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## Enhancing Project Management with Lean World Class Manufacturing in Construction

Jacob Randles

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ENHANCING PROJECT MANAGEMENT WITH  
LEAN WORLD CLASS MANUFACTURING IN CONSTRUCTION

by

JACOB D RANGLES

Under the Direction of Anoop Desai

ABSTRACT

In construction, the goal of commercial projects is to turn a profit. This is achieved by minimizing inputs and maximizing outputs while building a product that meets the customer's perception of value. Value is determined through pre-negotiated specifications, plans, and material quality. Even in U.S. military construction, the unit executing the construction wants to complete the task on time and on budget, which can be difficult to do. Studies on project completion showcase a surprisingly high rate of failure in reaching the aforementioned "on time, on budget" goal. It is important to understand the nuances and details of U.S. Army engineering and construction because the method used to test the viability of integrating Lean World Class Manufacturing (LWCM) into a construction project involved an Army Engineer Company. The purpose is to make a company more competitive in the marketplace; in the same way the Japanese automotive industry came to dominate American car manufacturers during the 1980s. This approach to manufacturing requires a firm's complete dedication to the implementation of the philosophy. The objective of this research is to determine the economic viability of applying LWCM techniques to a traditional construction methodology using a real world construction project. Application of LWCM precepts to a U.S. military construction project during a training exercise proves beneficial when compared to a project that did not use them; however, definitive savings in time, labor, and material costs could not be obtained to definitively state a case for their economic viability in the private sector.

Index Words: Lean World Class Manufacturing, Last Planner System, Project Management, Military Construction, Work Rates, Vehicle Readiness Rates, Fuel Consumption Rates, Survivability Construction

ENHANCING PROJECT MANAGEMENT WITH  
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MASTER OF SCIENCE

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December 2016

**DEDICATION**

To my sons, Logan and Victor.

## ACKNOWLEDGEMENTS

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## ABBREVIATIONS

AA	Assembly Area
ABET	Accreditation Board for Engineering and Technology
ALC	Advanced Leader Course
ANSI	American National Standards Institute
AAR	After Action Review
BEB	Brigade Engineer Battalion
BFV	Bradley Fighting Vehicle
BOLC	Basic Officers Leader Course
BOM	Bill of Material
BSA	Brigade Support Area
CBR	California Bearing Ratio
CPM	Critical Path Method
CSW	Crew Serve Weapon
ECCC	Engineer Captain's Career Course
ESC	Engineer Support Company
FA	Field Artillery
GSU	Georgia Southern University
JFEO	Joint Forcible Entry Operations
JIT	Just-In-Time Production
JRTC	Joint Readiness Training Center
FLS	Forward Landing Strip
HDP	Hull Defilade Position
LPS	Last Planner System
LWCM	Lean World Class Manufacturing
MKT	Mobile Kitchen Trailer
MRE	Meal Ready to Eat
MTOE	Modified Table of Organization and Equipment
NCO	Non-Commissioned Officer
NOD	Night Optical Device
O/C	Observer/Controller
PAA	Position Area for Artillery
PET	Percent Expected Time-overrun
PLT	Platoon



PM	Project Management
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PPC	Percent Plan Completed
SLC	Senior Leader Course
SOW	Statement of Work
TEI	Total Employee Involvement
TPM	Total Productive Maintenance
TQC	Total Quality Control
VFP	Vehicle Fighting Position

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## Chapter 1: Introduction

### 1.1 Problem Statement

In the world of construction the end-state of any commercial project is to turn a profit. This is achieved by minimizing inputs and maximizing outputs while building a product that meets the customer's perception of value. Value is determined through pre-negotiated specifications, plans, and material quality. Even in government construction where troop labor (Army, Air Force, and Navy Engineers) is used, the unit executing the construction wants to complete the task on time and on budget.

Project completion on time and on budget is often a difficult result to obtain. Studies on project completion showcase a surprisingly high rate of failure in reaching the aforementioned "on time, on budget" goal. Approximately 75% of all projects are left unfinished, exceed time, or exceed budget (Stöteau 2012). The integration of management techniques not traditionally used in construction to mitigate the issue of project failure while increasing economic benefits is the focus of this paper.

### 1.2 Background Information

Construction firms utilize a range of project management, project scheduling, and control techniques. There are several popular texts that outline common techniques used in construction. However, there is no unifying text preferred by all practitioners. Most texts discuss common techniques like the following: Work Breakdown Structures, Gantt charts, Precedence Diagramming Method, and Project Evaluation and Review Technique (Pellicer, Yepes, and Teixeira 2013).

The need for a uniform approach to managing projects led to the increasing popularity of guidelines set forth by organizations like the Project Management Institute (PMI). PMI provided a systemic approach to project management by tying together common themes and lessons from across the project management spectrum. Many construction firms, wanting to enhance their competitiveness, sent their foremen or managers through a 40 hour course followed by an exam that yielded the Project Management Professional certification (Project Management Institute 2015b).

In a field proliferated by common techniques, some firms began consulting other management practices outside of construction to obtain a competitive edge. The manufacturing industry was one



particular field that received increased scrutiny from project managers in construction. Managers directed their attention in particular towards the Japanese manufacturing sector due to the Japanese automotive manufacturers' success in outpacing their American counterparts in production and quality (Davis, Selvidge, and Waldrop 2012, 1-6).

The secret to Japanese's success is Lean World Class Manufacturing (LWCM), which is also known as the Toyota Production System. LWCM is the mission of a manufacturing firm committed to adopting strategies based on the "Total Quality Management" philosophy. The focus is on empowering the people of an enterprise in an effort to obtain never-ending improvement of quality and productivity to satisfy a customer's perception of value. Tachii Ohno, Vice President of Toyota in the 1950's, is responsible for developing the original LWCM precepts. The production philosophy includes a total of four precepts: Just-in-Time Production, Total Quality Control, Total Productive Maintenance, and Total Employee Involvement (Davis, Selvidge, and Waldrop 2012, 1-1).

### 1.3 Hypothesis

Manufacturing is comprised of repetitive processes that can be continuously improved. Construction projects are single occurrence events with a well-defined start and finish date. In spite of these differences, some benefit to integrating the techniques is bound to exist due to LWCM's focus on efficiency. If LWCM principles are applied to a construction project, then the application of its precepts, like Just-In-Time Production and Total Quality Control, could yield measurable savings in time, labor, and material related costs.

### 1.4 Objective of the Research

Experimenting with different management techniques in construction is often difficult because if the experiment fails the firm loses money. The objectives of this project contribute to the knowledge of project management and construction managers' skills in several areas. First, it details the strengths and shortcomings of traditional construction project managerial techniques. This is conveyed through the study of a horizontal construction crew conducting a forward landing strip (FLS) project and constructing survivability positions at Fort Polk, LA. Next it provides an analysis of the integration of LWCM

techniques with those construction methods. The following month, a second horizontal construction enterprise continues work on the FLS and constructs new survivability positions on Fort Polk, LA. Analysis of the two separate construction projects using different management techniques provides a case study in the benefits and limitations of integrating a popular manufacturing precept (LWCM) within the world of construction.

### 1.5 Organization of the Thesis

The literature review is presented in Chapter 2. It covers background information on Army Project Management, the Project Management Institute's Project Management, LWCM, and previous attempts to integrate LWCM with construction project management.

In Chapter 3 the methodology for completing the research is discussed. The methodology addresses the preparation and application of the project management techniques on an earthmoving construction operation. It also reviews the preparation and integration of LWCM techniques on a separate construction operation.

The results and analysis of the methodology are examined in Chapter 4. Similar to the methodology, the chapter contains results from the two separate construction operations. The success criteria for the experiment (troop and equipment work rates, fuel consumption rates, and vehicle readiness rates) are examined.

Chapter 5 presents an overview of the results and recommendations for future work. Additional documentation related to the research is provided in Appendices. The appendices include a list of formulas used, auditor reports, and an experiment audit report from the researcher.

## Chapter 2: Literature Review

### 2.1 Army Project Management

It is important to understand the nuances and details of U.S. Army Engineering because the method used to test the viability of integrating LWCM into a construction project involved a U.S. Army Engineer Company. The Company is the 712th Engineer Support Company (ESC), which has a mission to conduct rapid runway repair, initial base camp construction, non-explosive obstacle breaching, and roadway maintenance and construction (U.S. Department of the Army 2015). Of the 138 personnel assigned, 103 are heavy equipment operators. It is comprised of three 30 Soldier platoons and two 24 Soldier sections. The platoon leadership is similar to project managers and project foremen.

#### 2.1.1 Army Project Management Training

Army Project Supervisors come from one of two possible sources. The first source, known as the “Enlisted Route,” is the enlisted Soldier who obtains the majority of their construction knowledge from experience as a worker on projects. Soldiers from the second source are officers who received their training following completion of a four year degree from a degree granting institution.

Project supervisors (who followed the “Enlisted Route”) have approximately seven to twelve years of experience as a construction worker and team foreman. For an ESC, the enlisted foreman began their career as an earthmoving equipment operator. After several years earning experience, this individual obtained rank and was given more responsibilities. When promoted to the rank Staff Sergeant, a non-commissioned officer (NCO), the Soldier attended their first round of formal training. As a Staff Sergeant, the Soldier enrolled and graduated from a seven week long Advanced Leader Course. While enrolled the Soldier acquired the knowledge and learned the skills needed to supervise, inspect, plan, and assist in horizontal construction operations (U.S. Army Noncommissioned Officers Academy 2015a). Three to five years later, the Soldier attended a six week long Senior Leader Course (SLC). While at SLC, the Soldier learned how to build a schedule using the Critical Path Method (CPM), read a schedule,

how to plan a horizontal project, and how to manage a horizontal construction project from start to finish (U.S. Army Noncommissioned Officers Academy 2015b).

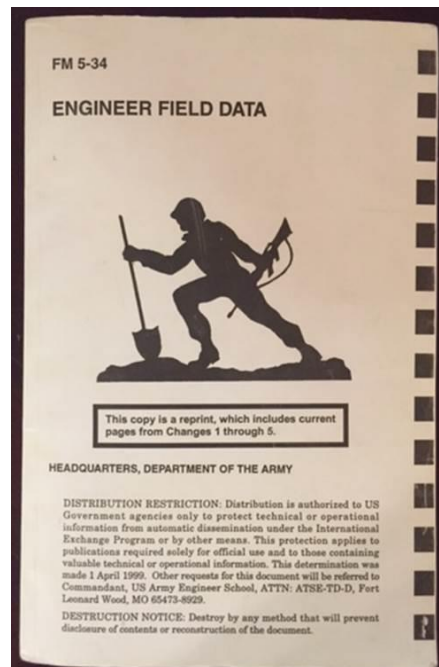
Officers comprise the other source of a unit's project managers. To become an officer in the Army Engineers, a person only needs a Bachelor's Degree and a commissioning source. Upon graduation the newly commissioned officer attends a 20 week program called Basic Officer Leader's Course (BOLC). The officer learns how to function as both a combat engineer and a construction supervisor while in attendance. Different aspects of construction covered are earthmoving operations, carpentry, concrete construction, geospatial techniques, and project management (U.S. Army Engineer School 2015a). Following this course, the officer spends one to three years working as a project manager or a project coordinator. Engineer officers placed in charge of a company attend a six month course before assuming control of the unit. The Engineer Captain's Career Course (ECCC) provides a uniform block of instruction to refresh the officer's engineering skills and prepare them for a role as the manager of a company that may specialize in construction (U.S. Army Engineer School 2015b).

