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HOW DOES DISAGGREGATING A POOLED INVENTORY AFFECT A MARINE AIRCRAFT GROUP?

December 2014

By: Charles M. Mohler and Stephen A. Lacovara

Advisors: Kenneth Doerr, Keebom Kang

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HOW DOES DISAGGREGATING A POOLED INVENTORY AFFECT A MARINE AIRCRAFT GROUP?

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

In 2013, Marine Aircraft Group 11 (MAG-11) directed Marine Aviation Logistics Squadron 11 (MALS-11) to move Marine Fighter Attack Training Squadron 101's (VMFAT-101) inventory allowances from MALS-11's warehouses to VMFAT-101's squadron spaces. The intent of this policy was to decrease requisition delivery time and increase VMFAT-101's aircraft readiness. In only one month, MALS-11 staged the appropriate inventory at the squadron along with a detachment of Marines to manage the material. We review the effects of the inventory move on MAG-11 as a whole, in terms of order lead time and capacity utilization. In addition, we examine the new inventory policy's other effects, such as workflow efficiency.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASD	Aviation Supply Department
CO	Commanding Officer
COMPL	Complete
EXREP	Expeditious Repair
LSC	Local Status Code
MAG	Marine Aircraft Group
MALS	Marine Aviation Logistics Squadron
MCAS	Marine Corps Air Station
MDD	Material Delivery Division
MLDT	Mean Logistics Delay Time
M/M/S	Markovian Multiple Channel Single-Phase Queuing Model
MOU	Memorandum of Understanding
MWSS	Marine Wing Support Squadron
NALCOMIS	Naval Aviation Logistics Command Management Information System
NC	not carried
NIIN	National Item Identification Number
NIS	not in stock
OOMA	Optimized-Organizational Maintenance Activity
PEB	pre-expended bin
SAMMS-II	Stand Alone Material Management System II
SKU	Stock Keeping Unit
SME	Subject Matter Expert
SOP	Standard Operating Procedures
SRD	Supply Response Division
SSP	Satellite Supply Point
T/M/S	Type/Model/Series
TSA	Training Squadron Allowance
VMFA	Marine Fighter Attack Squadron
VMFAT	Marine Fighter Attack Training Squadron

VMFA(AW)	Marine All Weather Fighter Attack Squadron
VMGR	Marine Aerial Refueler Transport Squadron

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I. INTRODUCTION

A. BACKGROUND

Marine Corps leadership consistently works to increase the operational availability of Marine Corps assets. One such example occurred at MAG-11 aboard Marine Corps Air Station (MCAS) Miramar in 2013. Attempting to reduce Mean Logistics Delay Time (MLDT) for VMFAT-101, the commanding officer (CO) of MAG-11 ordered the MALS-11 Aviation Supply Department (ASD) to separate VMFAT-101's inventory allowances from the MAG-11 pooled inventory located within MALS-11 and to place this inventory within VMFAT-101's work spaces. Under this scenario, when VMFAT-101 requisitioned a part, this part would hypothetically already be at the squadron (stored in the re-allocated inventory), minimizing this squadron's wait time for the part. Individual squadron inventory allowances are the spare aircraft parts specifically allocated to each flying squadron and which are "designed to support a specific type and number of aircraft at a predetermined level of repair" (Department of the Navy, 2009, p. 3–14) for a flying squadron. Generally, in the Marine Corps, the MAG pools these inventory allowances at the MALS located within the MAG. This decision to separate the pooled inventory was made with the assumption that if VMFAT-101 could reduce its MLDT, their overall aircraft operational availability would increase.

MAG-11 comprises eight different squadrons. Figure 1 depicts the composition of MAG-11. The eight squadrons are an aviation logistics squadron (MALS-11); an F/A-18 training squadron (VMFAT-101); four F/A-18 attack squadrons (VMFA[AW]-225, VMFA-232, VMFA-314, and VMFA-323); an aerial refueler transport squadron (VMGR-352); and a wing support squadron (MWSS-373). F/A-18 attack squadrons are able to deploy operationally throughout the world in support of the Marine Corps' mission.

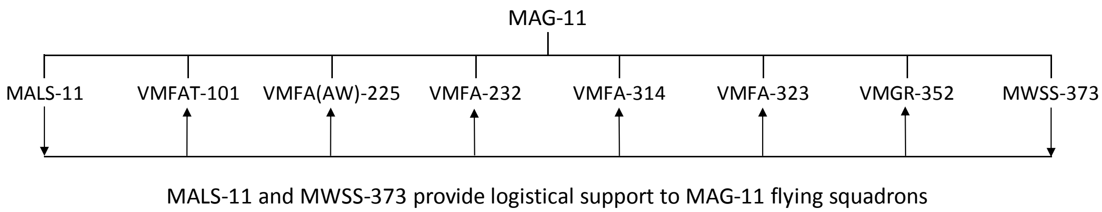

Figure 1. Organizational support relationship for MAG-11

VMFAT-101 is the Marine Corps' sole F/A-18 Fleet Replacement Squadron and is responsible for certifying new F/A-18 pilots and re-certifying F/A-18 pilots with expired certifications. VMFAT-101's aircraft comprise the majority of the F/A-18s within MAG-11. Of the 126 F/A-18s assigned to MAG-11, 66 FA-18s, or 52 percent, are assigned to VMFAT-101. It is essential that this squadron's aircraft maintain a high level of operational availability, as VMFAT-101 is responsible for supplying all F/A-18 pilots within the Marine Corps. Without a steady rate of replacement pilots, F/A-18 squadrons throughout the Marine Corps would face significant manpower issues.

From 2008 through 2010, MALS-11 physically stored a small portion of VMFAT-101's inventory allowances at a Satellite Supply Point (SSP) located within VMFAT-101. This SSP housed approximately 40 high-use repairable inventory components and increased the range and depth of consumable pre-expended bin (PEB) items. A pre-expended bin is, "a self-service storage area stocked with low cost, high usage, maintenance related items which have been expended from stock to department work centers" (Department of the Navy, 2009, p. N-51). Each MALS throughout the Marine Corps usually locates pre-expended bins at flying squadrons.

We were unable to locate any documentation supporting the 2008–2010 inventory re-allocation. To our knowledge, neither MALS-11 nor VMFAT-101 established a written Standard Operating Procedure (SOP) or Memorandum of Understanding (MOU). MALS-11, however, stated that the ASD did create a Microsoft Excel file to track all inventory transactions at the SSP. The MALS-11 Airspeed Office stated the inventory re-allocation was eventually cancelled due to (1) the reluctance of VMFAT-101 to have MALS-11 personnel operating within the squadron spaces and (2) the difficulty MALS-

11 experienced in accounting for the inventory located at the SSP (MALS-11 Airspeed, 2014).

In 2013, senior leadership directed MALS-11 to once again store VMFAT-101's inventory allowances at a SSP within VMFAT-101's squadron spaces within 30 days of the order. To our knowledge, once again, no MAG-11 entity created an SOP or MOU to facilitate the re-allocation. MALS-11 re-allocated almost the entire VMFAT-101 Training Squadron Allowance (TSA) from MALS-11 to the squadron; the only TSA items which remained at MALS-11 were repairable items in which MALS-11 only had a quantity of one stocked in the MALS warehouses. The SSP became operational on 03 April, 2013, and MALS-11 assigned six dedicated ASD personnel to support, work, and manage the SSP. Over time, this number decreased to four Marines manning the SSP. We depict both the before and after SSP requisition process flows in Chapter II.

It is important to note that after the SSP implementation in 2013, every MAG-11 squadron could still draw on VMFAT-101's inventory. For a MAG-11 squadron—other than VMFAT-101—to receive a part stocked in the SSP, all three of the following criteria had to be met: the requisitioned item prevented that squadron's aircraft from flying; MALS-11 did not have the part in stock; and the SSP had the part in stock. There would, however, be an added delay for the squadron to receive the part due to the amount of extra processing and/or steps required.

B. PURPOSE

The purpose of this thesis is to evaluate the effects of disaggregating a previously pooled inventory within a MAG. Our objective is to evaluate and analyze workflow efficiencies and changes in MAG-11 flying squadrons' order lead times after the relocation of an individual flying squadron's inventory allowance to the squadron's physical spaces. Historically, all MAG-11 squadrons' inventories were collectively pooled within MALS-11. Our research will analyze the effects on MAG-11 (specifically on MALS-11, the MAG-11 flying squadrons, and the MAG as a whole) storing some inventory allowances at a squadron instead of a MALS.

Proper inventory management can increase the operational availability of aircraft by decreasing the MLDT. Defense Acquisition University defines MLDT as "an indicator of the average time a system is awaiting maintenance" (Glossary: Defense Acquisition Acronyms and Terms, 2012). By understanding the implications and effects of disaggregating inventory, leadership can develop better processes and inventory practices within a MAG in order to minimize costs and maximize inventory efficiencies.

C. RESEARCH QUESTIONS

The intent of our project is to investigate the effects on order lead time of separating previously pooled inventory. In order to measure the effects of this policy change, we will research the following: (1) identify the in stock requisition process flow both before and after the SSP implementation; (2) measure the amount of time required to deliver an average requisition to MAG-11 F/A-18 squadrons both before and after the inventory re-allocation; and (3) measure the hypothetical effects of a SSP implementation without some of the inefficiencies identified in objective (1).

1. What were the *before* and *after* requisition delivery processes?

We will examine the in stock requisition process flow both before and after the 2013 inventory re-allocation. We will attempt to determine if the inventory policy change streamlined the process delivering requisitioned items to VMFAT-101 in order to better understand the before and after steady-state environment. Analyzing these processes will help us better understand inventory movement within MAG-11.

