC	N	620	K	ELEC	ELECTRICAL SYSTEM	71	RPR	REPAIR
K	ELEC	N	721	K	ELEC	ELECTRICAL SYSTEM			NOT GIVEN
L05	FUEL	N	17	L	FUEL	FUEL SYSTEM	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
L06	FUEL	N	28	L	FUEL	FUEL SYSTEM	6	CONT	CONTROL MECHANISMS
L08	FUEL	N	26	L	FUEL	FUEL SYSTEM	8	DIST	DISTRIBUTION SYSTEMS
L11	FUEL	N	249	L	FUEL	FUEL SYSTEM	11	HOSE	HOSE, TUBING, AND FITTINGS
L12	FUEL	N	274	L	FUEL	FUEL SYSTEM	12	HOUS	HOUSING AND CASTINGS
L13	FUEL	N	440	L	FUEL	FUEL SYSTEM	13	INJEC	INJECTOR SYSTEMS
L16	FUEL	N	404	L	FUEL	FUEL SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
L17	FUEL	N	686	L	FUEL	FUEL SYSTEM	17	PUMP	PUMPS AND COMPONENTS
L18	FUEL	N	6	L	FUEL	FUEL SYSTEM	18	RECL	RECOIL MECHANISM
L19	FUEL	N	53	L	FUEL	FUEL SYSTEM	19	REG	REGULATOR MECHANISMS
L22	FUEL	N	151	L	FUEL	FUEL SYSTEM	22	STEER	STEERING COMPONENTS
L27	FUEL	N	239	L	FUEL	FUEL SYSTEM	27	UNK	UNKNOWN
L29	FUEL	N	25	L	FUEL	FUEL SYSTEM	29	UNAUT	ABUSE/UNAUTHORIZED MAINTENANCE
L34	FUEL	N	1486	L	FUEL	FUEL SYSTEM	34	RPLC	REPLACE
L39	FUEL	N	58	L	FUEL	FUEL SYSTEM	39	CORR	CORRODED/RUSTED
L41	FUEL	N	27	L	FUEL	FUEL SYSTEM	41	SHORT	SHORTED/LOW RESISTIVE CIRCUITRY
L42	FUEL	N	3	L	FUEL	FUEL SYSTEM	42	MECH	MECHANICAL/LINKAGE OR DRIVE
L45	FUEL	N	3	L	FUEL	FUEL SYSTEM	45	MODUL	MODULATOR
L48	FUEL	N	505	L	FUEL	FUEL SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
L50	FUEL	N	19	L	FUEL	FUEL SYSTEM	50	COTO	COMPONENTS OUT OF TOLERANCE
L52	FUEL	Y	12	L	FUEL	FUEL SYSTEM	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
L54	FUEL	N	1	L	FUEL	FUEL SYSTEM	54	N/A	NOT APPLICABLE
L55	FUEL	N	587	L	FUEL	FUEL SYSTEM	55	INOP	INOPERATIVE
L56	FUEL	N	180	L	FUEL	FUEL SYSTEM	56	MINR	MINOR
L57	FUEL	N	14	L	FUEL	FUEL SYSTEM	57	ADJS	ADJUST
L58	FUEL	N	256	L	FUEL	FUEL SYSTEM	58	MOIST	MOISTURE FOUND
L59	FUEL	N	82	L	FUEL	FUEL SYSTEM	59	ARCB	ARCING/BURNT COMPONENTS
L60	FUEL	N	3	L	FUEL	FUEL SYSTEM	60	SAFDL	SAFETY DEADLINE
L61	FUEL	N	4	L	FUEL	FUEL SYSTEM	61	START	STARTER
L71	FUEL	N	46	L	FUEL	FUEL SYSTEM	71	RPR	REPAIR
L	FUEL	N	45	L	FUEL	FUEL SYSTEM			NOT GIVEN
M02	HYDR	N	42	M	HYDR	HYDRAULIC SYSTEM	2	BRK	BRAKE SYSTEMS AND COMPONENTS
M04	HYDR	N	10	M	HYDR	HYDRAULIC SYSTEM	4	CARR	CARRIAGE AND MOUNT MECHANISM
M05	HYDR	N	30	M	HYDR	HYDRAULIC SYSTEM	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
M06	HYDR	N	203	M	HYDR	HYDRAULIC SYSTEM	6	CONT	CONTROL MECHANISMS
M07	HYDR	N	1020	M	HYDR	HYDRAULIC SYSTEM	7	CYL	CYLINDERS, ACCUMULATORS, AND REPLENISHERS
M08	HYDR	N	23	M	HYDR	HYDRAULIC SYSTEM	8	DIST	DISTRIBUTION SYSTEMS
M09	HYDR	N	1	M	HYDR	HYDRAULIC SYSTEM	9	ELTR	ELEVATION AND TRAVERSING MECHANISMS
M10	HYDR	N	9	M	HYDR	HYDRAULIC SYSTEM	10	GUN	GUN TUBE, BREECH, AND FIRING MECHANISMS
M11	HYDR	N	3024	M	HYDR	HYDRAULIC SYSTEM	11	HOSE	HOSE, TUBING, AND FITTINGS
M12	HYDR	N	200	M	HYDR	HYDRAULIC SYSTEM	12	HOUS	HOUSING AND CASTINGS