2.1.2 Army Doctrine Technical Manual 3-34.42, Field Manual 5-34, and Army Techniques Publication 3-37.34

Standardization of learning is important for all professions. Higher education facilities seeking to develop Engineer programs seek ABET accreditation to demonstrate the application of an effective and uniform curriculum leading to a degree. The U.S. Army models this approach through the adoption of regulations and technical manuals that apply to all its members. There are two important regulations that are regularly referenced in the Army Engineering world. The best known is Field Manual (FM) 5-34: Engineer Field Data, another is Technical Manual (TM) 3-35.42: Construction Project Management; and for the Engineer tasked with protecting combat power there is Army Techniques Publication (ATP) 3-37.34: Survivability Operation.

FM 5-34 is a manual containing approximately 500 pages of data pertinent to Army Engineer tasks. Of this data Chapter 3 "Reconnaissance," Chapter 11 "Roads and Airfields, and Chapter 14 "Miscellaneous Field Data" are the most frequently referenced for construction projects. Chapter 3

provides instructions for calculating area drainage, road curvature, road gradient, and classification criteria for the type of traffic a road is able to support. Chapter 11 discusses the steps taken to classify soils. It also explains how to construct expedient roads and runaways. Chapter 14 is a catchall chapter that contains multiple tables and figures for the purpose of referencing (U.S. Department of the Army 2005).



*Figure 1: FM 3-34 Engineer Field Data*

Formal training courses for officers and NCOs use TM 3-35.42 as the foundation for training on construction management. TM 3-35.42 is written in a style that mimics textbooks. It is used as a core foundational document in Army General Engineering curriculums for ALC, SLC, BOLC, and ECCC. The manual provides instruction on the various phases of construction projects. This includes the initial planning phase, the execution phase, supervision throughout the project, and closeout. It lays out guidelines for developing and implementing quality control plans for the product being constructed and the material being used for construction (U.S. Department of the Army 2012).

U.S. NAVY	NTRP 4-04.2.5
U.S. ARMY	TM 3-34.42
U.S. AIR FORCE	AFPAM 32-1020
U.S. MARINE CORPS	MCRP 3-17.7F

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**CONSTRUCTION PROJECT  
MANAGEMENT  
NTRP 4-04.2.5**


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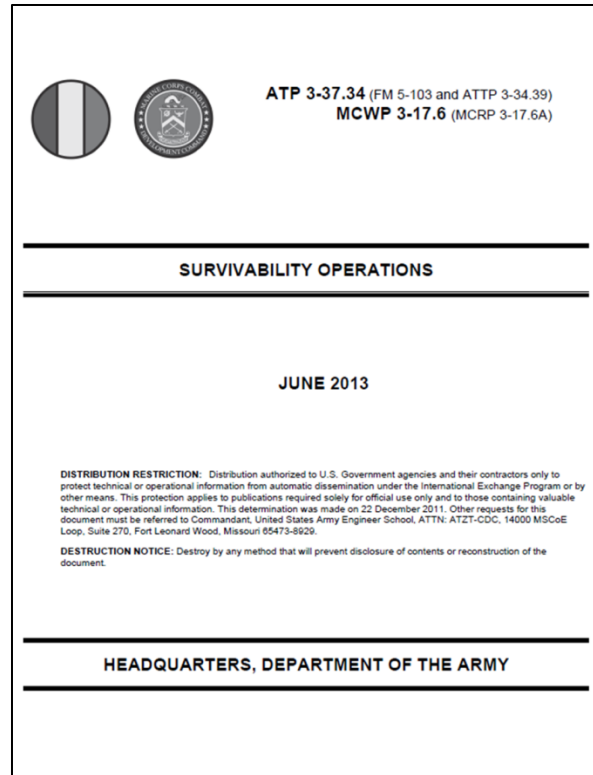
  
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Figure 2: TM 3-34.42 Construction Project Management

*Figure 2: TM 3-34.42 Construction Project Management*

As the U.S. Army shifts its focus from combating insurgencies overseas to fighting a traditional military force, the Engineer branch is increasingly called upon to use its construction assets to build earth works to protect combat power. ATP 3-37.34 provides instruction on how to construct various survivability positions using earth works. Understanding how to protect different types of combat assets to include M1A2 Abrams Tanks, Bradley Fighting Vehicles, and 155mm Howitzer Field Artillery pieces is a key element of survivability. The ATP provides an analysis of the level of protection offered by different types of soils, providing the Engineer with a resource adaptable to any environment. During the Army Engineer learning curriculums construction of survivability positions is presented with an emphasis on capabilities and limitations of a position. Additional focus is placed on the equipment available within the Army inventory and the types of survivability operations that equipment is best suited for (U.S. Department of the Army 2013).



*Figure 3: ATP 3-37.34 Survivability Operations*

## 2.2 Project Management Institute Project Management

Founded in 1969, the Project Management Institute (PMI) is the world's largest not-for-profit membership association for the project management profession. Its membership is approximately 700,000 as of January 1, 2015. PMI's worldwide project management advocacy is substantiated by its globally recognized standards and certification programs, its extensive academic and market research programs, its practicing chapters, and its professional development opportunities (Project Management Institute 2015a).

With accreditation as a standards developer by the American National Standards Institute (ANSI) in 1998, PMI credentials gained increasing prominence and importance amongst U.S. Army Project Managers (Project Management Institute 2015b). With the addition of an additional skill identifier for project management in 2013, Army Engineering demonstrated its commitment to enhancing the professional skill sets attributed to its managers.

### 2.2.1 Project Management Body of Knowledge

The Project Management Body of Knowledge (PMBOK) was first published in 1996 in an effort to document and standardize accepted project management practices and concepts. It contained the internationally recognized standard and guidelines for the project management profession. The consolidated knowledge within the text outlined PMI's established norms, methods, processes, and practices. Many of the guidelines and methods set forth in the PMBOK served as a reference for what PMI categorizes as "good practices" (PMI Standards Committee 2013, 2).

Processes were defined as "a set of interrelated actions and activities performed to create a pre-specified product, service, or result (PMI Standards Committee 2013, 47)." The PMBOK explained how the five separate Process Groups feed into one another through the generation of their respective outputs. Those outputs became inputs for subsequent processes. In an effort to streamline the understanding of how the five process groups interact, they were sub-divided further into ten Knowledge Areas. Knowledge Areas provided a detailed description of the process inputs and outputs in conjunction with an explanation of the techniques frequently utilized to yield the desired outcome. Breaking down the Knowledge Areas produced 47 project management processes. Table I referenced additional details outlining the organization of PMI's Process Groups.

Table I: Project Management Process Group and Knowledge Area Mapping

Knowledge Areas	Project Management Process Groups				
	Initiating Process Group	Planning Process Group	Executing Process Group	Monitoring and Controlling Process Group	Closing Process Group
<b>4. Project Integration Management</b>	4.1 Develop Project Charter	4.2 Develop Project Management Plan	4.3 Direct and Manage Project Work	4.4 Monitor and Control Project Work 4.5 Perform Integrated Change Control	4.6 Close Project or Phase
<b>5. Project Scope Management</b>		5.1 Plan Scope Management 5.2 Collect Requirements 5.3 Define Scope 5.4 Create WBS		5.5 Validate Scope 5.6 Control Scope	

A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Fifth Edition. ©2013 Project Management Institute, Inc. All rights reserved.



Table I: Project Management Process Group and Knowledge Area Mapping

Knowledge Areas	Project Management Process Groups				
	Initiating Process Group	Planning Process Group	Executing Process Group	Monitoring and Controlling Process Group	Closing Process Group
<b>6. Project Time Management</b>		6.1 Plan Schedule Management 6.2 Define Activities 6.3 Sequence Activities 6.4 Estimate Activity Resources 6.5 Estimate Activity Durations 6.6 Develop Schedule		6.7 Control Schedule	
<b>7. Project Cost Management</b>		7.1 Plan Cost Management 7.2 Estimate Costs 7.3 Determine Budget		7.4 Control Costs	
<b>8. Project Quality Management</b>		8.1 Plan Quality Management	8.2 Perform Quality Assurance	8.3 Control Quality	
<b>9. Project Human Resource Management</b>		9.1 Plan Human Resource Management	9.2 Acquire Project Team 9.3 Develop Project Team 9.4 Manage Project Team		
<b>10. Project Communications Management</b>		10.1 Plan Communications Management	10.2 Manage Communications	10.3 Control Communications	
<b>11. Project Risk Management</b>		11.1 Plan Risk Management 11.2 Identify Risks 11.3 Perform Qualitative Risk Analysis 11.4 Perform Quantitative Risk Analysis 11.5 Plan Risk Responses		11.6 Control Risks	
<b>12. Project Procurement Management</b>		12.1 Plan Procurement Management	12.2 Conduct Procurements	12.3 Control Procurements	12.4 Close Procurements
<b>13. Project Stakeholder Management</b>	13.1 Identify Stakeholders	13.2 Plan Stakeholder Management	13.3 Manage Stakeholder Engagement	13.4 Control Stakeholder Engagement	

A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Fifth Edition. ©2013 Project Management Institute, Inc. All rights reserved.

### 2.2.2 PMI Project Management Professional Certification

The Project Management Professional (PMP) certification was developed by PMI to validate an individual's knowledge of project management, experience, and ability to bring a project to completion. It became an effective tool for employers to select skilled managers to lead project teams and achieve successful results (Project Management Institute 2015c). The importance of the certification to the U.S. Army Corps of Engineers was conveyed when the Department of the Army developed a requirement for

its project managers to obtain the credential prior to assuming supervisory positions in construction management (Engineer Personnel Development Office 2012).