2. What were the *before* and *after* MAG-11 average requisition delivery times?

MALS-11 provides the logistical support for all MAG-11 squadrons. Similar to most Marine Corps units, it has finite resources. Since MALS-11 re-allocated resources—including manpower, equipment, and inventory—at the expense of other MAG-11 squadrons in order to support VMFAT-101, our goal is to quantify the effects of this new allocation of resources. We will do this by measuring the time required for MALS-11 to deliver an average squadron requisition (known as either order lead time or requisition fill time) under the two different process flows identified in the first objective.

We will compute delivery times for VMFAT-101 requisitions prior to and after disaggregating the pooled inventory. We will also compute average requisition fill times for the remaining F/A-18 squadrons within MAG-11 in order to identify the effects on these squadrons of separating the previously pooled inventories. We will analyze the MALS-11 supply databases to conduct the required measurements. Once we conduct a sampling of randomly selected requisitions and their corresponding delivery times both before and after implementation, we will use statistical tools to determine the validity of our measurements.

3. What is the hypothetical effect of an ideal implementation of the SSP at VMFAT-101?

We acknowledge—due to elements beyond MALS-11's control—that the implementation of the SSP at VMFAT-101 contained inefficiencies and was not ideal. We will discuss this in more detail in Chapter III. We will simulate an ideal SSP implementation and evaluate the overall effects on the requisition fill times for both VMFAT-101 and all other MAG-11 flying squadrons. Using this ideal implementation, we will simulate providing ASD Marines to service only VMFAT-101. How does providing MALS-11 Marines to service only VMFAT-101 affect the requisition fill times for both VMFAT-101 and the remaining MAG-11 flying squadrons?

D. LITERATURE REVIEW

Inventory pooling is a relatively new field of logistics. In 1979, Gary Eppen (1979) introduced an early model demonstrating that centralizing inventory contributed to reduced inventory costs. He found that the more uncorrelated the demands, the higher the impact on inventory levels; with more uncorrelated demand, savings were increased. His findings, however, did not examine the risk pooling effects on service levels. Captain Craig Barnett (2001) argued that inventory pooling greatly benefits the Marine Corps; he stated inventory pooling of Marine Corps repairable items drastically reduced costs while maintaining similar levels of asset availability. George Tagaras studied the effects of risk pooling on the corresponding service levels in a two location inventory system. He found that "pooling always improves the service level" (Tagaras, 1989, p. 2). Others argue that pooling does not always improve the service level (Li & Zhang, 2011) and that pooling does not always reduce the amount of inventory required (Gerchak & Mossman, 1991). Li and Zhang used a two location period review inventory system, while Gerchak and Mossman used a single period model.

E. SCOPE AND LIMITATIONS

The scope of this thesis covers one MAG within a Marine Aircraft Wing. Each MAG varies in type and number of aircraft assigned. Larger MAGs require a larger footprint and relatively greater logistical support from its supporting MALS. While each MALS has the same logistical mission to support its MAG, how each MALS provides logistical support varies between MALS. For the sake of simplicity, we will limit our research and analysis to MAG-11 only, and hence this research is best understood as a quantitative case study.

Our analysis will examine some seemingly generic issues in the pooling and disaggregation of inventory, and we know of no particular reason why those lessons learned might not be more broadly applied. Caution, however, should be used in generalizing our findings beyond the case study we examine, as our data is limited to that one case.

F. ORGANIZATION OF THESIS

Chapter II will discuss the before and after requisition delivery process flows. Chapter III will identify the data collection, sorting methodology, and assumptions used, and it will introduce the statistical methods used. Chapter IV will state the results from the requisition data (service times and queues) and analyze their significance. It will also analyze the process flows described in Chapter II. Chapter V will summarize our thesis, provide recommendations for further research, and close by providing our research conclusions.

II. PROCESS FLOWS

A. PROCESS FLOW INTRODUCTION

This chapter will depict the process flows used to deliver requisitions to MAG-11 flying squadrons in order to provide a basic fundamental understanding of the standard MAG-11 logistics delivery process. This chapter answers our first research question: What were the before and after requisition delivery processes? First, we will examine the original, standard MAG-11 requisition process flow when MAG-11 pooled all flying squadron inventory allowances within MALS-11's warehouses. This process flow is typical of how any MALS throughout the Marine Corps logistically supports a MAG. After the VMFAT-101 SSP implementation, this first process flow still applied for all MAG-11 squadrons with the exception of VMFAT-101. Second, we will look at the requisition process flow for VMFAT-101 after MALS-11 moved VMFAT-101's inventory allowances to VMFAT-101's squadron spaces on the flight line. We will conclude this chapter by summarizing the differences between the before and after process flows. After reading this chapter, one should better understand the basic requisitioning process for on-station requisitioned material at MAG-11.

The processes we will outline in this chapter do not consider requisitions that were not in stock (NIS) and/or not carried (NC) or that require special handling. Since our thesis only focuses on the delivery of on-station requisitions, we believe describing off-station process flows (i.e., the requisition was delivered using a supply chain entity external to the base) is irrelevant to the scope of our thesis. By on-station requisitions, we mean MALS-11 and/or the SSPs have inventory on their shelves which is able to satisfy the flying squadron's requisition requirements. Although MALS-11 must ultimately process and deliver the parts for NIS and/or NC requisitions, we will only focus on the processes directly affecting the amount of time it takes to deliver a carried, in stock requisition to a MAG-11 flying squadron. Additionally, our process does not consider requisitions needing special handling, such as a requisition requiring technical research, validation, or special transportation to the flying squadron. While we acknowledge there can be exceptions in the normal process flows for on-station requisitions, for simplicity's sake we will only describe the standard—without any complications—MAG-11 carried requisition process flow.

It is important to note that for both the standard and SSP requisition process flows, we did not list the time and capacity estimates. We did not have this data, as most MALS in the Marine Corps do not actively track this information. Most MALS only track the requisition order and delivery times within the process flows.

B. STANDARD REQUISITION PROCESS FLOW

This standard requisition process flow comprises the process flow for all MAG-11 flying squadrons before the SSP implementation and for all MAG-11 flying squadrons except for VMFAT-101 after the SSP implementation. Prior to the SSP implementation the MALS-11 ASD warehouses stored the inventory allowances assigned to all MAG-11 flying squadrons. Figure 2 graphically depicts the process for delivering an on-station requisition. The seven steps are:

(1) The MAG-11 flying squadron maintenance department orders an aircraft part using Optimized-Organizational Maintenance Activity (OOMA)—the flying squadron internal maintenance database and ordering system,

(2) A requisition picking ticket prints out in the MALS-11 warehouse,

(3) A Marine pulls the part from inventory in the warehouse,

(4) A Marine stages the part for delivery at the Material Delivery Division (MDD),

(5) A Marine delivers the part to the requisitioning squadron,

(6) The MALS-11 Marine has the flying squadron Marine sign—with signature, date, and time—the requisition ticket for proof of delivery and returns to MALS-11,

(7) Upon returning to the warehouse, the MALS-11 Marine completes the requisition, entering the delivery date and time into the Naval Aviation

Logistics Command Management Information System (NALCOMIS)—the MALS-11 internal inventory tracking system.

This completes the standard requisition process flow.

It is important to note that post SSP implementation, this standard requisition process flow generally remained the same for every MAG-11 squadron except for VMFAT-101. The only exception was for items issued from the SSP to a squadron other than VMFAT-101. Our assumption is that the SSP very rarely issued requisitions to any other MAG-11 squadron. Due to this, we did not focus on this process; rather, we focused solely on the normal processes the Marines experienced. The SSP would only issue an item to another squadron if all the following criteria were met: the requisition was high priority (preventing an aircraft from flying or conducting a mission); not currently stocked within the MALS' pooled inventories; and currently stocked in the SSP.