M13	HYDR	N	24	M	HYDR	HYDRAULIC SYSTEM	13	INJEC	INJECTOR SYSTEMS
M14	HYDR	N	234	M	HYDR	HYDRAULIC SYSTEM	14	MDRV	MECHANICAL DRIVE SYSTEMS
M16	HYDR	N	1606	M	HYDR	HYDRAULIC SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
M17	HYDR	N	2870	M	HYDR	HYDRAULIC SYSTEM	17	PUMP	PUMPS AND COMPONENTS
M18	HYDR	N	43	M	HYDR	HYDRAULIC SYSTEM	18	RECL	RECOIL MECHANISM
M19	HYDR	N	27	M	HYDR	HYDRAULIC SYSTEM	19	REG	REGULATOR MECHANISMS
M20	HYDR	N	12	M	HYDR	HYDRAULIC SYSTEM	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
M21	HYDR	N	50	M	HYDR	HYDRAULIC SYSTEM	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
M22	HYDR	N	6531	M	HYDR	HYDRAULIC SYSTEM	22	STEER	STEERING COMPONENTS
M23	HYDR	N	236	M	HYDR	HYDRAULIC SYSTEM	23	VALV	VALVES AND VALVE COMPONENTS

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
M25	HYDR	N	61	M	HYDR	HYDRAULIC SYSTEM	25	GLASS	GLASS REPLACEMENT
M27	HYDR	N	114	M	HYDR	HYDRAULIC SYSTEM	27	UNK	UNKNOWN
M28	HYDR	N	5	M	HYDR	HYDRAULIC SYSTEM	28	LKPM	LACK OF PREVENTIVE MAINTENANCE
M30	HYDR	N	18	M	HYDR	HYDRAULIC SYSTEM	30	AUX	AUXILIARY
M33	HYDR	N	19	M	HYDR	HYDRAULIC SYSTEM	33	HVSWR	HIGH VOLTAGE STANDING WAVE RATIO
M34	HYDR	N	2533	M	HYDR	HYDRAULIC SYSTEM	34	RPLC	REPLACE
M35	HYDR	N	2	M	HYDR	HYDRAULIC SYSTEM	35	FREQ	FREQUENCY SHIFT/STABILITY
M37	HYDR	N	36	M	HYDR	HYDRAULIC SYSTEM	37	CABL	CABLING MALFUNCTION
M38	HYDR	N	2	M	HYDR	HYDRAULIC SYSTEM	38	LPO	LOW POWER OUT
M39	HYDR	N	5	M	HYDR	HYDRAULIC SYSTEM	39	CORR	CORRODED/RUSTED
M42	HYDR	N	26	M	HYDR	HYDRAULIC SYSTEM	42	MECH	MECHANICAL/LINKAGE OR DRIVE
M44	HYDR	N	1	M	HYDR	HYDRAULIC SYSTEM	44	ALGN	SYSTEM ALIGNMENT
M48	HYDR	N	501	M	HYDR	HYDRAULIC SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
M50	HYDR	N	8	M	HYDR	HYDRAULIC SYSTEM	50	COTO	COMPONENTS OUT OF TOLERANCE
M52	HYDR	Y	5	M	HYDR	HYDRAULIC SYSTEM	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
M54	HYDR	N	4	M	HYDR	HYDRAULIC SYSTEM	54	N/A	NOT APPLICABLE
M55	HYDR	N	1560	M	HYDR	HYDRAULIC SYSTEM	55	INOP	INOPERATIVE
M56	HYDR	N	283	M	HYDR	HYDRAULIC SYSTEM	56	MINR	MINOR
M57	HYDR	N	30	M	HYDR	HYDRAULIC SYSTEM	57	ADJS	ADJUST
M58	HYDR	N	1576	M	HYDR	HYDRAULIC SYSTEM	58	MOIST	MOISTURE FOUND
M66	HYDR	Y	3	M	HYDR	HYDRAULIC SYSTEM	66	FAB	FABRICATION
M67	HYDR	Y	85	M	HYDR	HYDRAULIC SYSTEM	67	MODAP	MODIFICATION APPLICATION
M71	HYDR	N	878	M	HYDR	HYDRAULIC SYSTEM	71	RPR	REPAIR
M	HYDR	N	228	M	HYDR	HYDRAULIC SYSTEM			NOT GIVEN
N01	AIR	N	1	N	AIR	AIR SYSTEM	1	ALGEN	ALTERNATOR, GENERATOR MECHANISM
N02	AIR	N	3541	N	AIR	AIR SYSTEM	2	BRK	BRAKE SYSTEMS AND COMPONENTS
N03	AIR	N	23	N	AIR	AIR SYSTEM	3	CARB	CARBURETION SYSTEM
N05	AIR	N	113	N	AIR	AIR SYSTEM	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
N06	AIR	N	620	N	AIR	AIR SYSTEM	6	CONT	CONTROL MECHANISMS
N07	AIR	N	110	N	AIR	AIR SYSTEM	7	CYL	CYLINDERS, ACCUMULATORS, AND REPLENISHERS