Obtaining the certification requires an individual to obtain a set level of experience and follow a stringent credentialing process. The eligibility requirements establish educational and professional experience thresholds that must be obtained. Individuals with a four-year degree must also obtain a minimum of 4,500 hours spent leading or directing a project (Project Management Institute 2015c). Once eligibility is met, the person seeking certification submits an application detailing all work experience to be audited by PMI. The individual then takes a four hour exam within a year of the application review and audit's completion. If they pass the exam, the certification is granted with the expectation of maintaining a working knowledge by acquiring 60 professional development units every three years. (Project Management Institute 2015c).

### 2.3 Lean World Class Manufacturing

Lean World Class Manufacturing (LWCM) is a management philosophy committed to adopting Lean strategies based on the philosophy of empowering people in an enterprise aimed at never-ending improvement of quality and productivity to satisfy the customer's perception of value (Davis, Selvidge, and Waldrop 2012, 1-1). The purpose is to make a company more competitive in the national and international markets, in the same way the Japanese automotive industry came to dominate American car manufacturers during the 1980s. This approach to manufacturing requires a firm's complete dedication to the implementation of the philosophy.

Benefits for adopting the approach are considerable. A manufacturer can expect to increase productivity by as much as 40% in the first year with additional 10% annual gains in subsequent years. Its product quality can increase by up to 1000%, which can yield scrap reductions of approximately 60%. The firm's customer lead times can decrease by nearly 50%, and its work-in-progress inventory can shrink by 90% (Davis, Selvidge, and Waldrop 2012, 1-7).

As mentioned previously in Chapter 1, LWCM is comprised of four precepts that must be adopted simultaneously to fully realize the potential of adopting this manufacturing strategy. Total

Employee Involvement (TEI) and Total Productive Maintenance (TPM) are recent outgrowths of Just-in-Time Production (JIT) and Total Quality Control (TQC). When reviewing their applicability to construction project management, the focus shifts to JIT and TQC (Koskela 1992, 6).

### 2.3.1 Just-In-Time Production

JIT is a LWCM strategy for production aimed at continuous improvement of quality and productivity, with an emphasis on manufacturing what is needed, when it is needed, and in the quantity that is needed. The operating principles focus on waste elimination and continuous improvement (Davis, Selvidge, and Waldrop 2012, 2-2). Both of these tenets are applicable to construction. A project that is able to minimize required inputs by reducing wastes such as excess inventory, unneeded transportation, or unnecessary movement can yield significant savings for a firm. Those savings in turn allow the company to maximize their outputs and profits.

The other principle of JIT integrated into Army Construction is the element of continuous improvement. Each day on the construction site is meant to improve on the preceding day. LWCM focuses on removing inventory to expose production problems. Eliminating the buffer stock forces a manufacturer to invest in approaches that provide long term solutions to the issue improvement (Davis, Selvidge, and Waldrop 2012, 2-25). While working on unimproved surfaces, the construction company often procures extra aggregate as a buffer for poor quality work. In contrast, the lack of such a buffer forces the site foreman to study the process using a myriad of tools like the Continuous Improvement Five Step Process of defining the problem, measuring the problem, analyzing the problem, improving the process, and implementing controls to prevent the problem from reappearing when the wasteful buffer stock of material is no longer available. (Davis, Selvidge, and Waldrop 2012, 2-28).

Certain tools were developed that enabled the facilitating of JIT manufacturing. Focused factories enabled LWCM firms to consolidate product families to streamline production and eliminate waste by minimizing space and resource requirements (Wantuck 1989, 121). The next technique entailed group technologies. This was a layout of equipment dedicated to production of a family or group of parts by physically linking all possible operations in the process (Wantuck 1989, 131). Line balancing was

introduced as a method to eliminate non-value added time in group technology cells by shifting the value added time to different production team members with an end-state of achieving balanced workloads (Davis, Selvidge, and Waldrop 2012, 2-77).

For a road improvement project, elements of the JIT tools can be integrated into the process. A standard ESC Platoon is set-up like a focused factory. All the equipment needed to complete a task is provided by Department of the Army directives (U.S. Army Force Management Support Agency 2015). The platoon can create group technology work cells by staging the equipment needed for each aspect of the operation. For example, a dump truck, a grader, a water distributor, and a vibratory roller (compaction device) are required when constructing the base of a road. Removing the unrelated equipment and locating all these pieces of equipment together creates a group technology work cell and streamlines the operation.

Line balancing is conducted by eliminating bottlenecks created by operations rife with non-value added time. Referring back to the road base construction group technology work cell, there are a few bottlenecks in this operation. One of them is the dump truck. Before grading or compacting the fill material, the fill has to be hauled from a borrow pit. The lag time created waiting for the dump truck to arrive could be reduced by staging fill along the route in advance and amending the work cell to include a scoop loader to fill the dump truck on site. Another bottleneck is created by the water distributor. This operation is important for obtaining the optimum moisture content necessary for the fill to be compacted to a designated California Bearing Ratio (CBR). Waiting for the water distributor to run over a graded section of road creates the waste of time for personnel and equipment not involved in that task. A solution to reduce the operations dependency on the water truck is to add water to the fill at the borrow pit site. These are just a few examples of how JIT Production techniques can improve traditional construction management practices.

### 2.3.2 Total Quality Control

TQC is a LWCM precept focused on quality operations built around the theme “make it right the first time, every time” (Deming 1982, 23). This precept places an emphasis on defect prevention and the

assurance of quality at the source. Of the five operating principles, “operator responsibility” and “new customer definition” assimilate well into construction.

Operator responsibility focuses on empowering the value-adders on a production line to catch and correct any deficiencies in quality. A key aspect of this involves the operators performing self-check inspections on their own work, which are then followed by subsequent checks made by downstream operators. Placing the quality of the product in the hands of employees provides savings by eliminating inspectors and rework for large batches (Davis, Selvidge, and Waldrop 2012, 3-2).

Construction crews often rely on their foreman to inspect the quality of work they produce. The foreman relies on quality control inspectors hired by the customer to verify work progress throughout the life of the project, typically at 25%, 50%, 75% and 100%. Depending on the scope of work, observing a deficiency after 25% of the work is complete creates costly rework. Empowering the workers with training, responsibility, and reward for quality enhances their sense of ownership for the product and reduces the adversarial relationship between them and inspectors (Davis, Selvidge, and Waldrop 2012, 3-10).

New customer definition promotes a change in the paradigm of who the customer is. Instead of being solely the end product consumer, the next process in a production line or work cell becomes an internal customer. This creates a personalized link in the chain between a work cell operator and the remote customer. Additionally, it leads to a sense of interdependence amongst workers in a work cell. Work Station B is now the customer for Work Station A. If there is something wrong with the part, Work Station B can provide quick feedback to Work Station A, which in turn reduces the likelihood of a defective part making it to the end product consumer (Davis, Selvidge, and Waldrop 2012, 3-15).

Applying this paradigm to road construction makes sense when the TQC tools are factored into the incorporation of LWCM techniques. Referring back to the road construction example, the grader operator is the customer of the dump truck driver. The grader’s work is more time consuming if the dump truck driver drops his payload in a pile instead of evenly depositing it over the road. Finding a solution requires incorporating TQC problem solving techniques. The equipment operators do not wait for their

foreman to provide an answer. Solutions are developed at their level by empowering them with the TQC principles.

One approach entails “Poka-Yoke” (Japanese for mistake-proofing). This is a defect prevention measure developed by Shigeo Shingo, a Toyota Industrial Engineer (Davis, Selvidge, and Waldrop 2012, 3-33). It provides a clear signal to the worker that the process is out of control. A possible reason for the dump truck issue stems from the driver being unable to gauge when the truck bed is raised too high. A Poka-Yoke solution is painting a red line on the hydraulic lift arm. When the driver sees the red line, they know to stop raising the bed.

## 2.4 Integrating Lean World Class Manufacturing into Construction Case Studies

### 2.4.1 Lean Thinking in Construction

Technology was often regarded as the key to solving efficiency issues in the construction industry. Unfortunately this philosophy was unable to explain the steady decline in construction productivity. Many of the issues with new technology stemmed from an unrealistic expectation about the capabilities. Computer Aided Design (CAD) improved construction’s ability to draw and design projects; however, it was not able to reduce the number of design errors that could potentially lead to rework at a later time (Aziz and Hafez 2013, 680).

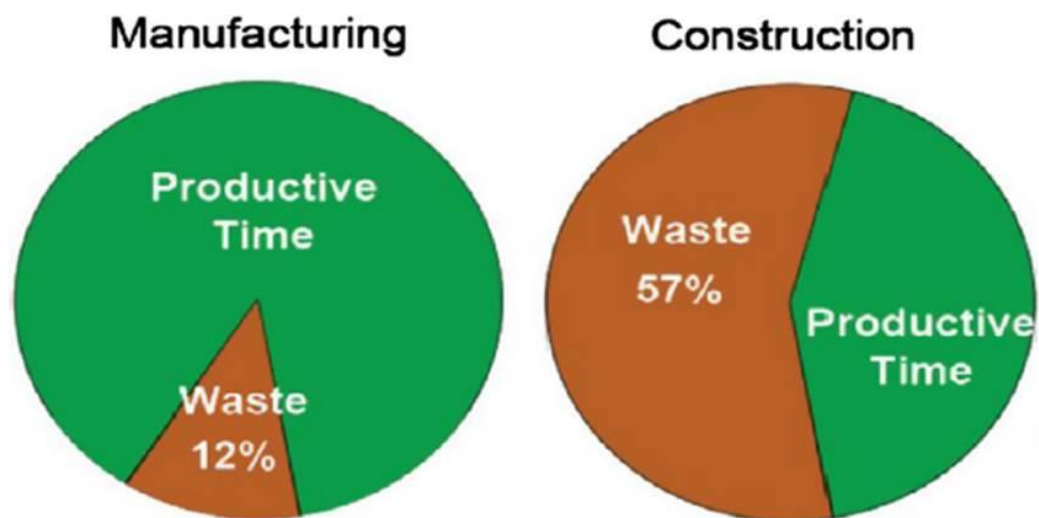
A project delivery method that uses CAD to reduce cost is the design/build method. This is a project delivery system in which the design and construction services are contracted to a single entity. It is a faster approach than the design-bid-build delivery method which contracts out the design and the build to separate entities (Cushman and Loulakis 2001, 45). In the construction industry, the design/build method did not generate the desired outcomes due to mistakes still occurring in the design phase or the contractor hiring a sub-contractor to complete the design.

Construction companies are looking to Lean thinking to improve upon the design/build process with greater frequency. The attraction stems from the management philosophy’s goals of better meeting a customer’s needs while using less of everything. Implementation of Lean tenets to construction is

problematic because no set standards have been established which provide uniform results (Aziz and Hafez 2013, 680).