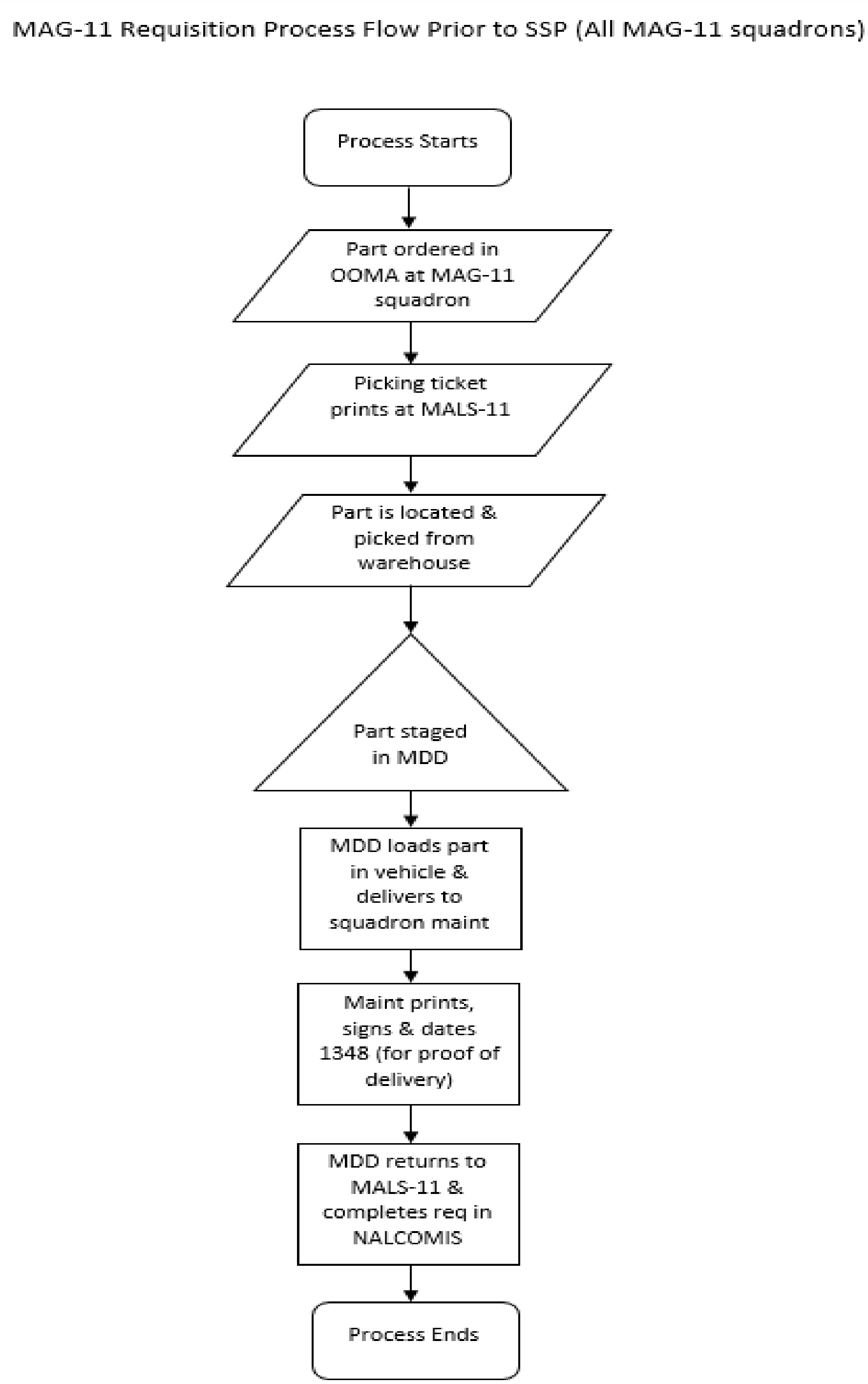

Figure 2. Normal requisition process flow

C. VMFAT-101 SSP REQUISITION PROCESS FLOW

MALS-11 implemented VMFAT-101's SSP requisition process flow after the creation of the SSP in April 2013. As mentioned in Chapter I, with the SSP implementation, MALS-11 now staged most of VMFAT-101's inventory allowances within VMFAT-101's work spaces.

In this new process flow, there are simultaneous steps occurring within both the MALS-11 organic warehouses and the SSP. Figure 3 graphically depicts the new process flow for delivering an on-station requisition to VMFAT-101. The steps are:

(1) VMFAT-101 maintenance Marine requisitions material in OOMA,

(2) A requisition ticket simultaneously prints out at both VMFAT-101 and in the MALS-11 warehouse. The MALS-11 warehouse ticket is a signal to replenish the SSP, while the VMFAT-101 ticket provides an order receipt,

(3) Due to a lack of connectivity at the SSP (mentioned further in Chapter III), the VMFAT-101 maintenance Marine manually walks the ticket to the SSP. Concurrently, a MALS-11 Marine pulls the replenishment from the MALS organic warehouse,

(4) A SSP Marine manually enters the requisition into Stand Alone Material Management System II (SAMMS-II), while MALS-11 stages the replenishment at the MDD for delivery. SAMMS-II is an expeditionary inventory tracking system used by MALS Marines when they are in austere environments without Internet connectivity or other supporting infrastructure,

(5) If the SSP carries inventory for the requisitioned material, the SSP pulls the inventory from stock and prepares it for delivery to the customer. If the SSP does not carry the requisitioned material, the SSP forwards the requisition to MALS-11 in SAMMS-II; in either scenario, MALS-11 concurrently delivers the replenishment or required issue to the SSP.

a. If the SSP carried the inventory, the SSP issued this inventory to VMFAT-101. VMFAT-101 signs for the material—with signature, date, and time—and the SSP completes the requisition in SAMMS-II. The SSP Marine signs for the MALS-11 replenishment—with signature, date, and time—and replenishes the SSP inventory,

b. If the SSP does not carry the inventory, the SSP must await the MDD delivery of the requisitioned material from MALS-11. After the SSP signs for the MALS-11 material—with signature, date, and time—the SSP Marine then delivers the requisition to VMFAT-101. The VMFAT-101 Marine would then also sign for the requisitioned material—with signature, date, and time. The SSP would then complete the requisition in SAMMS-II,

(6) The MDD Marine returns to the MALS-11 warehouse and completes the requisition in NALCOMIS.

This summarizes the VMFAT-101 SSP requisition process flow.

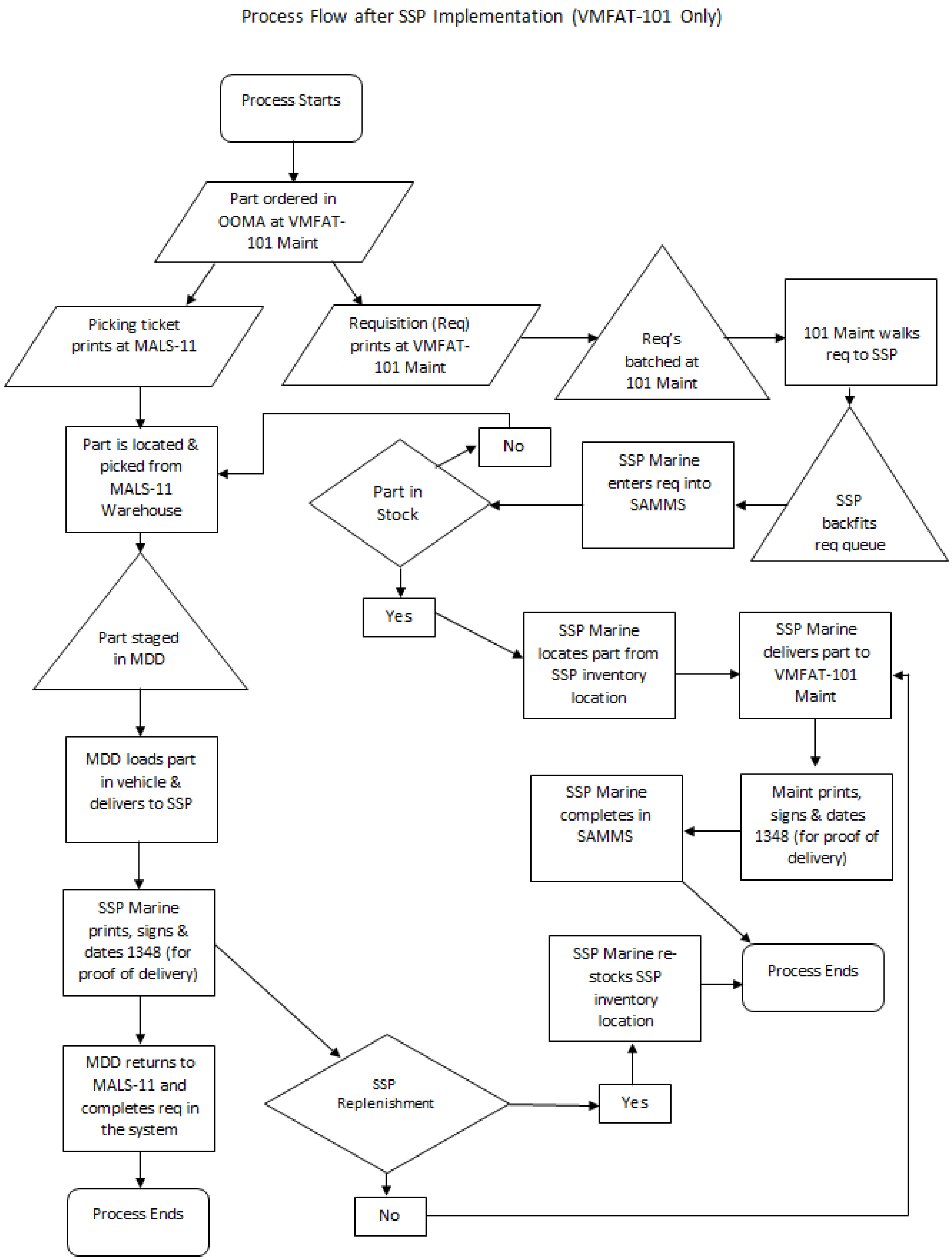

Figure 3. VMFAT-101 Satellite Supply Point process flow

D. SUMMARY

VMFAT-101's post-implementation process flow added numerous steps. Reducing the complexity in a process should reduce the cycle time (Ginn & Barlog, 1993); however the added logistical node (the SSP) and corresponding supply steps added complexity to the new process. This new process flow decreased automation in the overall process flow—primarily with a lack of synchronization between OOMA and SAMMS-II—and led to an increase in the number of queues in the process flow. We will provide a thorough analysis of the effects of this new process flow in Chapter IV.

III. METHODOLOGY

A. INTRODUCTION

We used two different models in order to analyze whether establishing a SSP at a squadron reduced MLDT at a MAG. We created the first model to measure the actual changes in requisition fill time after the inventory policy change, and we created the second model to calculate the hypothetical requisition fill times under an ideal SSP implementation.

We received all our data from MALS-11. We used the information provided by both the MALS-11 ASD and Airspeed Office to conduct our analysis and arrive at our conclusions. The MALS-11 ASD provided multiple Microsoft Excel spreadsheets containing NALCOMIS data for a two-year time period—one year before and one year after SSP implementation—and SAMMS-II data which recorded the SSP requisitions since inception in April 2013. Our spreadsheets contained all requisitions ordered by MAG-11 squadrons during this two-year time period (the SSP had one year's worth of data because it was only implemented after the base year). These data sets comprised almost 140,000 requisitions for all MAG-11 flying squadrons. Additionally, the MALS-11 Airspeed Office provided its own analysis of the SSP implementation effectiveness.

This chapter introduces the methods used to arrive at the results we list in Chapter IV. We begin by examining our first model and then examine our second model. Within each model, we will first discuss the model's purpose. Next, we will discuss the methods of each model, including data sorting and model construction. Finally, we will list the assumptions inherent in each model.

B. MODEL ONE: MEASURING THE PRE- AND POST-SSP IMPLEMENTATION REQUISITION DELIVERY TIMES

1. Purpose

Our first objective was to determine the actual effects of the inventory policy change within MAG-11. The main purpose of this model was to examine if requisition fill times increased or decreased for VMFAT-101 and for the other F/A-18 squadrons in

MAG-11 after implementation of the SSP at VMFAT-101. By examining the changes between the base year and the year proceeding the implementation, we hope to determine if the F/A-18 squadrons within MAG-11 had to wait for shorter or longer periods of time to receive their requisitioned material.