N08	AIR	N	162	N	AIR	AIR SYSTEM	8	DIST	DISTRIBUTION SYSTEMS
N10	AIR	N	73	N	AIR	AIR SYSTEM	10	GUN	GUN TUBE, BREECH, AND FIRING MECHANISMS
N11	AIR	N	4268	N	AIR	AIR SYSTEM	11	HOSE	HOSE, TUBING, AND FITTINGS
N12	AIR	N	417	N	AIR	AIR SYSTEM	12	HOUS	HOUSING AND CASTINGS
N13	AIR	N	56	N	AIR	AIR SYSTEM	13	INJEC	INJECTOR SYSTEMS
N14	AIR	N	14	N	AIR	AIR SYSTEM	14	MDRV	MECHANICAL DRIVE SYSTEMS
N16	AIR	N	1581	N	AIR	AIR SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
N17	AIR	N	192	N	AIR	AIR SYSTEM	17	PUMP	PUMPS AND COMPONENTS
N18	AIR	N	18	N	AIR	AIR SYSTEM	18	RECL	RECOIL MECHANISM
N19	AIR	N	217	N	AIR	AIR SYSTEM	19	REG	REGULATOR MECHANISMS
N20	AIR	N	25	N	AIR	AIR SYSTEM	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
N22	AIR	N	12	N	AIR	AIR SYSTEM	22	STEER	STEERING COMPONENTS
N23	AIR	N	1148	N	AIR	AIR SYSTEM	23	VALV	VALVES AND VALVE COMPONENTS
N24	AIR	N	6	N	AIR	AIR SYSTEM	24	TORS	TORSION COMPONENTS
N27	AIR	N	330	N	AIR	AIR SYSTEM	27	UNK	UNKNOWN
N30	AIR	N	33	N	AIR	AIR SYSTEM	30	AUX	AUXILIARY
N31	AIR	N	127	N	AIR	AIR SYSTEM	31	OVRHL	OVERHAUL
N34	AIR	N	3691	N	AIR	AIR SYSTEM	34	RPLC	REPLACE
N39	AIR	N	28	N	AIR	AIR SYSTEM	39	CORR	CORRODED/RUSTED
N40	AIR	N	17	N	AIR	AIR SYSTEM	40	OPEN	OPEN/HIGH RESISTIVE CIRCUITRY
N41	AIR	N	38	N	AIR	AIR SYSTEM	41	SHORT	SHORTED/LOW RESISTIVE CIRCUITRY
N42	AIR	N	4	N	AIR	AIR SYSTEM	42	MECH	MECHANICAL/LINKAGE OR DRIVE
N45	AIR	N	71	N	AIR	AIR SYSTEM	45	MODUL	MODULATOR
N48	AIR	N	1360	N	AIR	AIR SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
N49	AIR	N	2	N	AIR	AIR SYSTEM	49	GRND	GROUNDED
N50	AIR	N	92	N	AIR	AIR SYSTEM	50	COTO	COMPONENTS OUT OF TOLERANCE
N52	AIR	Y	26	N	AIR	AIR SYSTEM	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
N54	AIR	N	34	N	AIR	AIR SYSTEM	54	N/A	NOT APPLICABLE
N55	AIR	N	2758	N	AIR	AIR SYSTEM	55	INOP	INOPERATIVE
N56	AIR	N	575	N	AIR	AIR SYSTEM	56	MINR	MINOR
N57	AIR	N	419	N	AIR	AIR SYSTEM	57	ADJS	ADJUST
N58	AIR	N	32	N	AIR	AIR SYSTEM	58	MOIST	MOISTURE FOUND
N60	AIR	N	231	N	AIR	AIR SYSTEM	60	SAFDL	SAFETY DEADLINE
N63	AIR	N	46	N	AIR	AIR SYSTEM	63	EXSYS	EXHUAST SYSTEM
N64	AIR	Y	2	N	AIR	AIR SYSTEM	64	SL3AP	SL-3 APPLICATION
N67	AIR	Y	20	N	AIR	AIR SYSTEM	67	MODAP	MODIFICATION APPLICATION
N71	AIR	N	518	N	AIR	AIR SYSTEM	71	RPR	REPAIR
N	AIR	N	277	N	AIR	AIR SYSTEM			NOT GIVEN
O04	TURR	N	141	O	TURR	TURRET SYSTEM	4	CARR	CARRIAGE AND MOUNT MECHANISM
O09	TURR	N	1	O	TURR	TURRET SYSTEM	9	ELTR	ELEVATION AND TRAVERSING MECHANISMS
O10	TURR	N	47	O	TURR	TURRET SYSTEM	10	GUN	GUN TUBE, BREECH, AND FIRING MECHANISMS
O31	TURR	N	1	O	TURR	TURRET SYSTEM	31	OVRHL	OVERHAUL
O34	TURR	N	207	O	TURR	TURRET SYSTEM	34	RPLC	REPLACE
O48	TURR	N	44	O	TURR	TURRET SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
O55	TURR	N	11	O	TURR	TURRET SYSTEM	55	INOP	INOPERATIVE
O56	TURR	N	36	O	TURR	TURRET SYSTEM	56	MINR	MINOR
O60	TURR	N	9	O	TURR	TURRET SYSTEM	60	SAFDL	SAFETY DEADLINE