Several simulations were performed that produced positive results when LWCM principles were applied in a systematic manner. The simulations demonstrated that LWCM ideas enhanced reliable information flow amongst workers. In turn, the enhanced flow led to increased labor performance. Simulation data was compared to data from three bridge construction projects. Documentation from those projects demonstrated the negative effect poor flow of resources and information had on labor performance. Results from this study supported the case for LWCM's positive effects on overall performance by establishing predictable material, equipment, and information availability (Aziz and Hafez 2013, 681).

The LWCM precepts applied to construction are designed to minimize the waste of materials, time, and effort to generate the maximum possible amount of value. Effective determinants of construction are intended to enhance workflow and labor flow. Studies within the United Kingdom indicate that up to 30% of construction in that country is due to rework and 10% of materials are wasted (Aziz and Hafez 2013, 682). This added waste translates into unnecessary costs incurred that degrade a construction firm's ability to deliver a product within the budget.



Aziz and Hafez 2013, 682

*Figure 4: Waste Percentages of Time in Manufacturing and Construction*

Multiple studies on waste generated by the construction industry focused on the waste of materials, which is only one of many resources involved in construction. Evidence gathered for the study of material waste generation was the following: quality of work, constructability, material management, non-productive time, and safety issues. Additionally the classification of the reasons for waste generation were the following: overproduction, substituting a more expensive product for a cheaper one, waiting time caused by idle material flows, transportation of products on the project site, processing, inventories, unnecessary movements made by workers, and production of defective products (Aziz and Hafez 2013, 683).

According to this study there are five fundamental principles for Lean thinking. First, a firm must specify value from the customer's own definition and identify the value of activities that generate value for the end product. Second, the firm identifies the value stream by eliminating everything that does not generate value for the end product. Third, the firm ensures there is a continuous flow in the process and value chain by focusing on the entire supply chain. Fourth, using the pull method for construction instead of push is essential for success. Fifth, the firm must aim for perfection through a system that embraces continuous improvement. Ultimately this produces a product that lives up the customer's expectations (Aziz and Hafez 2013, 684).

Several techniques integrate LWCM into traditional construction management. Concurrent engineering is a parallel execution of various tasks by multi-disciplinary teams working towards obtaining products that enhance functionality, quality, and productivity (Aziz and Hafez 2013, 684). The idea transforms the CPM from a rigid step-by-step process into a guide that shows which tasks can be performed in tandem to expedite progress while enhancing communication between work crews, which replace work cells from the JIT group technologies tool.

Another technique is the Last Planner. This is the entity responsible for completion of individual tasks at the operational level. The Last Planner entity reviews work flow control, determining the stream of supply, design, or installation in production cells. It breaks the master schedule down into smaller tasks, which are then resourced according to the timeline for execution (Aziz and Hafez 2013, 685).



The daily huddle becomes a platform for team members to achieve a shared understanding of the status of the project while also working out any issues. Plan conditions and work environment in the construction industry are designed to produce a plan of health and safety for workers to follow. The safety plan imposes limitations on workers that affect the schedule, but those limitations are addressed during the daily huddles (Aziz and Hafez 2013, 686).

Currently there are two application channels for Lean construction: Lean Project Delivery System (LPDS) and Last Planner System (LPS). LPDS is a set of interdependent functions, decision making rules, execution procedures for functions, and implementation tools and aids (Aziz and Hafez 2013, 686). Based on a five phase model comprised of three modules each, the interdependence of the LPDS program underscores the importance of learning lessons from one engagement to another. The five phases are: project definition, Lean design, Lean supply, Lean assembly, and production control. Several essential features tie all the phases together. These include but are not limited to: structuring and managing a project to realize the customer's definition of value, building cross-function teams, optimizing work flow to improve productivity, and structuring work to increase value while reducing wastes (Aziz and Hafez 2013, 687).

With a focus on improving the planning and control process, LPS is able to allow a construction firm to apply Lean techniques to the construction process. One practitioner describes the system as collaboratively managing the network of relationship and conversations required for coordination, production planning, and project delivery, which is done by promoting communication between foreman and management at the necessary levels of detail prior to an issue becoming critical (Aziz and Hafez 2013, 687). A couple of LPS's objectives include making better assignments to direct workers through continuous learning and corrective action, and LPS causes the work to flow across production units in the best sequence and rate achievable. Use of the Percent of Planned Completed (PPC) in conjunction with master plans and weekly work plan aids the project manager in tracking the effectiveness of the generated project plan. The weekly work plan enables the project manager to track what tasks were scheduled for completion against uncompleted tasks. This enables the manager to generate the PPC and to evaluate

why work was not completed, which facilitates continuous improvement (Aziz and Hafez 2013, 687).

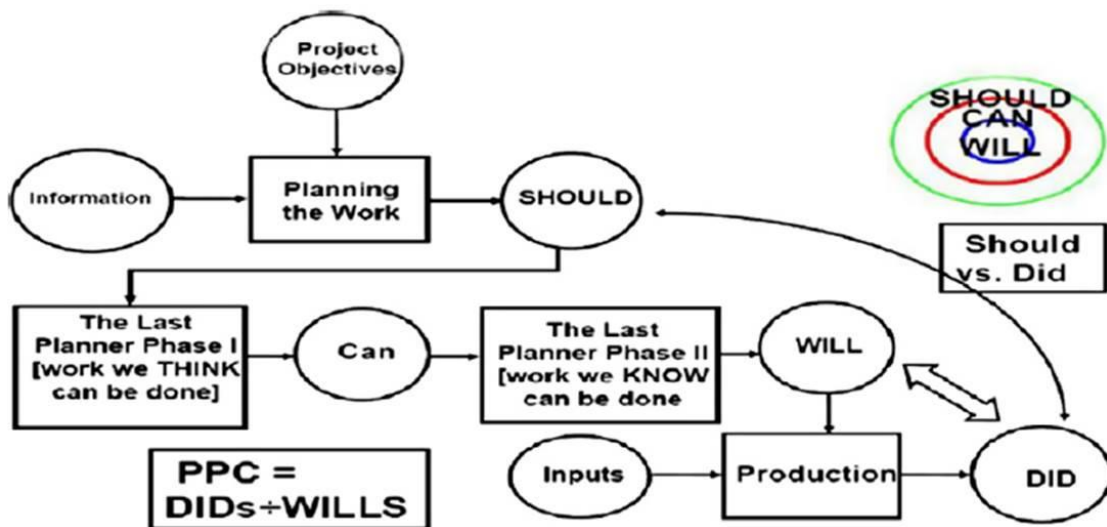
Below, Table II provides a comparison between LPS as production planning and the traditional CPM as strategic planning.

Table II: Separate Strategic Planning From Production Planning

Critical path method	Last Planner System
<ul style="list-style-type: none"> <li>• CPM logic embedded in software</li> <li>• High maintenance</li> <li>• Managing critical path</li> <li>• Focus on managing work dates</li> <li>• Planning based on contracts</li> </ul>	<ul style="list-style-type: none"> <li>• Applied common sense</li> <li>• Low maintenance</li> <li>• Managing variability</li> <li>• Focus on managing work flow</li> <li>• Planning based on interdependencies</li> </ul>

Aziz and Hafez 2013, 688

Execution of the last planner system follows a “Should-Can-Will-Do” model (see Figure 5). An assignment through look-ahead planning determines what tasks “Will” be performed after considering both what “Should” from a macro schedule and what “Can” be executed with consideration to present conditions (Aziz and Hafez 2013, 688). There is an increased likelihood of assignment completion when it is well defined, soundly resourced, sequenced properly, and within the worker’s capacity to perform. LPS aids a project manager in identifying when a job meets these criteria. In the event a job does not meet the aforementioned criteria, it becomes the manager’s responsibility to reject the assignment.



Azi and Hafez 2013, 689

Figure 5: Last Planner System

Improvement takes time and focus. Time spent on production reduces time spent on improvement, while work load and project pressures increase time spent on production. Management support increases time spent on improvement. The construction industry sees senior management support as critical to the effort of improvements. Employee motivation increases time spent on improvement. All organizations have a typically small percentage of employees who are actively seeking to improve work processes. A perceived need for improvement is typically the gap between organizational and target performance, so the need to improve decreases when the organization meets performance goals. However, improving the organization always increases performance, which means a firm must set high goals to maintain the perceived need to improve (Aziz and Hafez 2013, 691).

There are various methods and techniques to improve an organization. This study groups the learning mechanisms into the following three categories: learning from experience, gathering best practices from outside the organization, and learning through trial and error. Skills necessary to enhance performance include acquiring information, analyzing the information, and then applying the new knowledge. Perspectives of goals and problem root causes are important. A firm must determine if their goals are result-focused or process-focused. When issues arise during pursuit of those goals different perspectives from all levels of the organization's hierarchy are necessary to successfully resolve the root cause of the problem (Aziz and Hafez 2013, 692).

The study found success in applying Lean thinking to construction products proved dependent on the structure used and the goals set by the firm. A study found result-based programs had limited ability to address complex problems. This in turn limited the construction firm's ability to reduce wastes and enhance flow of information between work crews (Aziz and Hafez 2013, 693).

#### 2.4.2 Just-In-Time Production in the Chinese Construction Industry

Low Sui Pheng studied the application of JIT to the construction industry in China. He considered it as a method that would bring about positive changes to the local industry. Construction in China was noted as suffering from several maladies that inhibit the sector from being competitive on a global scale (Pheng and Shang 2011, 95).

The sector's issues with low productivity stemmed from human factors. In 1980 a person working in construction made only \$500 annually. As of 2008 that number had risen to \$20,000 annually (Pheng and Shang 2011, 96). The significance was that China only just recently reached a point where it was able to compensate its crafts people somewhat appropriately, although this annual income is still below many firms based in other developed countries like the U.S., United Kingdom, or Japan (Pheng and Shang 2011, 96).

Quality of work was another issue for the country. Attempts to implement quality management programs in the industry yielded mixed results. In 1992 the government introduced ISO 9000 training to improve quality. According to Low Sui Pheng's study the results increased overall quality, but progress was over shadowed by the large scale collapse of buildings during an earthquake in 2008 (Pheng and Shang 2011, 97). This leads to the conclusion that government involvement in regulating quality efforts was limited in its application.

There are several constraints the Chinese construction industry would face if it implemented JIT Manufacturing. Currently the Chinese labor pool for construction consists primarily of poor, uneducated workers with limited skill sets (Pheng and Shang 2011, 98). This limits the industry's ability to use sophisticated tools and the latest construction technology, since few of the workers have the skill set needed to operate them. Construction lacks an established project management system, which means there is no uniform method of instruction that most managers and foreman can be made familiar with. Another issue deals with the organization hierarchy in most construction firms (Pheng and Shang 2011, 99). Instead of being united by a common goal or mission statement, each layer of the hierarchy sets its own goals and targets. This creates a disjointed system of leadership that becomes a roadblock to progress.