2. Methods

We chose to examine the before and after changes in average requisition delivery time in order to determine the policy's effectiveness. To determine if the policy change was effective, one must first find a baseline. Our baseline was average requisition delivery time for the year prior to implementation. We compared this time to the average requisition delivery time for the year after the implementation of the SSP. By comparing these changes, we should be able to determine the effects of the inventory policy change.

Our model examines the effects of this change on the F/A-18 squadrons within MAG-11; we only examine F/A-18 squadrons because VMFAT-101 is an F/A-18 squadron. Moving VMFAT-101's inventory allowances from the MALS to the SSP should have a relatively larger effect on those squadrons that previously pooled and used the same type of spare parts—namely the MAG-11 squadrons with the same T/M/S aircraft (i.e., F/A-18 squadrons)—compared with those squadrons that have less parts in common with VMFAT-101's aircraft. While we acknowledge both F/A-18 aircraft and other T/M/S aircraft have some parts in common, there will be large amounts of parts in the VMFAT-101 inventory allowances which are T/M/S specific. Due to this, we did not use VMGR-352's requisitions in this model. The only aircraft attached to VMGR-352 are KC-130J T/M/S aircraft.

We were tempted to analyze changes in F/A-18 readiness rates to determine the policy's effectiveness, but we did not use readiness rates for two different reasons:

(1) We only examined requisitions which were in stock at the MALS or SSP when the squadron requisitioned the material (otherwise known as on-station requisitions). If the requisitioned item was already located at MALS-11 on the base, overall readiness should not be significantly affected by on-station requisition delivery times regardless if there was or

was not a SSP. Under circumstances where the part is required immediately, the MALS and requisitioning squadron could jointly work together to expedite the requisition delivery in an amount of time much shorter than an hour. This relatively short delivery time is insignificant to overall aircraft readiness.

(2) There are many different factors influencing readiness rates. We would be unable to definitively state that changes in aircraft readiness were due to the inventory policy change.

Working closely with MALS-11, we obtained all requisition data for all MAG-11 F/A-18 squadrons for one year prior to the SSP implementation and one year after the SSP implementation. Once we received the raw data, we filtered the data to exclude requisitions that did not meet our standard, normal requisition criteria and/or that we believed inaccurately depicted the time to complete the requisition. Reasons for excluding the data included:

(1) The requisitions were not ordered and delivered to the relevant squadron within the two-year relevant time frame. Our data used Julian dates 093 in 2012 through 092 in 2014; this corresponds to the calendar dates of 02 April, 2012 through 02 April, 2014.

(2) The requisitions went off-station (NIS or NC). An off-station requisition is a requisition unable to be filled from both the MALS-11 and SSP inventories, and which must be delivered from a supply chain entity external to the base. In order to obtain relevant delivery times, we must only look at the delivery times that would be affected by the policy change. For our research, only requisitions that were issued from on-hand stock were relevant. If the item was NIS or NC, the policy change would have a minimal effect on the overall delivery time.

(3) The requisitions were not high priority. By high priority we mean requisitions that prevented an aircraft from flying and/or conducting taskings. We excluded non-high priority requisitions because the original

intent of the SSP was to focus on delivering high priority requisitions to VMFAT-101 as fast as possible in an attempt to increase readiness by reducing MLDT.

(4) The requisitions had a local status code (LSC) which was not listed as complete (COMPL) in NALCOMIS. Requisitions normally delivered to the squadron and completed in the inventory system are displayed in NALCOMIS with an LSC of COMPL. If the requisition did not state COMPL, MALS-11 did not deliver the requisition from the MALS-11 warehouse. For this model, we only looked at requisitions that were ordered and actually delivered to the squadron. For example, we did not include in our data: cancelled requisitions, requisitions issued from a PEB already located at the squadron, etc.

(5) The requisitions had extenuating circumstances. By extenuating circumstances, we mean the requisition or its corresponding delivery was somehow different from the standard high priority requisition or its corresponding delivery process. For example, if the item notes in NALCOMIS stated the squadron or work center was secured during the delivery attempt and/or the requisition was a warehouse issue, we excluded the requisition. Additionally, we omitted requisitions from our dataset if:

- The forklifts were inoperable for large items when the squadron ordered these large parts,
- The requisition was reversed,
- The requisition was reordered multiple times from MALS-11,
- The requisition was no longer required by the squadron,
- The requisition was a payback to other units,
- The requisition was delivered to the Supply Response Division (SRD) located in the ASD,
- The item needed a container for the part,

- The time was improperly entered into NALCOMIS, and/or
- If the turn in (broken part) was not ready to be returned to ASD when the replacement repairable item arrived at the squadron.

If any special handling was needed, the requisition was excluded. Any requisitions that required special handling for the above reasons would skew our requisition delivery times and were thus excluded.

(6) The requisitions were backfit. Normally, squadrons requisition items through their automated order system OOMA. OOMA automatically transfers the requisition to the MALS. The MALS' organic software system, NALCOMIS, automatically records the requisition order time (the time of day the MALS receives the transferred requisition from OOMA). A backfit requisition is a requisition that was manually entered by a MALS Marine into NALCOMIS. We did not include backfits in our data set, as the backfit order and completion times frequently have inaccurate times input into the internal MALS inventory systems, and this would skew our data. While there were varying reasons for the requisitions being backfit, many backup requisitions from the data provided were for pack up issue/replenishments for MAG-11 F/A-18 squadrons on deployment throughout the United States and the world. A pack up contains spare parts, "that are deployed with Marine aviation units to enhance on-site mission support" (Department of the Navy, 2009, p. N-49). We did not use these requisitions in our dataset.

Our filtering criteria were quite rigorous. Prior to filtering the requisitions, we had over 105,000 total different requisitions for all MAG-11 F/A-18 squadrons. After subjecting the data to our filtering criteria, we had slightly less than 35,000 remaining requisitions, a decrease of almost 67 percent. We segregated the remaining data into four individual data sets:

(1) Pre-implementation VMFAT-101 data

(2) Pre-implementation data for all MAG-11 F/A-18 attack squadrons

(3) Post-implementation VMFAT-101 data, and

(4) Post-implementation data for all MAG-11 F/A-18 attack squadrons

After filtering the NALCOMIS data sets, we began conducting random samplings of the data. First, we conducted random samplings on the two years of data for the F/A-18 attack squadrons, and then we conducted random samplings on the two years of data for VMFAT-101. We used Microsoft Excel to generate random numbers which corresponded to specific requisitions. If the randomly generated number corresponded to a requisition that was delivered in less than 10 minutes or more than 5 hours, we excluded this data and generated a new random number. We view a delivery time of less than 10 minutes as inaccurate and unrealistic, even under ideal circumstances due to the common practice of batching in MALS throughout the Marine Corps. Similarly, we viewed a delivery time of more than 5 hours as excessive under normal circumstances. MALS throughout the Marine Corps must deliver their high priority on-station requisitions in an hour or less (Department of the Navy, 2012). We assumed any requisition that takes more than five times the required amount of time has extenuating circumstances preventing timely issuance. Common reasons include:

(1) The forklift was not working,

(2) The flying squadron was secured,

(3) The item was a repairable which had to be expeditiously repaired (EXREP) at the MALS before being re-issued to the squadron.

Once we obtained the randomly selected requisitions, we calculated the actual length of time it took from when the requisition was ordered to when it was completed. We then converted the data from hours and minutes to solely minutes. For example, we converted the amount of time it took to deliver a requisition to a squadron from an hour and 39 minutes to simply 99 minutes.

For the MAG-11 F/A-18 attack squadrons, we used a sample size of 150 randomly selected requisitions for each year. Next, we compared the difference in average times necessary to complete or deliver the requisition between the two years.

Finally, we conducted a two-sample assuming unequal variances one-tailed t-test in order to determine if our results were significant. A t-test is a comparison of means. In this case, it is a comparison of the mean delivery times before and after the implementation of the SSP. The t-test is conducted to see if, as expected, the delivery time was shortened in a statistically significant way by the implementation of the SSP.

We concluded our process by obtaining the p-value of our sample. "The p-value is the probability of obtaining the observed sample results (or a more extreme result) when the null hypothesis is actually true" (Wikipedia, n.d.). The p-value provides an indication of the statistical significance of the change in mean delivery times, before and after the SSP implementation. The p-value is the probability the mean delivery times could differ by as much as we found, due to random chance alone, if the SSP implementation had actually made no difference. When the p-value is small, it provides support for the argument that the difference in the mean delivery time was caused by the SSP implementation, rather than chance.

Once we obtained the requisition sampling results for the MAG-11 F/A-18 attack squadrons, we focused on obtaining requisition delivery times for VMFAT-101. We could not, however, simply compare NALCOMIS data between the two years like we did for the MAG-11 F/A-18 attack squadrons. The SSP was unable to use the ASD's organic inventory tracking system—NALCOMIS—due to the SSP lacking the appropriate data ports needed for connectivity to NALCOMIS. The SSP essentially acted as a "deployed detachment of MALS-11 aboard MCAS Miramar" (Marine Aviation Logistics Squadron 11 Airspeed, 2014, p. 7). NALCOMIS displayed an inaccurate delivery time for VMFAT-101 requisitions; the time it recorded was actually the time the SSP—not VMFAT-101—received and signed for the material. The SSP still had to deliver VMFAT-101's requisition to the squadron. In this case, NALCOMIS would understate total delivery time. To overcome this obstacle, we used data from SAMMS-II to record when the squadron actually received the material.