O64	TURR	Y	404	O	TURR	TURRET SYSTEM	64	SL3AP	SL-3 APPLICATION
O66	TURR	Y	359	O	TURR	TURRET SYSTEM	66	FAB	FABRICATION
O67	TURR	Y	769	O	TURR	TURRET SYSTEM	67	MODAP	MODIFICATION APPLICATION
O71	TURR	N	1	O	TURR	TURRET SYSTEM	71	RPR	REPAIR
O	TURR	N	9	O	TURR	TURRET SYSTEM			NOT GIVEN
P48	FCON	N	17	P	FCON	FIRE CONTROL SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
P67	FCON	Y	1	P	FCON	FIRE CONTROL SYSTEM	67	MODAP	MODIFICATION APPLICATION

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
Q01	IGNI	N	1	Q	IGNI	IGNITION SYSTEM	1	ALGEN	ALTERNATOR, GENERATOR MECHANISM
Q06	IGNI	N	13	Q	IGNI	IGNITION SYSTEM	6	CONT	CONTROL MECHANISMS
Q27	IGNI	N	11	Q	IGNI	IGNITION SYSTEM	27	UNK	UNKNOWN
Q34	IGNI	N	433	Q	IGNI	IGNITION SYSTEM	34	RPLC	REPLACE
Q37	IGNI	N	1	Q	IGNI	IGNITION SYSTEM	37	CABL	CABLING MALFUNCTION
Q47	IGNI	N	1	Q	IGNI	IGNITION SYSTEM	47	HVPS	HIGH VOLTAGE POWER SUPPLY
Q55	IGNI	N	489	Q	IGNI	IGNITION SYSTEM	55	INOP	INOPERATIVE
Q56	IGNI	N	4	Q	IGNI	IGNITION SYSTEM	56	MINR	MINOR
Q59	IGNI	N	22	Q	IGNI	IGNITION SYSTEM	59	ARCB	ARCING/BURNT COMPONENTS
Q60	IGNI	N	24	Q	IGNI	IGNITION SYSTEM	60	SAFDL	SAFETY DEADLINE
Q61	IGNI	N	278	Q	IGNI	IGNITION SYSTEM	61	START	STARTER
Q62	IGNI	N	25	Q	IGNI	IGNITION SYSTEM	62	BTRY	BATTERY
Q71	IGNI	N	23	Q	IGNI	IGNITION SYSTEM	71	RPR	REPAIR
Q	IGNI	N	54	Q	IGNI	IGNITION SYSTEM			NOT GIVEN
R02	LIFT	N	3	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	2	BRK	BRAKE SYSTEMS AND COMPONENTS
R04	LIFT	N	15	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	4	CARR	CARRIAGE AND MOUNT MECHANISM
R05	LIFT	N	2	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	5	CONV	CLUTCH, CONVERTER, AND COUPLINGS
R06	LIFT	N	103	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	6	CONT	CONTROL MECHANISMS
R07	LIFT	N	236	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	7	CYL	CYLINDERS, ACCUMULATORS, AND REPLENISHERS
R09	LIFT	N	71	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	9	ELTR	ELEVATION AND TRAVERSING MECHANISMS
R11	LIFT	N	24	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	11	HOSE	HOSE, TUBING, AND FITTINGS
R12	LIFT	N	14	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	12	HOUS	HOUSING AND CASTINGS
R14	LIFT	N	33	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	14	MDRV	MECHANICAL DRIVE SYSTEMS
R16	LIFT	N	48	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	16	SEAL	PACKING, SEALS, AND GASKETS
R17	LIFT	N	33	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	17	PUMP	PUMPS AND COMPONENTS
R18	LIFT	N	9	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	18	RECL	RECOIL MECHANISM
R19	LIFT	N	18	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	19	REG	REGULATOR MECHANISMS
R20	LIFT	N	24	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
R23	LIFT	N	1	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	23	VALV	VALVES AND VALVE COMPONENTS