Larger organizations with well-established finances are the most likely to successfully adopt JIT techniques. Remodeling the firm to implement JIT would yield the added bonus of organizational adjustments. For these reasons, Mr. Pheng believes that the best candidates for implementation are the

large, state-owned construction firms because they are more likely to adopt JIT as a long-term strategy (Pheng and Shang 2011, 99).

#### 2.4.3 Lean Construction – Advanced Project Delivery for the AEC Industry

In its white paper on Lean Construction, Corner Cube Inc. analyzes the pitfalls of project delivery in the modern construction industry. The paper offers the implementation of Lean Project Delivery (LPD) as a solution to those pitfalls (Espana, Hauser, and Ryan 2013, 1).

Lean Construction or LPD is based on the principles originating from the work of Taichi Ohno of Toyota, which gave rise to the Lean World Class Manufacturing philosophy. Through the integration of Lean principles, LPD is built to improve production systems and increase the level of value customers perceive in delivered projects. LPD effectiveness entails addressing the integrated governance, value management, and delivery management to customize management's approach to each unique project. Essential to achieving this customization is the free flow of information across the organization. Cultivating and harvesting knowledge is critical to success. Additionally, it entails involving organizations, teams, and people committed to executing the project (Espana, Hauser, and Ryan 2013, 1).

To transform an organization into a Lean enterprise, the company must work towards ensuring they give the customer what they want, give it to them when they want it, and give it to them as efficiently as possible. Accomplishing these objectives means identifying the various types of waste inherent in the system. Taichi Ohno identifies seven types of waste; however, the construction industry's differences from the manufacturing sector calls for the addition of five types of waste: delivery of a final product that doesn't meet customer requirements, untapped intellect, disruptive workforce, waste that adds no value and can be completely eliminated, and waste that adds no value but is necessary to complete work (The LWCM philosophy covers the aforementioned wastes with the use of different verbiage). LPD addresses these wastes by focusing on enhancing a project's temporary production system, exposing the waste currently generated, and by identifying opportunities to increase value through the exploitation of available work-site knowledge (Espana, Hauser, and Ryan 2013, 3).

The adherence to traditional construction practices and the highly fragmented network of service providers were the greatest challenges faced when adopting Lean Construction practices. Traditional construction contracting practices parceled out production scopes in small risk avoidance packages which degraded the free-flow of information concerning the project. It was difficult to eliminate contracts with built-in language that provided buffers to a contractor in regards to the project's cost, time, and quality. These buffers were a form of waste that bogged down the construction process (España, Hauser, and Ryan 2013, 4).

LPD is a production management-based approach to project delivery applied at the concept stage. It is structured to minimize waste and increase value by redefining control from a command and control hierarchy to a distributed control paradigm that uses LPD operating frameworks. This eliminates a project focus on reacting to an indicator with built in lag due to the contractor hierarchy that exists. Incorporating Lean concepts into LPD allows the construction industry to better adapt to the needs of the customer. Value from the perspective of the customer means ranking internal and external customers to establish a priority list for need fulfillment. The incorporation of end users, construction managers, sub-contractors, and suppliers ensures that each participant receives attention to correct issues, which ensures a product that meets the end-users definition of value. Treating projects as temporary production systems allows a construction firm to incorporate Just-In-Time Production principles of Lean such as continuous improvement, eliminate waste, setup reduction, pull system, and produce to exact customer demand (España, Hauser, and Ryan 2013, 5).

As a project's life cycle progresses, the opportunity to influence or improve the project's development and outputs decreases. When broken down into its basic components a project is comprised of a basic production flow: establish goals, design and engineering requirements, detailed design, fabrication, assembly, delivery, and installation. This flow occurs at the macro level and micro level of sub-contractor specialty work. Monitoring and controlling this process is difficult, which is why many firms are turning to 3D Modeling, integrated virtual design and construction (iVDC) teams, and social

software platforms (PlanGrid and Procore) to mitigate risk while ensuring improved project outputs (España, Hauser, and Ryan 2013, 7).

#### 2.4.4 Implementation of Lean Construction Techniques for Minimizing the Risk Effects On Project Construction Time

In this analysis of Lean Construction, the researcher approached measuring the benefits of incorporating Lean practices by measuring their effects on Percent Expected Time-overrun (PET) and Percent Plan Completed (PPC). The experiment incorporated these tenets while using a last planner system to execute an industrial construction project in Egypt. The results showed the total project time was reduced due to decreasing PET values, while PPC values increased. A lack of detailed and documented data from previous project endeavors in the Egyptian construction industry minimized the paper's ability to compare overall results with similar projects constructed by other companies (Issa 2013, 697).

In this paper, Lean construction is defined as a production management strategy for achieving significant continuous improvement, in the performance of the total business process of a contractor through elimination of all wastes of time and other resources that do not add value to the product or deliver service to the customer. This series of flow conversion activities must generate value to the customer. Lean tenets incorporated in the process include just-in-time delivery, utilization of pull-driven scheduling, reduction of variability in labor productivity, improvement of flow reliability, elimination of waste, simplification of the operation, and implementation of benchmarking (Issa 2013, 698).

The basis for the last planner concept used for this experiment is a focus on minimizing waste in a system through assignment-level planning or detailed look-ahead scheduling. Utilization of formal and flexible planning procedures is an essential first step to keep the production environment stable. A common method used when adopting Lean techniques in construction is the Last Planner System (LPS). By using a pull technique for its look-ahead, LPS is able to reach some of the following objectives: shaping work flow sequence and rate, matching work flow and capacity, developing a work completion method, and maintaining a backlog of ready work (Issa 2013, 698).

Risk management is an important characteristic of successfully managing a project, and it has a direct relationship with project success. In construction risk a typical practice entails passing the risk onto contractors who use high price mark-ups account for potential risk. Response to risks are typically grouped according to the four following groups: avoid – making it impossible for the risk to occur, transfer –pass the risk on to someone better suited to manage it , mitigate – reduce the size of the risk to acceptable levels, and accept – proceeding without mitigating the risk (Issa 2013, 699).

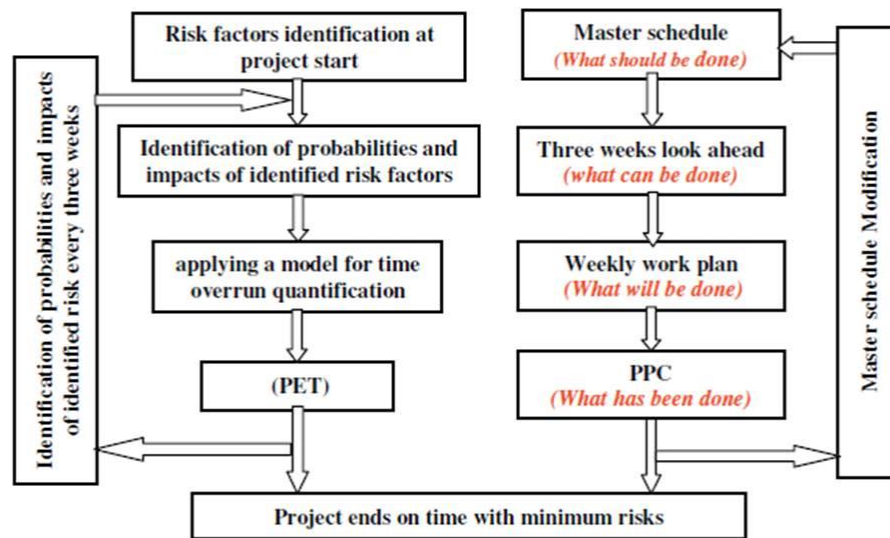


Figure 6: Steps of the Proposed Research Methodology (Issa 2013, 699)

Above Figure 6 shows the case study's proposed research methodology. The study applies the LPS to the execution of a flour milling factory in an Egyptian industrial zone. With a fixed finish date and a short duration to execute the master schedule the duration calculated is 12 weeks with six working days per week for a total duration of 72 days (Issa 2013, 700).

Determining the percent expected time-overrun (PET) required the use of a time-overrun model that factors the relationships among the impacts of risk factors on time and the time-over-run through application of a series of logic rules that take into consideration the probabilities of the risk factors. For the case study, the most critical risk factors were identified then data were used to calculate the probability of occurrence and impact on time for each factor in the form of two indices, the Impact Index



for Time (IIT) and the Probability Index (PI). IIT showed the impact of a risk factor on time, and PI represents the probability of occurrences for a risk factor (Issa 2013, 700).

Table III: Risk Factors Affecting Time, Their Indices, and PET Values

Factors affecting time	At project start		At week 4		At week 7		At week 10	
	PI	IIT	PI	IIT	PI	IIT	PI	IIT
1. Contractor problems and inadequate experience	H	VH	VL	VL	VL	VL	0	0
2. Change in material prices or price escalation	M	M	VL	VL	VL	VL	0	0
3. Unskilled workers and poor labor productivity	H	VH	M	VH	M	H	M	L
4. Inefficient use of equipments	L	L	L	L	VL	VL	0	0
5. Delay in running bill payments to the contractor	L	M	L	M	L	VL	VL	VL
6. Delay in material procurement	L	VH	L	H	L	M	VL	L
7. Design errors and suitability to the nature	L	M	M	M	L	M	VL	VL
8. Client's problems such as bureaucracy in client's organization	M	M	M	M	M	M	L	M
9. Inadequate and slow decision-making mechanism	H	VH	H	VH	H	M	M	L
10. Poor quality of local materials	H	VH	H	VH	H	H	M	L
11. Poor coordination among parties	H	H	L	L	L	L	0	0
12. Rework due to error in execution	H	VH	H	VH	H	H	H	M
13. Improper accommodations for workers	M	H	L	L	0	0	0	0
PET using time-overrun quantification model	22.5		15.1		12.35		4.7	

Issa 2013, 700

At the onset of the project, the effect of risk factors on PET was calculated to add 16 days to the projects original duration. Three week look-ahead weekly work plans (WWP) were produced to mitigate the anticipated impact of risk factors on the project and updated weekly. Similar to LWCM's Total Quality Control tool of "Ask "Why?" Five Times and "How?" Once," the WWPs were used to investigate cause for delays instead of assessing blame. Concurrently the PPC was calculated weekly as a measuring metric for the LPS (Issa 2013, 701). When used with two PPC values an upward slope showed improvement and a downward slope showed the opposite. During this project effective look-ahead scheduling and management of handoff points between separate disciplines were used to mitigate or eliminate risks. Through reviewing the attributes of a particular outcome and then developing a solution for negative results, the project team learned from mistakes. The result led to the completion of the project on time. (Issa 2013, 702).