SAMMS-II, however, was also inaccurate. VMFAT-101 requisitions had to be manually carried over to the SSP (and they were frequently batched), causing the recorded requisition order time in SAMMS-II to be significantly later than the actual order time listed in NALCOMIS. In this scenario, SAMMS-II order times would also understate the length of time it took to complete the requisition.

To overcome this problem, we combined the order times of VMFAT-101 requisitions listed in NALCOMIS with the completion times listed in SAMMS-II in order to obtain a more accurate requisition delivery time. By subtracting the completion time in SAMMS-II from the order time listed in NALCOMIS, we found the actual length of time MALS-11 took to deliver each requisition to the squadron. If the requisition was listed in SAMMS-II but not in NALCOMIS (or vice versa), we did not use that requisition for our sample. Instead, we generated a new, randomly selected requisition.

After generating the random numbers and locating the corresponding requisition order and completion times, we obtained the mean completion time for VMFAT-101 requisitions for both the first and second years. For each year, we used a sample size of 50. Next, we compared the difference between the two years and conducted another two-sample assuming unequal variances one-tailed t-test and found the p-value.

3. Assumptions

We used multiple assumptions in our model in order to determine the average requisition delivery times. They are:

(1) Requisition order and delivery times are accurately recorded in either NALCOMIS or SAMMS-II unless there were extenuating circumstances which were listed in the NALCOMIS requisition notes. If there were extenuating circumstances, we excluded the data from our observations.

(2) Requisition delivery times of less than 10 minutes or more than 5 hours were considered outliers.

(3) The only relevant squadrons for this model are F/A-18 squadrons. We did not include VMGR-352's (a squadron which does not fly F/A-18 T/M/S aircraft) requisitions in this model because we wanted to compare similar T/M/S requisitions. A squadron composed of non-F/A-18 aircraft would be less likely to requisition inventory designed for VMFAT-101's F/A-

18s, making it more difficult to compare the effects of separating pooled inventory. We were comparing the delivery of F/A-18 requisitions both before and after the implementation of the new inventory policy.

(4) We assumed the MAG-11 F/A-18 attack squadrons' requisition completion times have similar distributions. We treated every requisition for the MAG-11 F/A-18 attack squadrons as interchangeable between these squadrons. By interchangeable, we mean it was irrelevant from which squadron the requisition originated as long as it did not originate from the VMFAT-101 squadron.

(5) We assumed backfit requisitions to be inaccurate. A backfit requisition is a requisition that was manually entered into the internal MALS-11 inventory system after it was previously ordered or issued. We assumed these delivery times to be inaccurate because usually the Marine processing the requisition manually puts the current time and date for both the order and completion times.

(6) We assumed every National Item Identification Number (NIIN, the civilian equivalent of a Stock Keeping Unit (SKU)) had a similar distribution of delivery times. This assumption allowed us to randomly select requisitions for each part of our model regardless of the NIIN.

C. MODEL TWO: MEASURING THE HYPOTHETICAL EFFECTS OF PROVIDING ADDITIONAL RESOURCES TO VMFAT-101 UNDER IDEAL CONDITIONS

1. Purpose

The lack of data ports at the SSP lead to a suboptimal, inefficient policy implementation. As the MALS-11 Airspeed Office noted, "SAMMS does not interface directly with NALCOMIS … causing inventory tracking issues and a lack of transparency for both units" (Marine Aviation Logistics Squadron 11 Airspeed, 2014, p. 7). This suboptimal implementation was entirely out of MALS-11's and VMFAT-101's control. Neither entity had control over data port connectivity. If the SSP had

NALCOMIS connectivity, our answers found in the first model might be significantly different. To present a more compelling argument on the effectiveness of the SSP, we wanted to see what the data would show if this policy was conducted under notional, ideal conditions. The purpose of this second model is to discover the effects on requisition delivery times for this inventory policy change under a best case scenario. Hypothetically, this second model should show us the best results (in terms of requisition delivery times) MAG-11 could hope to obtain for its squadrons by locating a SSP at VMFAT-101. Our purpose is to discover if notional, on-station requisitions would be delivered faster or slower to MAG-11 squadrons under ideal, hypothetical SSP implementation conditions.

2. Methods

This model used a Markovian multiple channel, single phase queuing (M/M/S) model. This model computes average requisition fill times given different system inputs. Within this M/M/S model, we conducted two different scenarios (see Figure 4). Our first scenario was our baseline. This scenario predicts an average, on-station requisition delivery time for all MAG-11 squadrons with all inventory pooled at MALS-11. Our second scenario depicted the splitting of MALS-11's resources used to service MAG-11 squadrons. Part one of our second scenario predicts an average, on-station requisition delivery time for VMFAT-101 under an ideal SSP implementation at VMFAT-101. Part two of our second scenario predicts an average, on-station requisition delivery time for all remaining (non-VMFAT-101) MAG-11 flying squadrons under an ideal SSP implementation at VMFAT-101.

Using two scenarios allowed us to analyze the hypothetical before and after effects on requisition delivery times for all MAG-11 flying squadrons in order to determine the effects of splitting the pooled inventory under ideal conditions. It allowed us to measure the change in requisition delivery times for VMFAT-101 and all other MAG-11 squadrons with the policy change. It is important to stress that we did not use actual measured time for individual requisitions like we did in the first model. Instead, based on different model inputs or variables, we computed how long it should take for an average requisition to be delivered to the requisitioning squadron under each scenario.

For this model, we only used the data from the year prior to the SSP implementation; and similar to our first model, model two only deals with on-station requisitions. We examined what the hypothetical requisition delivery times would have been in the first year for all MAG-11 squadrons if the SSP was actually in place during this time, relative to what the hypothetical requisition delivery times would have been if the inventory continued to be pooled at MALS-11. We only used this first year of data because we wanted to compare what would have hypothetically happened if we had and/or did not have a SSP at VMFAT-101. By only analyzing the first year, we were able to "compare apples to apples." We could now measure how long it hypothetically would have taken under each scenario. We compared the inputs and discovered how the outcomes changed within each scenario given the same overall demand.

Our model examines the effects of this ideal implementation on all flying squadrons—including VMGR-352—within MAG-11. We included VMGR-352 in this model because we believe all flying squadrons would be affected by the ideal SSP implementation. This model re-allocates some scarce resources—including MALS personnel—which previously serviced all MAG-11 flying squadrons. After the re-allocation, these re-allocated resources primarily serviced VMFAT-101.

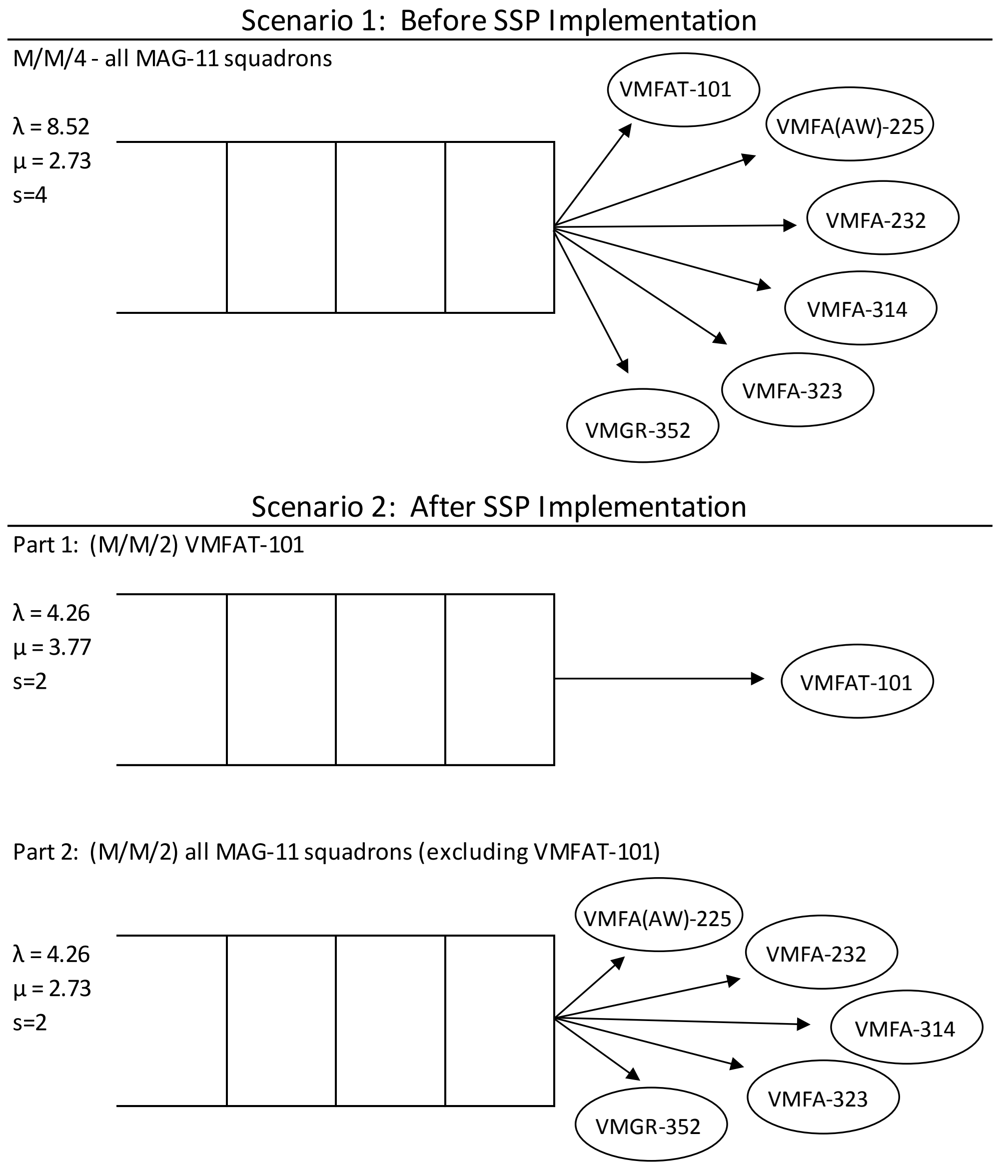

Figure 4. M/M/S scenarios before and after SSP implementation

In order to have the model fulfill the M/M/S single-phase criteria, we combined all the requisition delivery steps (displayed in Chapter II's process flows) into one all-encompassing step. Under our single-phase criteria, when a squadron orders a requisition, the requisition enters and exits the process flow in one phase.

a. ***Model Variables***

In this section we list and provide a brief explanation of the variables in our model. We can derive the M/M/S model based on three different variables: the arrival rate (λ), average service rate (μ), and number of servers (s) in the model.