R27	LIFT	N	47	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	27	UNK	UNKNOWN
R30	LIFT	N	3	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	30	AUX	AUXILIARY
R34	LIFT	N	1438	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	34	RPLC	REPLACE
R37	LIFT	N	363	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	37	CABL	CABLING MALFUNCTION
R41	LIFT	N	6	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	41	SHORT	SHORTED/LOW RESISTIVE CIRCUITRY
R42	LIFT	N	10	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	42	MECH	MECHANICAL/LINKAGE OR DRIVE
R48	LIFT	N	616	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	48	CBB	CRACKED, BROKEN, OR BENT
R50	LIFT	N	30	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	50	COTO	COMPONENTS OUT OF TOLERANCE
R52	LIFT	Y	38	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
R55	LIFT	N	860	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	55	INOP	INOPERATIVE
R56	LIFT	N	88	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	56	MINR	MINOR
R57	LIFT	N	123	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	57	ADJS	ADJUST
R58	LIFT	N	2	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	58	MOIST	MOISTURE FOUND
R60	LIFT	N	159	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	60	SAFDL	SAFETY DEADLINE
R64	LIFT	Y	178	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	64	SL3AP	SL-3 APPLICATION
R71	LIFT	N	13	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM	71	RPR	REPAIR
R	LIFT	N	166	R	LIFT	BOOM, CABLE, AND LIFT SYSTEM			NOT GIVEN
S06	XMOC	N	3	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	6	CONT	CONTROL MECHANISMS
S11	XMOC	N	5	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	11	HOSE	HOSE, TUBING, AND FITTINGS
S14	XMOC	N	15	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	14	MDRV	MECHANICAL DRIVE SYSTEMS
S16	XMOC	N	14	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	16	SEAL	PACKING, SEALS, AND GASKETS
S34	XMOC	N	79	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	34	RPLC	REPLACE
S48	XMOC	N	27	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	48	CBB	CRACKED, BROKEN, OR BENT
S55	XMOC	N	40	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	55	INOP	INOPERATIVE
S58	XMOC	N	90	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	58	MOIST	MOISTURE FOUND
S62	XMOC	N	2	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY	62	BTRY	BATTERY
S	XMOC	N	2	S	XMOC	TRANSMITTER/OUTPUT CIRCUITRY			NOT GIVEN
T12	RCIC	N	19	T	RCIC	RECIEVER/INPUT CIRCUITRY	12	HOUS	HOUSING AND CASTINGS
T34	RCIC	N	1	T	RCIC	RECIEVER/INPUT CIRCUITRY	34	RPLC	REPLACE
T48	RCIC	N	1	T	RCIC	RECIEVER/INPUT CIRCUITRY	48	CBB	CRACKED, BROKEN, OR BENT
T55	RCIC	N	17	T	RCIC	RECIEVER/INPUT CIRCUITRY	55	INOP	INOPERATIVE