While executing this construction project some risk factors were not affected by the incorporation of Lean construction techniques. The following four risk factors were mentioned: 1) change in material prices or price escalation; 2) delay in running bill payments to the contractor; 3) design errors and suitability to the task; and 4) poor quality of local materials. The remaining nine risk factors listed in Table II were affected by Lean construction techniques. The PET average value represented

approximately 67% from PET values for minimized risks. From the project start to Week 10 the effects of Lean were gradual but consistent. The project's PPC increased from 83% at the end of Week 4 to 93% by the conclusion of Week 10 (Issa 2013, 702).

Findings from this study demonstrate that Lean construction techniques and principles had a potential for reducing the effects of risk factors on time objectives for construction projects. Utilizing Lean techniques in construction projects decreases PET values while increasing PPC values. Most risk factors' effects were reduced and the impact of factors affected by Lean techniques decreased with the increase in time. The results proved the success and suitability of using the time-overrun qualification model for evaluating the implementation of Lean into construction. In conclusion, adoption of Lean techniques in construction projects was recommended based on the observations made during this case study (Issa 2013, 703).

## Chapter 3: Methodology

### 3.1 Method Overview

The objective of this research is to determine the economic viability of applying Lean World Class Manufacturing techniques to a traditional construction methodology. Solving this question requires the application of LWCM precepts to a real construction project.

As stated previously the 712th Engineer Support Company was tasked with supporting two training rotations at the Joint Readiness Training Center (JRTC) in Fort Polk, LA during the months of April 2016 (Rotation 16-06) and May 2016 (Rotation 16-07). Each rotation required one platoon to support. The method used to test the hypothesis required using one platoon as a control group and one platoon as an experimental group.

In support of Rotation 16-06, 2nd Platoon was the control group. This platoon used traditional Army and Civilian project management techniques. The techniques used were adopted from TM 3-34.42 Construction Management, FM 5-34 Engineer Field Data, and ATP 3-37.34 Survivability Operations.

1st Platoon was the experimental group and supported Rotation 16-07. This platoon integrated LWCM tools and techniques with the traditional project management approaches taught in Army Engineering schools. The integration process incorporated weekly lessons with the platoon leaders and the investigator on LWCM precepts and principles. A total of nine lessons occurred, each lasting approximately 45 minutes for a total of 6.75 hours of instruction.

The project outcome assessments were framed by comparing the outcomes from both platoons at the end of their training rotations. The criterion for success was set at achieving a minimum of 10% increased efficiency by the end of the training period in two of three categories. The first category was work rates and work shifts required per assigned construction task. Category two was the rate of fuel consumption by piece of equipment and overall per assigned construction task. The third category was the vehicle readiness rate for each piece of equipment throughout the entire exercise and per assigned construction task.

## 3.2 Experiment Controls

### 3.2.1 Personnel

To prevent one rotation from having an advantage in regard to experience, the Rotation support rosters were built to evenly distribute construction experience and competence. Four roster reviews occurred to ensure an even mix of equipment operators, supervisors, and support personnel was maintained; however, rotation rosters were populated largely on the basis of Soldier availability, which was limited by civilian work or school requirements. Soldiers were only able to attend one rotation, which prevented Rotation 16-07 from using personnel who supported Rotation 16-06.

#### a. 16-06 Personnel Breakdown by Military Occupation Specialty (MOS):

Horizontal Construction Engineer (12N) =	22 Personnel
Horizontal Construction Supervisor (12N) =	6 Personnel
Engineer Officer =	2 Personnel
Maintenance and Support =	6 Personnel
Total =	36 Personnel

#### b. 16-06 Personnel Breakdown by Rank

Lieutenant (O-1/O-2) =	2 Personnel
Sergeant First Class (E-7) =	1 Personnel
Staff Sergeant (E-6) =	3 Personnel
Sergeant (E-5) =	4 Personnel
Lower Enlisted (E-1 - E-4) =	26 Personnel

#### c. 16-07 Personnel Breakdown by Military Occupation Specialty (MOS):

Horizontal Construction Engineer (12N) =	25 Personnel
Horizontal Construction Supervisor (12N) =	10 Personnel
Engineer Officer =	2 Personnel
Maintenance and Support =	2 Personnel
Total =	39 Personnel

## d. 16-07 Personnel Breakdown by Rank

Lieutenant (O-1/O-2) =	2 Personnel
Sergeant First Class (E-7) =	0 Personnel
Staff Sergeant (E-6) =	3 Personnel
Sergeant (E-5) =	7 Personnel
Lower Enlisted (E-1 - E-4) =	27 Personnel

## 3.2.2 Equipment

One set of equipment was shipped from the 712th to North Fort Polk, LA to support each rotation. Equipment staged at Fort Polk, LA in the Prepositioned Fleet Yard was coordinated for to supplement the equipment being shipped from home station. Equipment available for each rotation was identical, with the exception of two additional haul asset (2 x M1088 w/M172) made available for Rotation 16-07. A complete breakdown of equipment found below in Table IV.

Table IV: List of Equipment Available for Each Rotation


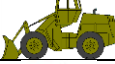




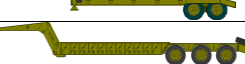










Item #	LIN	Nomenclature	QTY Available	Image
1	H53576	HMEE	2	
2	L76556	Light Loader/MW24C	1	
3	L77147	Skid Steer	2	
4	M05001	Grader 130G	2	
5	R13167	Roller Vibratory	2	
6	S30039	Scraper 613B	1	
7	S70517	SemiTrailer 25T M172	2	
8	S70594	Trailer 40T 870A1	2	
9	T05026	Dozer T5	2	
10	T05029	Dozer T5 w/Ripper	2	
11	T56383	Truck Utility M1165A1	2	
12	T63161	Wrecker M984A4	1	

Table IV: List of Equipment Available for Each Rotation


Item #	LIN	Nomenclature	QTY Available	Image
13	T60081	LMTV M1078A1	1	
14	T65274	Dump 10T W/Winch	2	
15	T65342	Dump 10T M1157A1P2	2	
16	T88983	Truck Tractor M1088A1P2	2	
17	T91656	Truck Tractor M916A3	2	

In an effort to prevent Rotation 16-06 equipment breakdowns from affecting the availability of equipment for Rotation 16-07, coordination for maintenance support was made with the units being supported for each respective training rotation and with the Maintenance crews at Equipment Collection Site 17 Fort Polk, LA. This meant that 2nd Platoon was to receive sustainment support in the form of maintenance for major equipment malfunctions and Petroleum, Oil, Lubricant (POL) resupply from the 326th Brigade Engineer Battalion (BEB) during Rotation 16-06. 1st Platoon was to receive sustainment support in the form of maintenance for major equipment malfunctions and POL resupply from the 21st BEB during Rotation 16-07.

### 3.2.3 Training Objectives


The 712th provided each Battalion being supported during JRTC Rotations 16-06 and 16-07 with a list of its training objectives (Reference Figure 7 below). Additionally those training objectives were provided to the Observer/Controller (O/C) team from Task Force 5, Operations Group Fort Polk, LA. The purpose of providing the training objectives to these units was to ensure each platoon performed the same type of construction projects, which would allow for a better comparison of the success criteria. Despite providing Company training objectives, many of the tasks executed during the defense phase of operations were assigned based upon the training objectives and goals of the Battalion and Brigade receiving support from the 712th. This did not prevent training objectives and goals from being realized; however, it did prevent each platoon from executing exactly the same type of construction projects.

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## 712 ESC

### Commander's Training OBJ



**MET 05-TS-2301:** Conduct Engineer Company Operations ESC  
05-3-3006 Establish Work Site Security for General Engineer Mission  
05-2-5250 Perform Construction Operations

**MET 05-TS-3435:** Provide Horizontal Construction Support to Assured Mobility  
05-2-5142 Construct a Tactical Airstrip  
05-3-2015 Construct a Tank Ditch

**MET 05-TS-4366:** Conduct Platoon Operations, RDE Platoons  
05-3-5101 Construct Combat Roads/Trails  
05-3-0407 Perform an EN Recon

**MET 05-TS-3436:** HORZ Support to Protection Efforts  
05-3-3014 Construct Vehicle Protective Positions

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*Figure 7: 712th Commander's Training Objectives for JRTC*

#### 3.2.4 Construction Projects

The JRTC training timeline was broken down into three phases (see Figure 8): Phase 1 Joint Forcible Entry Operations (JFEO) 3 day duration, Phase 2 Defensive Operations 4 day duration, and Phase 3 Offensive Operations 4 day duration. Each platoon spent much of the time leading up to the JFEO drawing equipment and preparing for movement into the training area. The opportunity for projects during this phase was limited to whether the unit being supported wanted to begin defensive operations preparations early. During Phase 2 each platoon was provided the opportunity to construct various types of survivability positions depending on the need of Brigade units. In Phase 3 each platoon received a change of mission tasking to go work on Forward Landing Strip (FLS) Berry. Progress on FLS Berry was dependent on atmospheric conditions and logistics support from the Brigade Engineer Battalion (BEB).