(1) Average arrival rate (λ)

For this model, the average arrival rate (frequently denoted as λ) reflects the hourly arrival rate of requisitions arriving into MALS-11. For example, if MALS-11 received 120 requisitions over a six-hour period, the arrival rate would be 20 requisitions on average arriving per hour into MALS-11 (120 requisitions / 6 hours).

(2) Average service rate (μ)

For this model, the average service rate (frequently denoted as μ) is the average amount of requisitions each server can process in an hour. For example, if the average server can process an average requisition in 20 minutes, each server has an average service rate of three requisitions per hour (60 minutes / 20 minutes per requisition).

(3) Servers (s)

The number of servers in the model denotes the number of Marines able to process requisitions. The more servers (i.e., Marines delivering the requisitioned material) in MALS-11, the more requisitions MALS-11 is able to process per hour. Multiplying average service rate by the number of servers provides the overall capacity for the system (i.e., how many requisitions overall the MALS is able to process and deliver in an hour).

b. ***Variable Values***

(1) Arrival Rate

Our first step was determining how to obtain the values of λ, μ, and s. Obtaining the average arrival rate, λ, of on-station requisitions arriving at MALS-11 was the most difficult part of this step. We started with the raw MALS-11 NALCOMIS data consisting of almost 127,000 requisitions for the two-year time period.

Most MALS ASDs have three shifts: a day, night, and middle shift. As customer demand is usually lower during the night and middle shifts, they generally have minimal staffing levels. We chose to use data from only the day shift because we acknowledge that demand changes between shifts, and we wanted to examine arrival rates when MALS-11 operates at its highest capacity, i.e., during the normal day shift. We viewed the day shift as occurring between 0700 and 1600 every day.

We sorted the data to exclude:

- Requisitions ordered outside the first year time period (prior to 02 April, 2012 and after 02 April, 2013)
- Off-station requisitions
- Cancelled requisitions
- Requisitions issued from the PEB
- Requisitions not ordered during the day shift

We included both low and high priority and backfit requisitions in this model. Our rationale for including all priority requisitions in this model was that even though low priority requisitions did not have the same urgency as high priority requisitions, MALS-11 personnel must eventually process all requisitions regardless of their priority. Thus, the arrival rate must include all requisition priorities in order for the model to account for the time spent processing and delivering each requisition. Additionally, we included backfit requisitions in this model. We included backfit requisitions in this model because we looked at arrival rates—not delivery times (which were skewed by incorrect backfit requisition inputs)—in this model. We considered backfit arrival rate data—especially since we examined the entire day shift and not individual times—to be accurate for this model. For this reason, we included backfit requisitions in our data.

Once we obtained an arrival rate for every day of the year prior to SSP implementation (02 April, 2012 through 02 April, 2013), we eliminated the days where the MAG-11 squadrons did not conduct business as usual. If the MAG-11 squadrons' maintenance personnel had minimal staffing levels due to special circumstances, we excluded those days. Specifically, we eliminated:

- Weekends. During these days, MAG-11 flying squadrons generally had a skeleton crew on day shift. The arrival rate of requisitions into MALS-11 was abnormally low, and MALS-11 generally had minimal staffing levels.

- Federal holidays. During each federal holiday, MAG-11 squadrons usually had either three or four days off work. During this time, the arrival rate of requisitions at MALS-11 would be abnormally low and in some occasions, zero. From the arrival rate data, it was readily apparent which days the squadrons did not work or only had skeleton crews on hand.

- The dates of the Miramar Air Show. During the air show, MAG-11 squadrons' personnel generally spent minimal time at work due to the large influx of visitors and extreme difficulty navigating the base. Due to this, once again the arrival rate of requisitions into MALS-11 was abnormally low during this time.

Once we filtered the data based on our criteria, we counted all requisitions arriving per day into MALS-11 during the day shift. Next, we calculated the arrival rate of requisitions into MALS-11 for the day shift on each normal day of operation. After calculating each day's arrival rate, we calculated the average arrival rate for the year during normal working conditions. The day shift hourly average arrival rate for the year prior to SSP implementation was 8.52 on-station requisitions arriving into MALS-11 per hour. The standard deviation of the average arrival rate was 3.41 requisitions per hour.

We used this arrival rate ($\lambda = 8.52$) for scenario one. We could not, however, use this same value of λ for parts one and two of scenario two. Parts one and two of scenario two must together have an overall arrival rate of 8.52 requisitions arriving into MALS-11 and/or the SSP per hour ($\lambda_{\text{VMFAT-101}} + \lambda_{\text{MAG-11 flying squadrons (excluding VMFAT-101)}} = \lambda_{\text{MAG-11 flying squadrons}}$). The amount of requisitions ordered by VMFAT-101 was almost half of all requisitions ordered by MAG-11 flying squadrons. To arrive at a value of λ for parts one and two of scenario two, for simplicity's sake we evenly divided the arrival rate between each part. At the end of the year, the arrival rate for VMFAT-101 would average out to be half of the overall arrival rate for all MAG-11 flying squadrons if they ordered half of the overall requisitions during this time period.

(2) Average Service Rate

Our second step required us to find the average service time, μ. In this case, we sought the advice of subject matter experts (SME) at MALS-11 ASD. The consensus was that under ideal conditions an average requisition should hypothetically be delivered to a squadron in 20 minutes. This time assumes no batching of requisitions; as a requisition orders arrive into MALS-11, they are handled one by one and then delivered one by one to the requisitioning squadron. Thus, our model does not factor in the amount of time a requisition would be in a queue during the delivery process, i.e., the single phase. This model, however, does allow for a queue prior to beginning the single phase. In other words, if the servers are servicing other requisitions when a new requisition arrives at MALS-11, the new requisition will sit in a queue. Once that requisition exits the queue, we assume no more wait time in the process.

The MALS-11 ASD estimated under ideal circumstances it should take on average approximately 20 minutes to deliver a requisition. We factored an additional 2 minutes for the delivery driver to return to the MALS, for a total time of 22 minutes spent per requisition. We divided 60 minutes per hour by 22 required minutes to deliver each requisition to obtain the average per hour μ of 2.73 requisitions. This value of μ works for the first scenario and part two of the second scenario, as both of these scenarios do not incorporate the SSP (see Chapter II process flow for more information).

Part one of the second scenario—VMFAT-101 requisition delivery times under SSP implementation—must factor in the average time it takes to deliver a requisition from the SSP to VMFAT-101. The MALS-11 ASD stated that under ideal circumstances, the average requisition which had stock on hand at the SSP could be delivered in 5 minutes. The MALS-11 Airspeed Office calculated the SSP was able to issue 29 percent of consumable and 61 percent of repairable requisitions ordered by VMFAT-10 (Marine Aviation Logistics Squadron 11 Airspeed, 2014). We calculated from our data that approximately 79 percent of material ordered from the SSP was consumable material, and 21 percent of the material was repairable material. From these two sets of numbers, we calculated that approximately 36 percent of overall VMFAT-101 demand was met by the SSP, from which ideally the SSP was able to issue in only 5 minutes. Thus, approximately 64 percent of demand was met by MALS-11's warehouses. Once we calculated these numbers, we took a weighted average of $\mu_{\text{MALS issue}}$ and $\mu_{\text{SSP issue}}$. The computed weighted average for $\mu_{\text{MALS issue + SSP issue}}$ was approximately 3.77. Thus, in part one of scenario two the MALS and SSP working in conjunction could deliver on average 3.77 requisitions per server per hour to VMFAT-101.

(4) Servers

The last variable that we had to define was the amount of servers, s, within the model. We chose to use the number of servers based on the system constraints (or bottlenecks). Bottleneck resources prevent the system from processing and delivering requisitions faster than the processing rate of the bottleneck resource. We viewed the bottleneck as the amount of drivers located at the MDD within MALS-11. Our rough approximation for the average number of MALS-11 MDD drivers/servers was four. This is a rough approximation because this number frequently varies. The amount of servers can change throughout the day based on manning levels during the two-hour lunch break, mandatory meetings, the amount of vehicles operational, etc. It can also change from day to day based on a variety of reasons associated with managing Marine manpower, including annual training requirements, personal issues, as well as frequent Marine turnovers due to permanent change of duty stations or billets.

For scenario one of our model, we approximated that there were four servers. We pooled all servers at MALS-11. For scenario two (under the ideal SSP implementation), however, we split the total number of servers available between the two parts.

As previously mentioned in Chapter I, VMFAT-101 comprised over half of the aircraft in MAG-11. In addition, VMFAT-101's requisitions comprised almost 50 percent of the total requisitions used in our second model. Since VMFAT-101's on-station requisitions comprised approximately 50 percent of MAG-11 requisitions, we allocated 50 percent of the servers to service VMFAT-101 and 50 percent of the servers to service the remaining (non-VMFAT-101) MAG-11 squadrons. Under scenario two, the MALS servers dedicated to each part can now no longer service the aircraft in the other part during times of increased demand.

Once we solved for λ, μ, and s, we inserted these values into our Markovian queuing formulas to receive an average requisition delivery time for each scenario. We also solved for each scenario's average capacity utilization. Based on the daily arrival rate, actual capacity utilization could vary widely from day to day.

3. Assumptions

We used multiple assumptions in determining requisition delivery times. They are:

(1) Our model assumes requisitions arriving into MALS-11 and/or the SSP follow a Poisson distribution and that service times are exponentially distributed.