T67	RCIC	Y	4	T	RCIC	RECIEVER/INPUT CIRCUITRY	67	MODAP	MODIFICATION APPLICATION
U27	ANTL	N	1	U	ANTL	ANTENNA/TRANSMISSION LINE	27	UNK	UNKNOWN
U33	ANTL	N	2	U	ANTL	ANTENNA/TRANSMISSION LINE	33	HVSWR	HIGH VOLTAGE STANDING WAVE RATIO
U34	ANTL	N	26	U	ANTL	ANTENNA/TRANSMISSION LINE	34	RPLC	REPLACE
U55	ANTL	N	1	U	ANTL	ANTENNA/TRANSMISSION LINE	55	INOP	INOPERATIVE
U56	ANTL	N	2	U	ANTL	ANTENNA/TRANSMISSION LINE	56	MINR	MINOR
U64	ANTL	Y	33	U	ANTL	ANTENNA/TRANSMISSION LINE	64	SL3AP	SL-3 APPLICATION
U65	ANTL	N	1	U	ANTL	ANTENNA/TRANSMISSION LINE	65	SEW	SEWING RIPS/TORN AREAS
U67	ANTL	Y	17	U	ANTL	ANTENNA/TRANSMISSION LINE	67	MODAP	MODIFICATION APPLICATION
U68	ANTL	Y	66	U	ANTL	ANTENNA/TRANSMISSION LINE	68	CAL	CALIBRATION
U71	ANTL	N	3	U	ANTL	ANTENNA/TRANSMISSION LINE	71	RPR	REPAIR
V34	MODM	N	1	V	MODM	MULTIPLEX/MODULATION-DEMODULATION	34	RPLC	REPLACE
V52	MODM	Y	8	V	MODM	MULTIPLEX/MODULATION-DEMODULATION	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
V53	MODM	Y	1	V	MODM	MULTIPLEX/MODULATION-DEMODULATION	53	SAPM	SEMIANNUAL SCHEDULED PREVENTIVE MAINTENANCE
V54	MODM	N	4	V	MODM	MULTIPLEX/MODULATION-DEMODULATION	54	N/A	NOT APPLICABLE
V56	MODM	N	119	V	MODM	MULTIPLEX/MODULATION-DEMODULATION	56	MINR	MINOR
V58	MODM	N	1	V	MODM	MULTIPLEX/MODULATION-DEMODULATION	58	MOIST	MOISTURE FOUND
V64	MODM	Y	8	V	MODM	MULTIPLEX/MODULATION-DEMODULATION	64	SL3AP	SL-3 APPLICATION
V67	MODM	Y	6	V	MODM	MULTIPLEX/MODULATION-DEMODULATION	67	MODAP	MODIFICATION APPLICATION
V	MODM	N	8	V	MODM	MULTIPLEX/MODULATION-DEMODULATION			NOT GIVEN
W12	DADI	N	1	W	DADI	DATA/DIGITAL SYSTEMS	12	HOUS	HOUSING AND CASTINGS
W34	DADI	N	2	W	DADI	DATA/DIGITAL SYSTEMS	34	RPLC	REPLACE
W50	DADI	N	5	W	DADI	DATA/DIGITAL SYSTEMS	50	COTO	COMPONENTS OUT OF TOLERANCE
W54	DADI	N	1	W	DADI	DATA/DIGITAL SYSTEMS	54	N/A	NOT APPLICABLE

Defect_Code	Subsystem	Sched.	Count	Major_System	MS_Code	MS_Explanation	System_Component	SC_Code	SC_Explanation
W55	DADI	N	150	W	DADI	DATA/DIGITAL SYSTEMS	55	INOP	INOPERATIVE
W56	DADI	N	24	W	DADI	DATA/DIGITAL SYSTEMS	56	MINR	MINOR
W57	DADI	N	132	W	DADI	DATA/DIGITAL SYSTEMS	57	ADJS	ADJUST
W60	DADI	N	13	W	DADI	DATA/DIGITAL SYSTEMS	60	SAFDL	SAFETY DEADLINE
W66	DADI	Y	1	W	DADI	DATA/DIGITAL SYSTEMS	66	FAB	FABRICATION
W67	DADI	Y	1718	W	DADI	DATA/DIGITAL SYSTEMS	67	MODAP	MODIFICATION APPLICATION
W68	DADI	Y	1	W	DADI	DATA/DIGITAL SYSTEMS	68	CAL	CALIBRATION
W71	DADI	N	247	W	DADI	DATA/DIGITAL SYSTEMS	71	RPR	REPAIR
X16	MTR	N	6	X	MTR	METER	16	SEAL	PACKING, SEALS, AND GASKETS
X20	MTR	N	0	X	MTR	METER	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
X25	MTR	N	17	X	MTR	METER	25	GLASS	GLASS REPLACEMENT
X34	MTR	N	395	X	MTR	METER	34	RPLC	REPLACE
X37	MTR	N	22	X	MTR	METER	37	CABL	CABLING MALFUNCTION
X44	MTR	N	2	X	MTR	METER	44	ALGN	SYSTEM ALIGNMENT
X48	MTR	N	4	X	MTR	METER	48	CBB	CRACKED, BROKEN, OR BENT