### JRTC 16-06/16-07 Projected Rotational Design (JFE/FOF)

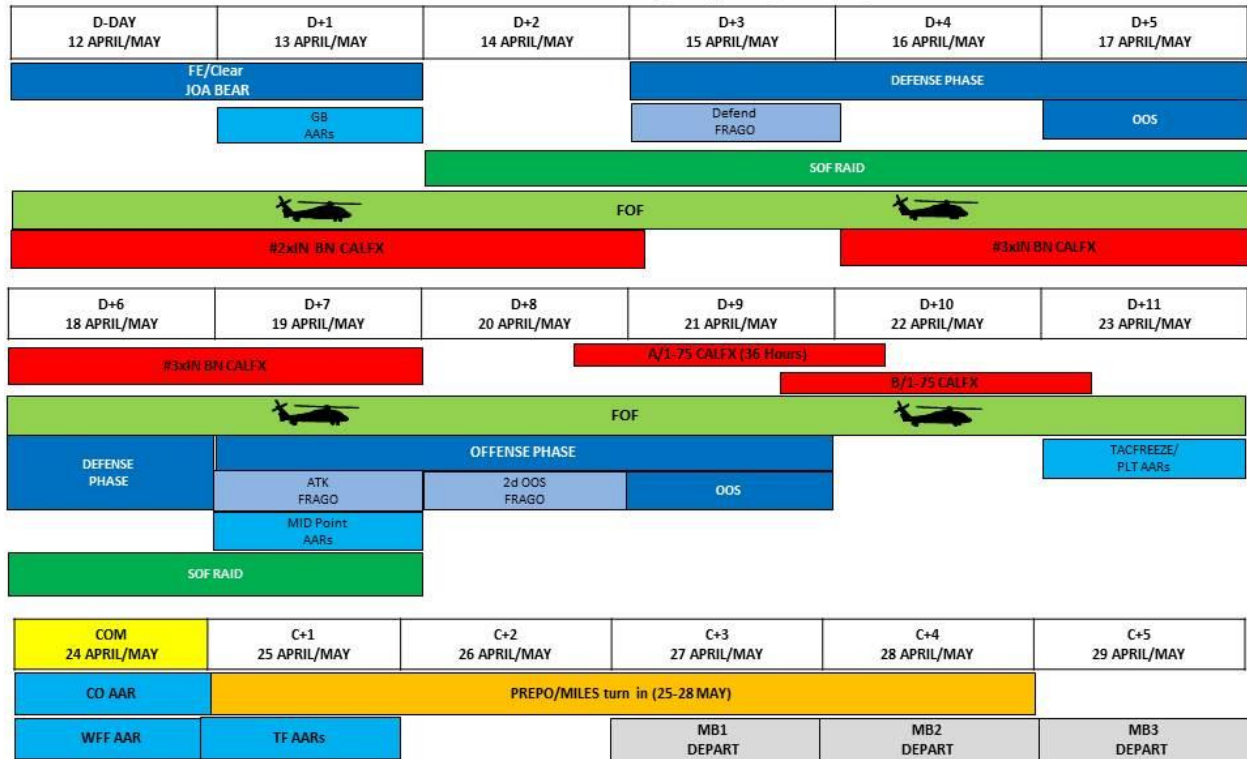
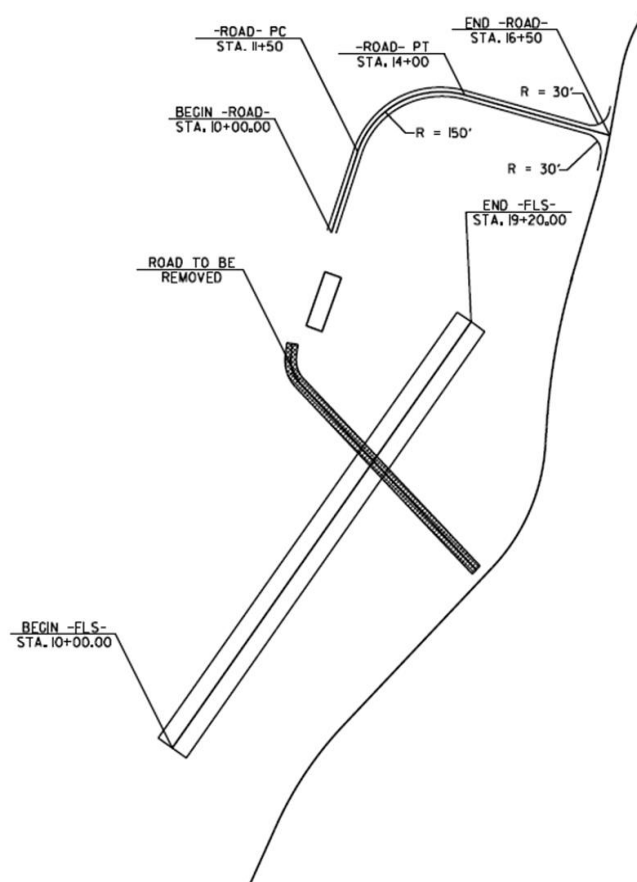


Figure 8: JRTC Rotation Timeline

FLS Berry (See Figure 9) was a multiple phase, multiple stakeholder project put together by Operations Group to support future training rotations with a landing strip capable of supporting Unmanned Aircraft Systems (UAS). The Scope of Work (SOW) stated, “construct an UAS landing strip capable of supporting a RQ-7 Shadow launch and recovery site (LRS); the LRS will be constructed from grid 15R WQ 0912 3486 to 15R WQ 0929 3512 at a length of 1000ft in accordance with Engineer Technical Letter (ETL) 1110-3-510 dated 31MAY13; suitable fill material has been stockpiled at WQ 1015 3300 and WQ 0335 4140; and fill in all ruts and holes created from clearing activities.” 2nd Platoon was the second unit to work on the FLS site, and 1st Platoon was the third unit to work on the FLS.





*Figure 9: Plans for FLS Berry, Fort Polk, LA*

The pavement schedule (see Figure 10) was designed by First Lieutenant (1LT) Charles Young, 2nd Platoon Leader, and approved by the Operations Group Engineer, Major Larry Workman. 1LT Young expanded the FLS width from 50ft to 60ft. The runway included an extra 5ft on either side to accommodate the high level of rainfall experienced annually by Fort Polk, LA. Four courses were designed into the pavement schedule placed in the following sequence: 6in subgrade of compacted fill material, 3in compacted base course material, 6in compacted base course material, and 3in compacted surface course material. The grade was designed at 1.5% over 30ft lanes.

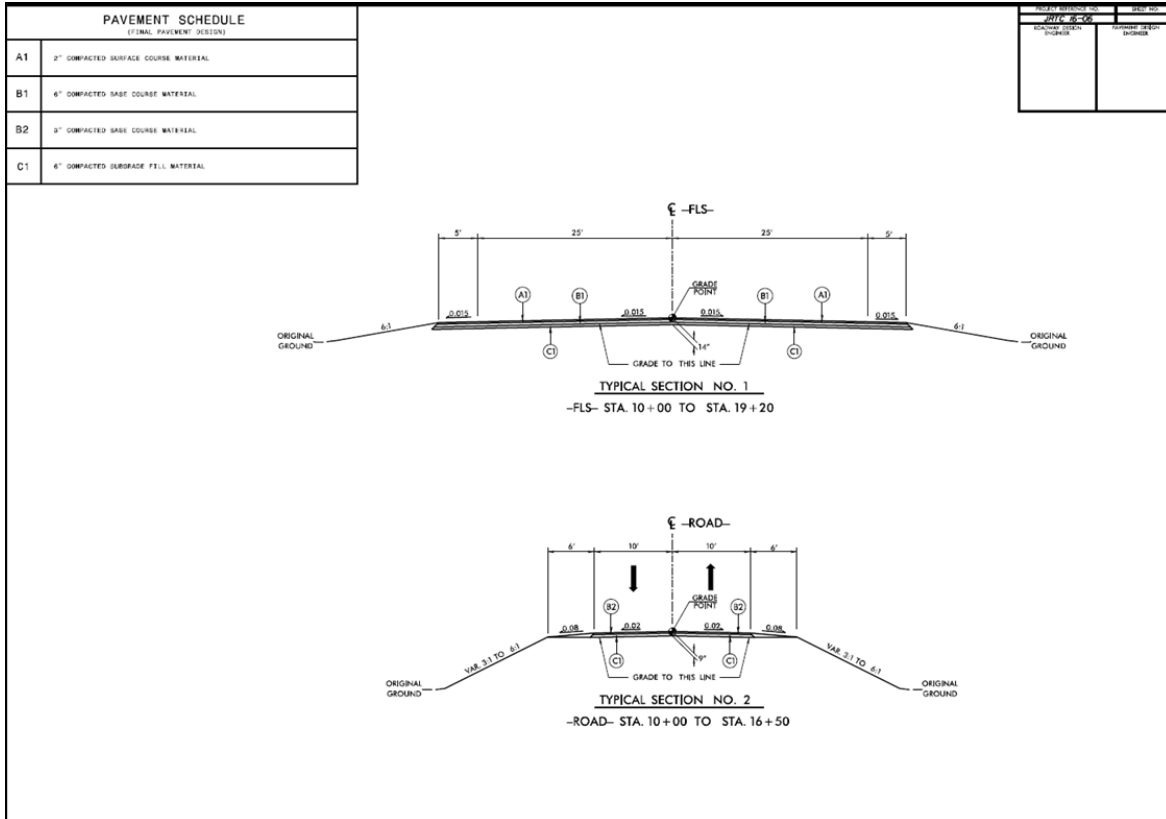


Figure 10: Design for FLS Berry, Fort Polk, LA

ATP 3-37.34 Survivability Operations and FM 5-34 Engineer Field Data provided each rotation with a baseline of knowledge on the construction of survivability and counter-mobility positions designed to support a maneuver unit in a traditional force on force combat role. Rotation 16-06 and 16-07 each had one mechanized company supporting the light infantry Brigade Combat Teams. Constructing vehicle fighting positions required following the aforementioned manuals' design specifications (see Figure 11).

All Brigade Combat Teams have a field artillery battalion included in their Modified Table of Organization and Equipment (MTOE). Field artillery battalions have 105mm and 155mm Howitzer cannons capable of firing 100lb shells of high explosive over 15 miles. Protecting these cannons requires the construction of specialized protective positions (see Figure 12).