(2) Our model assumes MALS-11 and/or the SSP deliver the requisitions on a first come, first served basis.

(3) We assumed the model was a single phase model (i.e., requisitions entered and exited the process flow in only one step).

(4) Under scenario one, we assumed all MAG-11 flying squadrons to be interchangeable and on average have the same requisition delivery time due to all material arriving to the squadrons from the single pooled location at MALS-11.

(5) Under part two of scenario two, we assumed all MAG-11 flying squadrons (excluding VMFAT-101) to be interchangeable and have on average the same delivery time under the ideal SSP implementation conditions of the model.

(6) We assumed the completion dates and times for both scenarios to be irrelevant. The only relevant issue was the order date and time, as we were primarily concerned with the arrival rate.

(7) We split the overall arrival rate for all MAG-11 flying squadrons evenly between parts one and two of scenario two. We assumed half of the arriving requisitions into MALS-11 and/or the SSP were from VMFAT-101 and the other half were from all other MAG-11 flying squadrons.

(8) All MAG-11 flying squadrons were affected by allocating more resources to service VMFAT-101. Since there were limited resources, allocating resources to one squadron will come at the expense of the other squadrons.

(9) Our model assumed no batching occurred for the requisitioned material. As a squadron requisitioned an item, we assumed the item was picked from the shelf and delivered to the squadron one by one.

(10) Our model assumed there was no queue time once the requisition was being worked, since we had a single phase model and assumed the requisitions flowed through the system without batching.

(11) Once a server is assigned to support either VMFAT-101 or the remaining MAG-11 squadrons, the servers cannot support the other group. By this, we mean a server supporting VMFAT-101 cannot assist a server supporting the remaining MAG-11 squadrons, even under periods of increased demand for the other group.

D. SUMMARY

In this chapter, we mentioned the purpose of our two models, described the methodology of these models, and also provided the assumptions inherent in each model. This chapter provided the overall framework and description of each model. Chapter IV analyzes the results of the models we described in this chapter.

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IV. RESULTS AND ANALYSIS

A. INTRODUCTION

In the previous chapter, we discussed our methodologies used. In this chapter, we will first display our results and analysis for Model One. Secondly, we display our results and analysis for Model Two. Thirdly, we will provide analysis on the process flows we described in Chapter II, and then we will discuss how the changes between the two process flows added complexity to the process. This chapter answers the two remaining research questions:

(1) What were the before and after MAG-11 average requisition delivery times?

(2) What is the hypothetical effect of an ideal implementation of the SSP at VMFAT-101?

B. MODEL ONE RESULTS AND ANALYSIS

As explained in the previous chapter, Model One is a comparison of actual before and after delivery response times based on a statistical sampling of requisitions. The amount of time (and standard deviation) required to deliver requisitions to both VMFAT-101 and the MAG-11 F/A-18 attack squadrons significantly increased after the implementation of the SSP. Our null hypothesis for both t-tests was that there was no change in requisition delivery times between the two years examined. Based on our sampling results, we rejected the null hypothesis at the .05 significance level for both VMFAT-101's and the MAG-11 F/A-18 attack squadrons' on-station, high priority requisition wait times. The percentage change in requisition delivery times is the best estimate of the effect of the policy change on MAG-11 aircraft. Tables 1 and 2 depict our results.

According to our data, the SSP had the exact opposite effect of its original intent to reduce VMFAT-101's requisition delivery wait time. Even more surprising, the policy change had approximately twice the negative impact on VMFAT-101 as the policy change had on the MAG-11 F/A-18 attack squadrons. From our sample, the average amount of time it took VMFAT-101 and the MAG-11 F/A-18 attack squadrons to receive an on-station, high priority requisition increased after the SSP implementation by approximately 84 and 43 minutes, respectfully. The average amount of time it took VMFAT-101 to receive an on-station, high priority requisition increased from about an hour and 5 minutes to almost two and a half hours after the SSP implementation, an increase of 130 percent. The average amount of time it took the MAG-11 F/A-18 attack squadrons to receive an on-station high priority requisition increased from about an hour and 11 minutes to about an hour and 54 minutes, an increase of approximately 60 percent.

VMFAT-101 t-Test: Two-Sample Assuming Unequal Variances

	Delivery Time (After)	*Delivery Time (Before)*	*Delta*
Mean	148.96	64.72	**84.24**
Coefficient of Variation	0.53	0.72	
Observations	50	50	
Hypothesized Mean Difference	0		
df	79		
t Stat	6.49		
P(T<=t) one-tail	0.000000003		
t Critical one-tail	1.66		

Table 1. VMFAT-101 t-Test

One could argue that the original, status quo state was already working at acceptable levels. Both groups sampled had roughly the same delivery times, which were just above the one-hour goal discussed in Chapter III. These times are relatively close to the goal delivery times, and comprise a very small portion of the total MLDT. Moreover, in the original state, VMFAT-101 already received its on-station high priority requisitions about 6 minutes faster than the F/A-18 attack squadrons. After the SSP implementation, both groups experienced delivery times well out of the goal delivery times.

F/A-18 MAG-11 Attack Squadrons t-Test: Two-Sample Assuming Unequal Variances			
	Delivery Time (After)	*Delivery Time (Before)*	*Delta*
Mean	114.18	71.31	**42.87**
Coefficient of Variation	0.64	0.65	
Observations	150	150	
Hypothesized Mean Difference	0		
df	253		
t Stat	6.10		
P(T<=t) one-tail	0.000000002		
t Critical one-tail	1.65		

Table 2. MAG-11 F/A-18 Attack Squadrons t-Test

It is important to note that not only did the average delivery times increase for all MAG-11 F/A-18 squadrons, but the variability in these delivery times increased as well. The coefficient of variation for both VMFAT-101 and the F/A-18 attack squadrons, however, actually decreased. This is due in part to the relatively large increase in the average times required to deliver the requisitions after implementation. Not only did the squadrons have to wait longer to receive their requisitioned parts after the SSP implementation, but now there was also less predictability when the maintenance personnel at the squadron would receive their parts.

The p-values obtained for both the t-tests for VMFAT-101 and the MAG-11 attack squadrons were miniscule. The p-value for VMFAT-101's t-test shows that there was a three in a billion chance—given the null hypothesis was true—that we would receive a value equal to or greater than the observed t-statistic. Similarly, the MAG-11 F/A-18 attack squadrons' p-value for their t-test shows—given the null hypothesis was true—that there was only a two in a billion chance that we would receive a value equal to or greater than the observed t-statistic. These p-values lend credibility to our results. The p-value for our randomly sampled observations were highly unlikely to be obtained if after the SSP implementation, there was no change in requisition delivery times.

C. MODEL TWO RESULTS AND ANALYSIS

As explained in the previous chapter, Model Two is a queuing model developed to predict what delivery lead times might have been in a best-case scenario without some of the inefficiencies described in Chapter II. Model Two's results showed that there were definite hypothetical impacts on the policy change for all involved parties. In this model, the average amount of time it took for a squadron to receive a requisition was 36 minutes. After the SSP implementation, VMFAT-101 received their notional requisitions faster, while the remaining MAG-11 flying squadrons experienced a longer wait time for their notional requisitions. Table 3 depicts our results.

	Inventory Pooled	Post SSP	
	All MAG-11 Squadrons	VMFAT-101	Remaining MAG-11 Squadrons
Average amount of time it takes a squadron to receive a requisition:	36.13 minutes	23.41 minutes	56.40 minutes
Utilization factor:	78.10%	56.54%	78.10%
Avg number of requisitions in queue:	2.01	0.53	2.44

Table 3. Model Two results

In this model, what is important is the *comparison* between times, not the predicted changes in lead time itself. Since this is a hypothetical model (thoroughly described in Chapter III), many elements in this model are purely theoretical. The main take away from this model is that even under an ideal implementation of the SSP (including utilizing the correct data drops), VMFAT-101 benefits at the expense of the remaining five flying squadrons at MAG-11. The model predicts that VMFAT-101 will attain a notional requisition delivery time decrease relative to the baseline, while the remaining MAG-11 flying squadrons' notional requisition delivery times increase relative to the baseline.

One factor influencing the delivery times for Model Two is the size of the queue of requisitions waiting to be processed, referred to as L_q in queuing models. Prior to the SSP implementation, Model Two predicts the overall, average number of on-station requisitions in the total MAG-11 requisition queue to be 2.01 requisitions. After the implementation, the total number of requisitions waiting to be processed for all MAG-11 squadrons increased to 2.97 requisitions (.53 requisitions in the queue for VMFAT-101 and 2.44 requisitions in the queue for the remaining MAG-11 squadrons), an increase of almost 50 percent in the overall amount of requisitions waiting to be processed.

The effects on the queues after the policy change, however, vary significantly between squadrons. After the implementation, VMFAT-101 has an average queue of only .53 requisitions waiting to be processed. The remaining MAG-11 squadrons now have an average queue size of 2.44 requisitions, which is approximately 21 percent larger than the total MAG-11 queue prior to the SSP implementation. In fact, the remaining MAG-11 squadrons' average queue size is over 4.6 times larger than VMFAT-101's queue. With VMFAT-101 requisitions comprising approximately half of the overall requisitions processed in MAG-11, this is a noteworthy difference. This would suggest that VMFAT-101 benefits with a reduced queue—which ultimately translates to faster requisition delivery times—at the expense of the remaining MAG-11 squadrons.

Another factor influencing the delivery times for Model Two is the utilization factor, referred to as ρ in queuing models. In this case, the average utilization of the servers (i.e., the Marines picking the material and delivering the requisitions to the squadrons) prior to the SSP implementation was 78 percent. After creating the SSP at VMFAT-101, however, the average utilization factor for the Marines logistically supporting VMFAT-101 decreased to 57 percent due to the decreased time required to process and deliver an average requisition. The utilization factor for the Marines supporting the remaining MAG-11 squadrons, however, remained at 78 percent.