X52	MTR	Y	4	X	MTR	METER	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
X55	MTR	N	81	X	MTR	METER	55	INOP	INOPERATIVE
X56	MTR	N	1	X	MTR	METER	56	MINR	MINOR
X67	MTR	Y	9	X	MTR	METER	67	MODAP	MODIFICATION APPLICATION
Y09	WPNS	N	102	Y	WPNS	WEAPONS/SMALL ARMS/CREW SERVED	9	ELTR	ELEVATION AND TRAVERSING MECHANISMS
Y12	WPNS	N	27	Y	WPNS	WEAPONS/SMALL ARMS/CREW SERVED	12	HOUS	HOUSING AND CASTINGS
Y34	WPNS	N	12	Y	WPNS	WEAPONS/SMALL ARMS/CREW SERVED	34	RPLC	REPLACE
Y48	WPNS	N	8	Y	WPNS	WEAPONS/SMALL ARMS/CREW SERVED	48	CBB	CRACKED, BROKEN, OR BENT
Y52	WPNS	Y	2	Y	WPNS	WEAPONS/SMALL ARMS/CREW SERVED	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
Y56	WPNS	N	7	Y	WPNS	WEAPONS/SMALL ARMS/CREW SERVED	56	MINR	MINOR
Y64	WPNS	Y	14	Y	WPNS	WEAPONS/SMALL ARMS/CREW SERVED	64	SL3AP	SL-3 APPLICATION
Y67	WPNS	Y	6	Y	WPNS	WEAPONS/SMALL ARMS/CREW SERVED	67	MODAP	MODIFICATION APPLICATION
Z52	LVTP	Y	59	Z	LVTP	LANDING VEHICLE, TRACKED, PERSONNEL	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
11	NMAJ	N	110		NMAJ	NO MAJOR DEFECT	11	HOSE	HOSE, TUBING, AND FITTINGS
12	NMAJ	N	20		NMAJ	NO MAJOR DEFECT	12	HOUS	HOUSING AND CASTINGS
16	NMAJ	N	153		NMAJ	NO MAJOR DEFECT	16	SEAL	PACKING, SEALS, AND GASKETS
17	NMAJ	N	199		NMAJ	NO MAJOR DEFECT	17	PUMP	PUMPS AND COMPONENTS
19	NMAJ	N	2		NMAJ	NO MAJOR DEFECT	19	REG	REGULATOR MECHANISMS
20	SUSP	N	40		NMAJ	NO MAJOR DEFECT	20	SPRG	SPRINGS, SHOCKS, AND STABILIZER COMPONENTS
21	NMAJ	N	22		NMAJ	NO MAJOR DEFECT	21	TORQ	TORQUE, SPROCKET, OR DRIVE MECHANISM
22	NMAJ	N	247		NMAJ	NO MAJOR DEFECT	22	STEER	STEERING COMPONENTS
23	NMAJ	N	5		NMAJ	NO MAJOR DEFECT	23	VALV	VALVES AND VALVE COMPONENTS
24	NMAJ	N	13		NMAJ	NO MAJOR DEFECT	24	TORS	TORSION COMPONENTS
25	NMAJ	N	371		NMAJ	NO MAJOR DEFECT	25	GLASS	GLASS REPLACEMENT
26	NMAJ	Y	468		NMAJ	NO MAJOR DEFECT	26	PAINT	PAINTING, BODY WORK
27	NMAJ	N	31		NMAJ	NO MAJOR DEFECT	27	UNK	UNKNOWN
28	NMAJ	N	132		NMAJ	NO MAJOR DEFECT	28	LKPM	LACK OF PREVENTIVE MAINTENANCE
29	NMAJ	N	49		NMAJ	NO MAJOR DEFECT	29	UNAUT	ABUSE/UNAUTHORIZED MAINTENANCE
30	NMAJ	N	48		NMAJ	NO MAJOR DEFECT	30	AUX	AUXILIARY
31	NMAJ	N	139		NMAJ	NO MAJOR DEFECT	31	OVRHL	OVERHAUL
34	NMAJ	N	4348		NMAJ	NO MAJOR DEFECT	34	RPLC	REPLACE
36	NMAJ	N	7		NMAJ	NO MAJOR DEFECT	36	ADJS	SUBASSEMBLY ADJUSTMENT
39	NMAJ	N	110		NMAJ	NO MAJOR DEFECT	39	CORR	CORRODED/RUSTED
42	NMAJ	N	1		NMAJ	NO MAJOR DEFECT	42	MECH	MECHANICAL/LINKAGE OR DRIVE
44	NMAJ	N	56		NMAJ	NO MAJOR DEFECT	44	ALGN	SYSTEM ALIGNMENT
48	NMAJ	N	827		NMAJ	NO MAJOR DEFECT	48	CBB	CRACKED, BROKEN, OR BENT
50	NMAJ	N	50		NMAJ	NO MAJOR DEFECT	50	COTO	COMPONENTS OUT OF TOLERANCE
51	NMAJ	Y	268		NMAJ	NO MAJOR DEFECT	51	QSPM	QUARTERLY SCHEDULED PREVENTIVE MAINTENANCE
52	NMAJ	Y	37874		NMAJ	NO MAJOR DEFECT	52	ASPM	ANNUAL SCHEDULED PREVENTIVE MAINTENANCE
53	NMAJ	Y	1942		NMAJ	NO MAJOR DEFECT	53	SAPM	SEMIANNUAL SCHEDULED PREVENTIVE MAINTENANCE