Due to the relatively lower average utilization factor for the servers supporting VMFAT-101, VMFAT-101's servers would be better able to handle demand variability than the servers supporting the remaining MAG-11 squadrons. Thus, ceteris paribus, under periods of increased demand for all MAG-11 squadrons, delivery times and queues would be lower for VMFAT-101 relative to the remaining MAG-11 squadrons. Moreover, with requisition demand spikes between individual MAG-11 squadrons, disaggregating the servers previously pooled to support all MAG-11 squadrons leads to less flexibility in overall support. After the SSP implementation, if VMFAT-101's dedicated servers experienced minimal demand and had spare utilization, they would be unable to support the other servers if they were experiencing increased demand at the remaining MAG-11 squadrons. Prior to the SSP implementation, the servers could use their pooled resources to support those squadrons experiencing increased demand, making the system overall more efficient.

The model demonstrates that splitting capacity and inventory can be advantageous to VMFAT-101, but only at the expense of the other squadrons.

D. PROCESS FLOWS ANALYSIS

The process flows depicted in Chapter II display the actual steps both the Marines at MALS-11 and the SSP experienced. In this section, we will only refer to Model One because this model numerically depicts the tangible process flow times experienced at MAG-11 (see Section B of this chapter). A quick comparison of Figures 2 and 3 from Chapter II shows that relative to the original process flow, the SSP implementation added a large amount of complexity and additional steps to the requisition delivery process. It is intuitive that the more steps inherent in a process, the more difficult it is for the process to flow. "…ceteris paribus, a lower level of complexity of the system yields a joint improvement of system's efficiency and effectiveness" (Perona & Miragliotta, 2004, p. 12). These additional steps contributed to increased workloads, processing errors, redundant actions, and inventory discrepancies at both MALS-11 and the SSP.

Along with the additional steps inherent in the SSP implementation process flow, there were also multiple queues added to the process for VMFAT-101's requisitions. These additional queues were created due to the lack of the appropriate data ports at the SSP. As a result, the automated ordering process was no longer available throughout the MAG-11 supply chain. We believe these queues had a significant impact on the overall delivery times. VMFAT-101's average requisition delivery time actually increased much more than the F/A-18 attack squadrons' average requisition delivery time, even though MALS-11 provided VMFAT-101 enhanced logistical support and staged inventory within VMFAT-101.

After the SSP implementation, the requisition delivery times for the F/A-18 attack squadrons also increased. We believe that this was in part due to MALS-11 providing enhanced levels of logistical support—including personnel to work at the SSP—to VMFAT-101. As was previously mentioned in Chapter I, MALS-11 has a finite pool of resources. When MALS-11 provides additional resources to one squadron, MALS-11 must provide fewer resources to at least one other squadron. In this scenario, we believe it is accurate to state MALS-11 provided fewer resources to the MAG-11 F/A-18 attack squadrons after implementing the SSP, resulting in an increase in requisition delivery times for these squadrons.

E. SUMMARY

In this chapter, we identified and analyzed the actual results experienced by the SSP implementation. Additionally, we listed the theoretical wait times experienced for all MAG-11 squadrons before and after the SSP implementation and provided an analysis of our results. We concluded the chapter by discussing the interrelatedness of Model One and the process flows identified in Chapter II in order to explain our actual results. Chapter V summarizes our thesis and provides our recommendations for the future.

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V. SUMMARY AND RECOMMENDATIONS

A. INTRODUCTION

In our research, we quantified the changes in on-station requisition delivery time caused by separating previously pooled inventory. If the military had an unlimited supply of inventory and money, pooling (or separating) inventory would not be an issue; the military would merely keep sufficient stores of inventory at each squadron. This scenario, however, is unrealistic, especially as the military is currently experiencing a period of fiscal austerity. Best practices, especially regarding inventory, must be found in order to optimize resources and continually do more with less. The models we used in our research suggest that the most efficient use of resources is to pool inventory within a MALS.

In the previous chapter, we discussed our results and analysis. In this chapter, we will first provide an overall summary of our thesis; then we provide recommendations for further study; and we close by providing our research conclusions.

B. SUMMARY

In our study, we used two different models to identify the real and theoretical changes in requisition delivery times both before and after separating the pooled inventory. For the first model, we conducted random samples of the before and after data to find an average time to deliver requisitions to VMFAT-101 and the MAG-11 F/A-18 attack squadrons. Then, we compared the data and measured for statistical significance in the difference between the mean delivery times. We recognized the SSP implementation occurred under non-ideal circumstances, so we used a second model—a Markovian queuing model—to measure theoretical requisition delivery times under ideal conditions.

Our study found that actual requisition delivery times significantly increased after SSP implementation, especially for VMFAT-101. We believe these times increased because the post-SSP process flow added complexity to the process and introduced numerous queues. We also found that under an ideal, notional implementation of the SSP, VMFAT-101 could achieve reduced average requisition delivery time, but this benefit would come at the expense of all other MAG-11 squadrons. Under this second hypothetical model, these remaining squadrons' average requisition delivery times are predicted to increase.

C. RECOMMENDATIONS FOR FURTHER STUDY

Our current study examined on-station, high priority requisitions and their corresponding delivery times from April 2012 through April 2014. We have shown in our thesis that implementing a SSP does not provide a positive net benefit to MAG-11 in terms of delivery times for MAG-11 squadrons.

We recommend further study into the root causes of the SSP implementation. What was the intent of creating the SSP, and why was it created multiple times? As mentioned in Chapter I, the SSP was created, disbanded, and re-established—under different leadership—twice over the previous six years. It is important to note that different leaders at multiple times determined it made sense to create a SSP. If one can understand leadership's intended goal and strategy, it would allow one to better understand the dynamics of the SSP policy change and potentially provide alternative courses of action.

In our study, we did not evaluate the effects of the SSP on aircraft readiness. We assumed the SSP had a negligible effect on MAG-11 readiness. This is because we believed the actual requisition delivery times comprised a very small portion of the total MLDT, the cause of decreased aircraft readiness. Our sampling of requisition delivery times prior to implementation found that the average high priority requisition delivery time was just over an hour for all MAG-11 squadrons. With no complications, aircraft can frequently be in a non-mission capable status for 12–24 hours (in this case, requisition delivery time would comprise only 4–8 percent of overall MLDT), although MLDT can drastically increase with complications or multiple requisitions ordered against that same aircraft (under this scenario, requisition delivery times could comprise a fraction of 1 percent of overall MLDT). Decreasing the delivery time for VMFAT-101 from one hour to less than an hour has a very small quantitative impact on the total MLDT. Consequently, we believe future study is warranted to examine potential root causes for increased MLDT—and decreased squadron aircraft readiness—in order to determine what actually has a large impact on squadron aircraft readiness rates.

Merely having the necessary aircraft parts readily available is not a panacea for increased readiness. Many different factors affect aircraft readiness, including maintenance practices, operational demands, properly trained personnel, leadership priorities, and the availability of spare aircraft parts. Some factors may be outside MAG-11's control. For example, if the maintenance repair depots have a long repair turnaround time (meaning the depots take a long amount of time to fix assets), this can have a large impact on readiness, as it may take longer to replenish the repairable inventory in the MALS' warehouses. We recommend further research to identify root causes of readiness degradation, the relative impact on readiness of each root cause and possible solutions to increase readiness.

We also recommend further research into the effect the SSP implementation had on MALS-11. Each MALS throughout the Marine Corps has a finite amount of assets used to provide logistical support. Any inefficient use of a MALS' assets and resources used to provide logistical support should have a detrimental effect on the logistical support a MALS provides to a MAG. Without cost-effective logistical support, squadron readiness and any significant squadron evolution becomes at best highly doubtful. Anecdotally, the SSP implementation had a negative impact on the MALS, especially with maintaining proper accountability and accurate inventory levels. Due to the scope of our research, we did not quantify or focus on the effects of this policy on MALS-11. We recommend that future research analyze the SSP's effects on MALS-11's ability to provide logistical support to the entire MAG. We recommend studying how MALS-11 was able to meet unforeseen logistical challenges for the rest of MAG-11 given the amount of personnel dedicated to VMFAT-101. This research might identify best practices implemented in other parts of the ASD in order to compensate for the increased demand placed upon MALS-11 resources by the SSP. These practices could potentially benefit MALS throughout the Marine Corps.

D. CONCLUSION

We recommend MAG-11 re-visit its decision to move VMFAT-101's inventory allowances to the SSP. Under the current MAG-11 operating environment (i.e., organizational structure and manpower allocations), the quantitative results suggest that separating the MAG-11 inventory allowances is non-optimal, decreases efficiencies, and increases the strain on logistical support. Even if MAG-11 implemented the SSP at VMFAT-101 under ideal circumstances, the remaining squadrons that did not have the SSP would be negatively affected. This is because these squadrons would have to wait longer periods of time to receive their parts. MAG-11 needs to be cognizant that if they want a SSP to support VMFAT-101, there will be negative consequences—both for VMFAT-101 under the status quo and for all remaining MAG-11 squadrons under any scenario. MAG-11 must determine if focusing on expediting VMFAT-101's requisitions is a worthwhile policy. Our research shows that at best, a SSP can improve VMFAT-101's requisition delivery times but degrade requisition delivery times for the rest of MAG-11. At worst, the SSP could negatively impact all MAG-11 squadrons' average requisition delivery times.

We believe the SSP has a low chance of having an ideal implementation. If the SSP continues as is, the situation will continue to get worse. Based on our analysis, we believe the SSP is an ineffective policy which does not justify the amount of resources consumed. We recommend MAG-11 disband the SSP and move all squadron inventory allowances back to MALS-11.

This study provides quantifiable evidence that separating previously pooled inventory was not beneficial to MAG-11. While every MAG in the Marine Corps is different, we believe that each MAG should carefully examine the potential impact of separating pooled inventory prior to actually implementing change.

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