54	NMAJ	N	801		NMAJ	NO MAJOR DEFECT	54	N/A	NOT APPLICABLE
55	NMAJ	N	234		NMAJ	NO MAJOR DEFECT	55	INOP	INOPERATIVE
56	NMAJ	N	24264		NMAJ	NO MAJOR DEFECT	56	MINR	MINOR
57	NMAJ	N	91		NMAJ	NO MAJOR DEFECT	57	ADJS	ADJUST
58	NMAJ	N	23		NMAJ	NO MAJOR DEFECT	58	MOIST	MOISTURE FOUND
60	NMAJ	N	97		NMAJ	NO MAJOR DEFECT	60	SAFDL	SAFETY DEADLINE
61	NMAJ	N	10		NMAJ	NO MAJOR DEFECT	61	START	STARTER
62	NMAJ	N	104		NMAJ	NO MAJOR DEFECT	62	BTRY	BATTERY
63	NMAJ	N	143		NMAJ	NO MAJOR DEFECT	63	EXSYS	EXHUAST SYSTEM
64	NMAJ	Y	115438		NMAJ	NO MAJOR DEFECT	64	SL3AP	SL-3 APPLICATION
65	NMAJ	N	64		NMAJ	NO MAJOR DEFECT	65	SEW	SEWING RIPS/TORN AREAS
66	NMAJ	Y	31		NMAJ	NO MAJOR DEFECT	66	FAB	FABRICATION
67	NMAJ	Y	3805		NMAJ	NO MAJOR DEFECT	67	MODAP	MODIFICATION APPLICATION
68	NMAJ	Y	60		NMAJ	NO MAJOR DEFECT	68	CAL	CALIBRATION
69	NMAJ	Y	1148		NMAJ	NO MAJOR DEFECT	69	SPM	SCHEDULED PREVENTIVE MAINTENANCE
70	NMAJ	N	1980		NMAJ	NO MAJOR DEFECT	70	LTI	ACCEPTANCE/LIMITED TECHNICAL INSPECTION
71	NMAJ	N	99		NMAJ	NO MAJOR DEFECT	71	RPR	REPAIR
	NA	N	167720			NOT GIVEN			NOT GIVEN

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# APPENDIX B. REGIONAL ACTIVITY CODES FOR MIMMS AND SASSY

Description	Short Description	SASSY_X_REF	MIMMS_X_Ref
I MEF Camp Pendleton, CA	I MEF	MMC300	MIM001
II MEF Camp Lejeune, NC	II MEF	MML300	MIM002
III MEF Okinawa, JP	III MEF	MMR300	MIM003
IV Reserves	RES	MMM300	MIM004
Hawaii	HI	MMR300	MIM003
MPS/MCPP-N	PREP	MMV100	MIMMPS
Bases Posts and Stations	BPS	MMQ300	MIM008
Blank (No MEF specified)			
Marine Corps Forces Spec Ops Cmd	MARFORSOC	MMI300	MIM002
USMC In Stores	MCLBINS		
VII MEF A	VII MEF	MMX300	MIM007
VII MEF I	VII MEF		
FSD I MEF	FSD-IMEF	MMX300	MIM007
FSD II MEF	FSD-IIMEF	MMX300	MIM007
FSD III MEF	FSD-IIIMEF	MMX300	MIM007
FSD Hawaii	FSD-Hawaii	MMX300	MIM007
Comm Elec Schools 29 Palms	TECOM	MMT300	

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APPENDIX C. ELECTRICAL SYSTEM PLOTS

A.   DEADLINES_ELEC VS. INDEPENDENT VARIABLE PLOTS
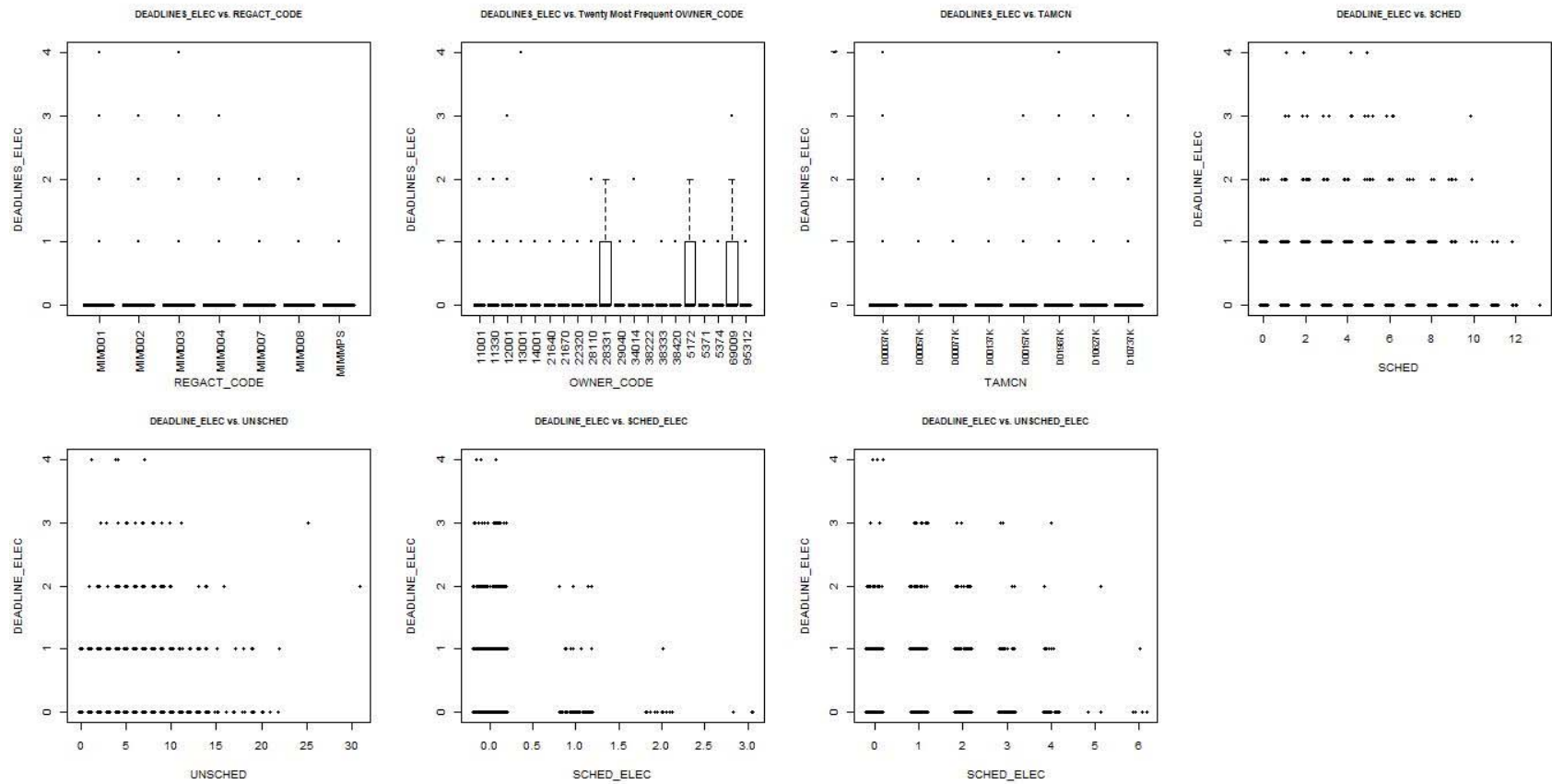
B.   ELECTRICAL SYSTEM PARTIAL RESIDUAL PLOTS
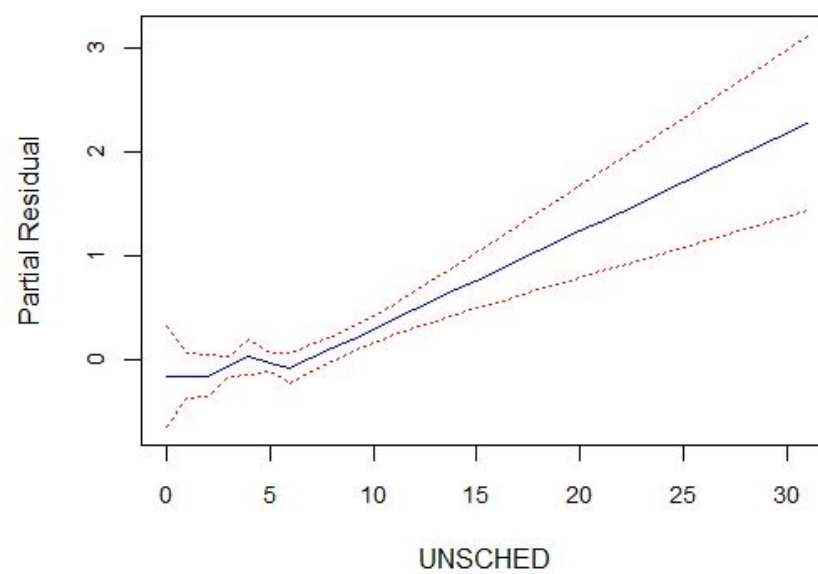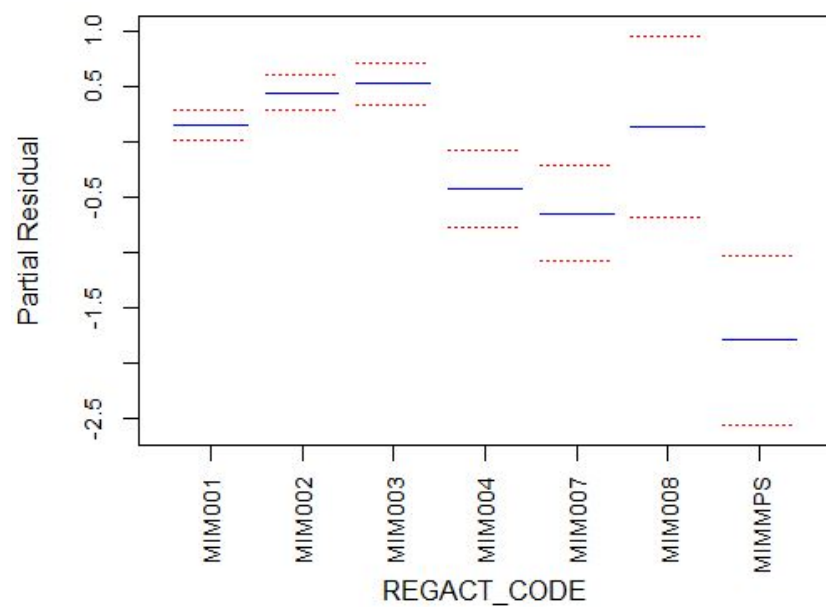
APPENDIX D. BODY SYSTEM PLOTS

A. DEADLINES_BODY VS. INDEPENDENT VARIABLE PLOTS
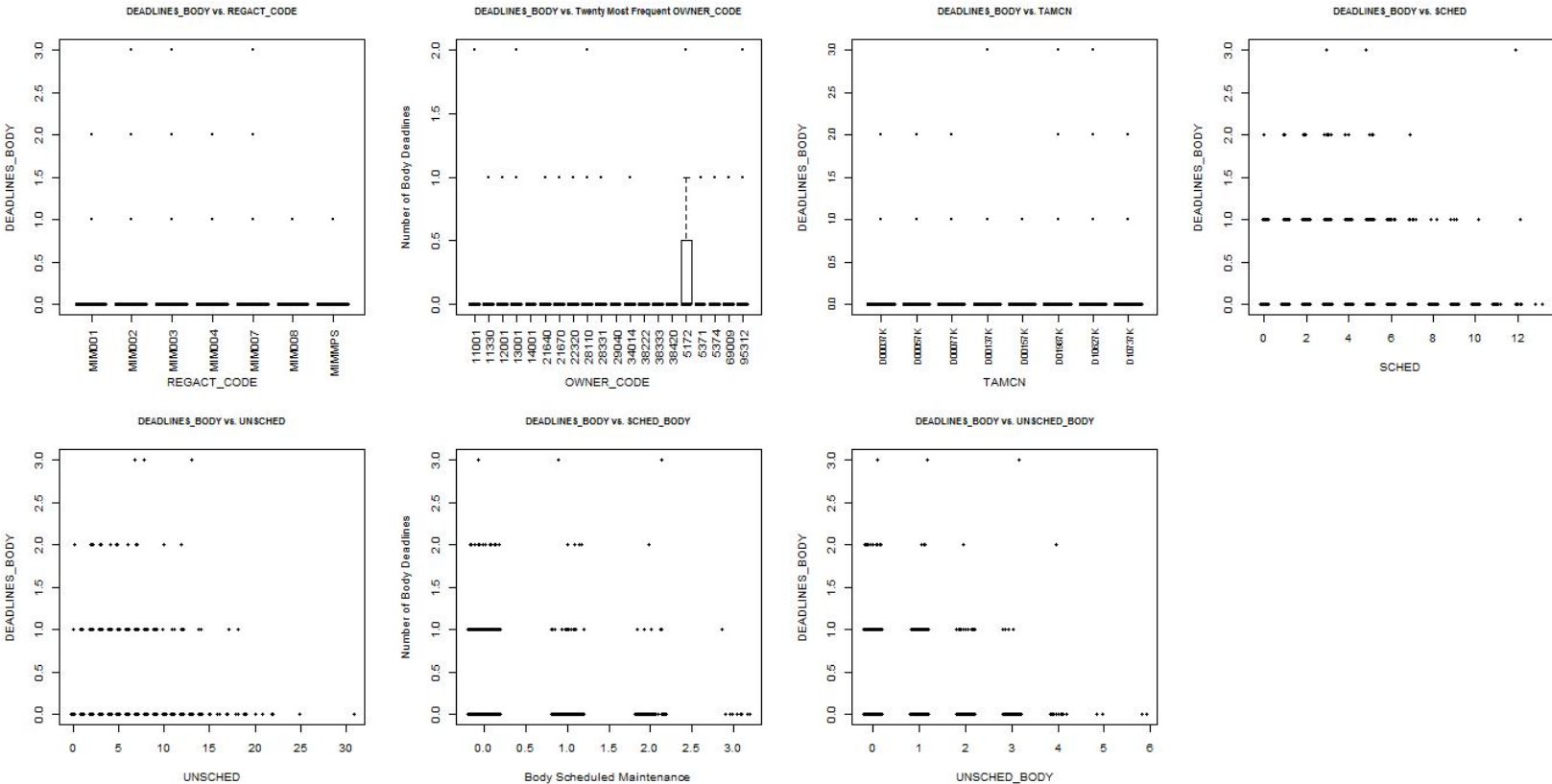
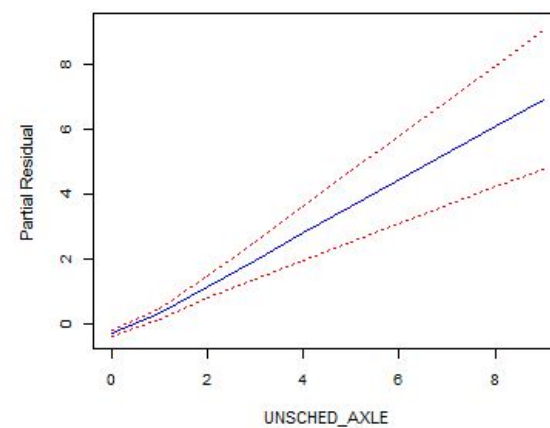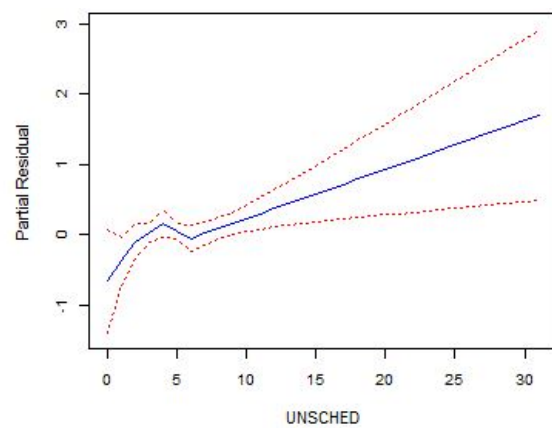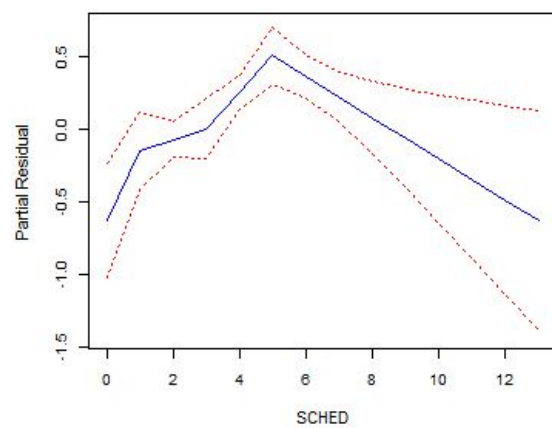**B.   BODY SYSTEM PARTIAL RESIDUAL PLOT**
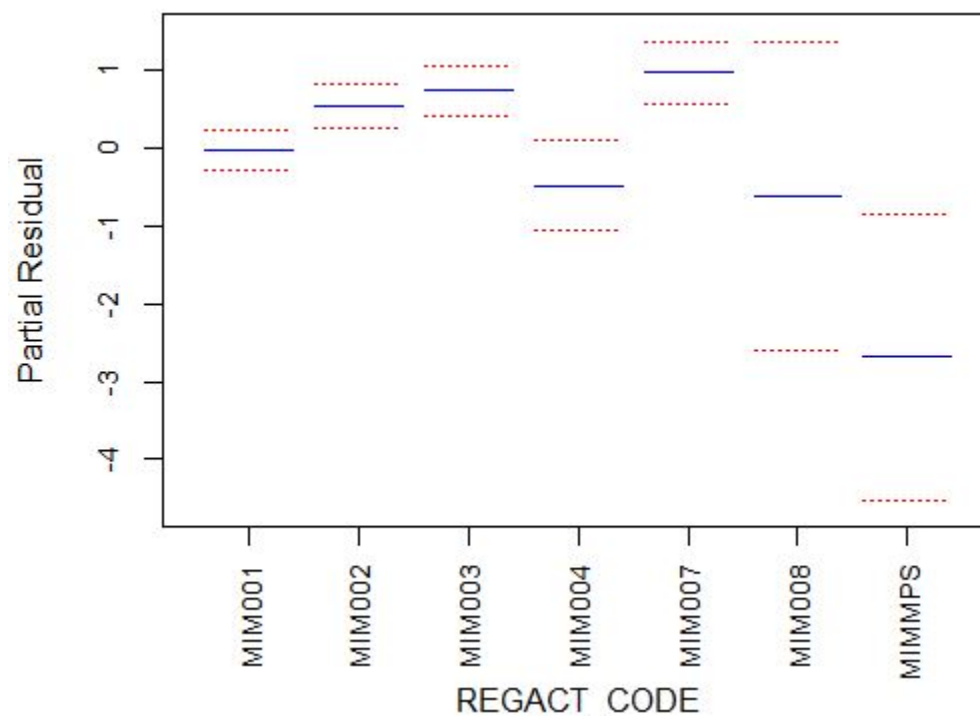
APPENDIX E. AXLE SYSTEM PLOTS

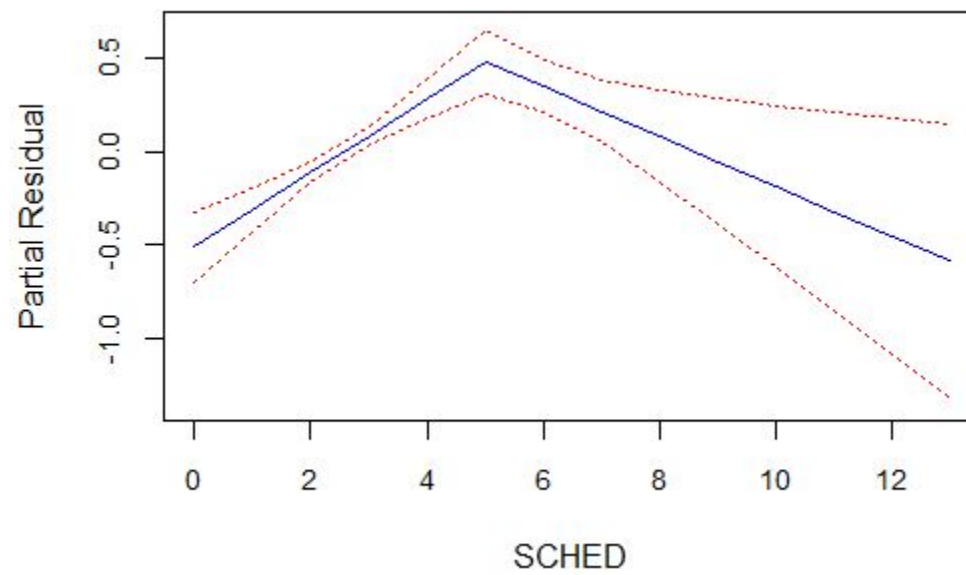## A.   DEADLINES_AXLE VS. INDEPENDENT VARIABLE PLOTS
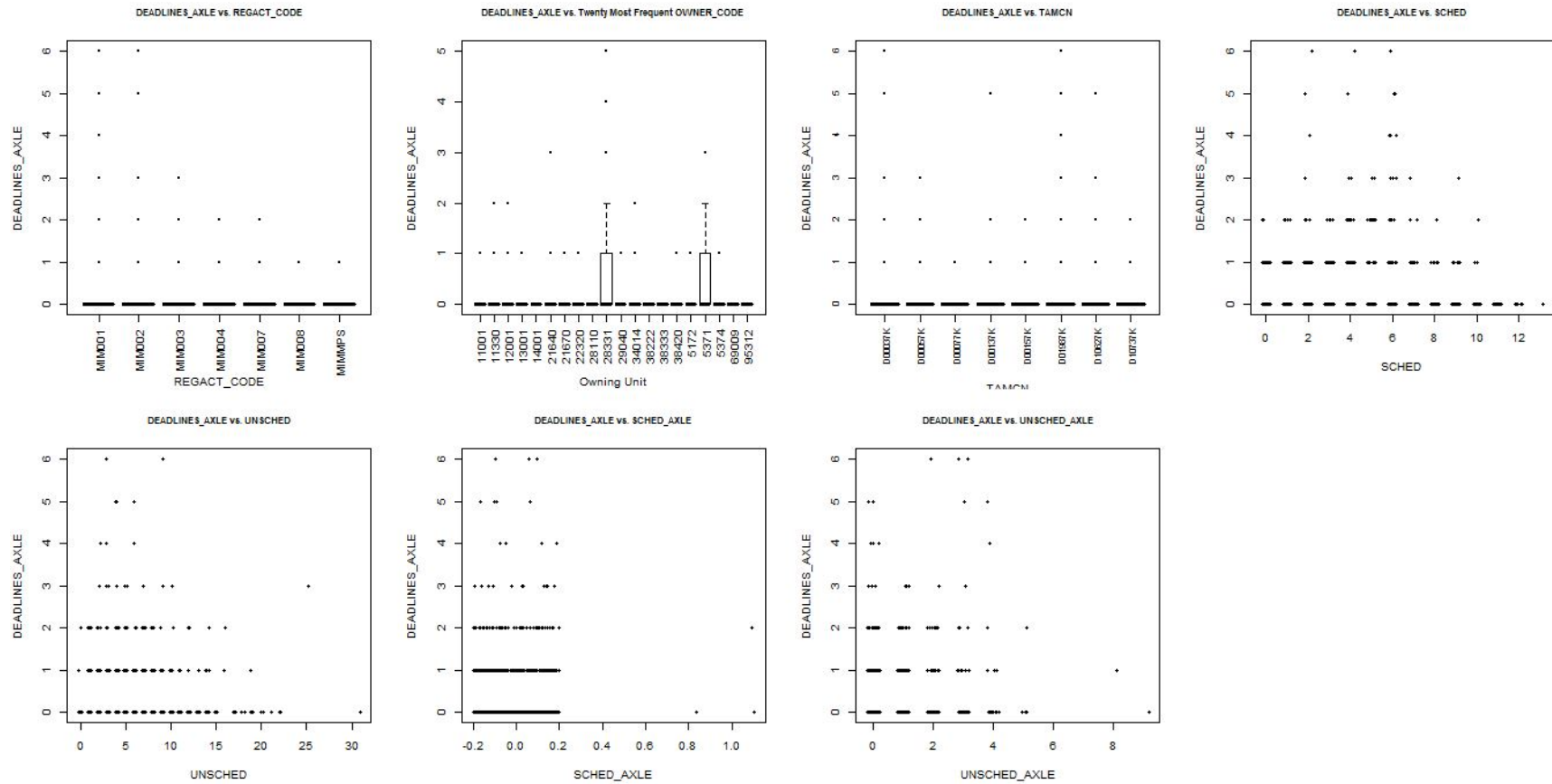
B.   AXLE SYSTEM PARTIAL RESIDUAL PLOTS

C.   SCHED TERM PLOT FOR AXLE SYSTEM MODEL

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