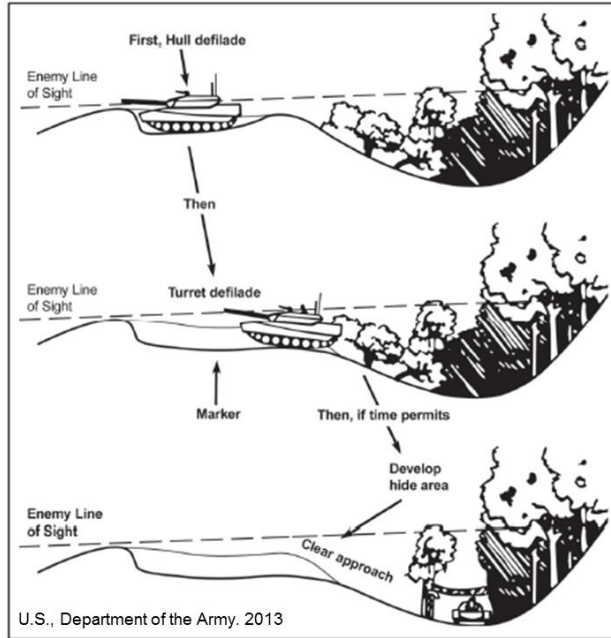


Figure 11: Defilade Fighting Position

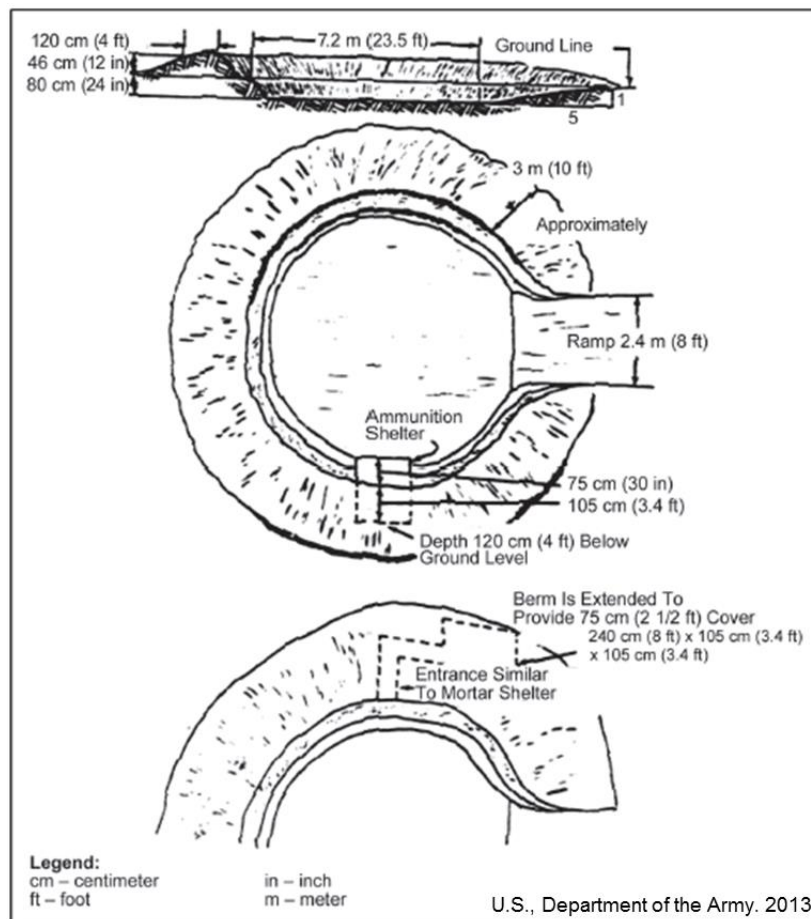


Figure 12: Howitzer Emplacement Position

### 3.2.5 Additional Controls

Due to the number of variables involved with incorporating a construction project into an Army training event, several controls were established. The personnel in the platoons were cross leveled to evenly distribute the experience level. Each platoon was provided with the same equipment. No Soldier participating in Rotation 16-06 was allowed to support Rotation 16-07. Both platoons were given the same training objectives, quantity of FLS to repair or construct, and an equal number of days to work. The platoon supporting Rotation 16-07 performed no rework on survivability positions or the FLS constructed or repaired during Rotation 16-06. Lastly, all assessments of work progress were validated by a third party comprised of Fort Polk stationed training Observers and Controllers (O/C).

Each platoon was given the same instructions on what units of measure to collect during their time at JRTC. The first was work rate based on equipment hours per project and man hours per project. One project equaled a single task such as one CSW position or one HDP. Second, the fuel consumption rate or fuel usage information was to be tracked. The third piece of data to collect was the vehicle readiness rates, which entailed logging when or for how long a piece of equipment was broken. Finally, each platoon needed to track the number of shifts worked per day through the exercise.

## Chapter 4: Results and Analysis

### 4.1 Rotation 16-06 Results

Table V: Rotation 16-06 Project Summary

Project Site #	Scope of Work
1	423th BSA- 300m berm x 2.5m tall. Project included pushing an existing 100m x 0.5m tall berm 80m down to new berm location to extend parking area at BSA.
2	FA site- Dig in 6 gun positions approx. 60m circumference each with 2.5m tall berm all around. Bermed an additional 100m x 2.5m for protection from MSR.
3	423th BSA Ridgeline- Dug 4 x HDPs and 5 x fighting positions for Cav. Company defense of the southern sector of BSA.
4	MSR Steel & Zinc intersection #1- Dug 5 x HDPs and 7 x fighting positions for Bradley company for defense of Dara Lam.
5	Geronimo FLS- Dug 4 x fallback HDPs for Bradley company in defense of Dara Lam.
6	MSR Steel & Zinc intersection #2- Dug 2 x HDPs and 2 x fighting positions for Bradley company for defense of Dara Lam.
7	323th Sapper Eagle BSA- Dug 4 x HDPs on ridgeline of BSA for defense.
8	Geronimo Obstacle Belt- 600m x 2.5m tall berm to tie into C-wire belt in preparation for attack.
9	FLS Berry- removed 207m <sup>3</sup> (8cm off the top of FLS) of fill, installed 200m x .25m deep drainage ditches

2nd Platoon, 712th Engineer Support Company deployed to JRTC in support of 1st Brigade Combat Team, 101st Air Assault Division from 09-27APR2016. The platoon was comprised of 36 Soldiers. A total of nine missions were executed while executing training during the 12 days of operations. Table V provided a brief summary of each mission assigned while deployed to JRTC. The Vehicle Fighting Positions (VFP) constructed were for the M2 Bradley Fighting Vehicles (BFV). Of note it rained for nine of the 12 days, which adversely affected work rates. The inexperience of the equipment operators in regard to constructing survivability positions further compounded challenges created by atmospheric conditions, which limited the unit's overall output during mission execution.

Each of the following tables reviews the nine projects assigned the platoon during its 12 days of training. Task work rates are calculated by dividing the quantity of construction by the duration of a shift. Man hours required per project include the operators and the supervisors directing their work. Per safety standards that is a minimum of one supervisor during day time and two supervisors during night time operations. Equipment hours are calculated by multiplying the total pieces of equipment in use by the duration of a shift.

Table VI: Rotation 16-06 Project Site 1 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
1	2000-0200	2 x T5	70m x 2.5m berm	11.67m/HR	24	12
	2000-0200	2 x HMEE	4 fighting positions	0.67FP/HR	24	12
	0200-0700	1 x T5s	60m x 2.5m berm	12m/HR	15	5
	0200-0700	1 x HMEE	6 fighting positions	1.2FP/HR	15	5
	0700-1400	2 x T5	170m x 2.5m berm	24.29m/HR	28	14
	0700-1400	2 x HMEE	17 fighting positions	2.43FP/HR	28	14

While conducting combat operations, it is important to limit exposure to the enemy. The oppositional force has scouting capabilities similar to U.S. Forces. This means they have night optical devices (NOD), thermal sights, scouts, civilian informants, and aerial reconnaissance capabilities. Limiting exposure to these intelligence collection capabilities means operating during hours of low visibility to mask troop movements and construction efforts. Military land forces categorize engineer equipment (earthmoving capable) as a high value target when on the attack. Destruction of those assets prevents the force defending from fortifying its positions, which increases the chance of an attack to succeed.

As denoted by the shift times listed in Table VI, work for this mission occurred predominantly during night time hours to hinder the oppositional forces ability to spot the earthmoving equipment. Denying the enemy knowledge of its high value targets prevented the loss of any 2nd Platoon engineering assets during project execution. However, the equipment operators within the 712th ESC were

inexperienced at operating their equipment under black-out (no white lights) conditions while using NODs to see. JRTC safety regulations called for a minimum of two non-commissioned officers (NCO) to ground guide equipment in operation at all times when operating equipment with NODs. For a platoon with only six Horizontal Construction Supervisors (NCOs) this affected the amount of rest they were able to acquire nightly and in turn affected the platoon's work efficiency negatively over the course of the training exercise. Work rates during a daytime versus nighttime shift (ref. Table VII) demonstrated the impact of operating earthmoving equipment under NODs instead of day-light conditions.

Table VII: Rotation 16-06 Project Site 2 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
2	1900-2030	2 x HMEE	3 fighting positions	2FP/HR	9	3
	1900-0600	2 x T5	150m berm	13.64m/HR	66	22
	0600-1400	2 x T5	310m berm	38.75m/HR	32	16

The fighting positions constructed using a JCB High Mobility Engineer Excavator (HMEE) varied from crew serve weapon positions to two man fighting positions. Crew serve positions were "T" shaped and required digging to a depth of 1.5m with leg lengths of 2m and 1.5m (See Figure 13). Individual fighting positions consisted of shallow holes of varying depth and structure. Most often individual fighting positions were constructed using hand-tools. All fighting positions constructed by 2nd Platoon were for crew serve weapon systems.



*Figure 13: Crew Serve Fighting Position from Rotation 16-06*

Constructed Field Artillery (FA) Howitzer (155mm and 105mm) gun positions were 60m in circumference with a height of 2.5m. The six gun positions constructed for 2-32nd FA Battalion required additional supervision during construction to mitigate the amount of rework. Prior to the exercise neither the officers nor the NCOs had constructed a FA Howitzer gun position. The leadership's increased level of scrutiny for construction projects initiated the beginning of poor work-rest cycles for themselves. In turn this prevented them from receiving adequate rest and began the degradation of their mission effectiveness.



*Figure 14: Howitzer Gun Position for 2-32 FA Battalion*



Table VIII: Rotation 16-06 Project Site 3 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
3	1430-1900	1 x HMEE	5 x fighting positions	1.11FP/HR	9	4.5
	1430-2030	2 x T5	4 x HDPs	0.67HDP/HR	24	12

Project Site 3 was the first project that included the construction of hull defilade positions (HDP) for a mechanized unit. Throughout the exercise, these positions were hasty products that provided protection to combat assets for the brigade combat team despite not being constructed in accordance with the standards stipulated in the ATP 3-37.34: Survivability Operations. Below standard work was attributed to two conditions: one, the platoon was inexperienced at survivability construction; and two, the customer was willing to sacrifice quality for the sake of an increase in quantity. The standard work rate for a practiced T5 Bulldozer team (1 x Team = 2 x T5s) was two hours per position. Many of the survivability positions constructed during the first two days of the defense were meant to deter harassing attacks by the enemy, not stop a major attack.



*Figure 15: HDP Near the Brigade Support Area (BSA)*

Table IX: Rotation 16-06 Project Site 4 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
4	1000-1600	2 x HMEE	7 x fighting positions	1.17FP/HR	24	12
	1000-1700	2 x T5	5 x HDPs	0.71HDP/HR	28	14

On the second day of the defense, 2nd Platoon received a mission from B Company, 326th BEB to construct survivability positions for an Infantry Company equipped with M2 BFVs. The HDPs were critical to the defense of the town Dara Lam. Unfortunately the location for the HDPs was chosen by the Company Commander of B Company and not the leadership of the Infantry Company. When conducting engagement area development for a defensive positions the seven steps were not followed.

Step one is identify the enemy's avenues of approach, which means determine what roads or routes they will use to reach friendly forces. Step two is determining the enemy's course of action. The following question must be answered, "where will the enemy concentrate its forces?" Step three is determining where to kill the enemy based on the friendly forces analysis of steps one and two. Step four entails planning and integrating obstacles to slow the enemy force's advance. Step five involves emplacing weapon systems. This step requires deducing the best location for available weapon systems to inflict the most damage possible on the enemy. Step six focuses on planning and integrating indirect fires from mortars and field artillery. Step seven is to rehearse, which is critical to success. This allows different units an opportunity to practice communicating and implementing fire control measures that prevent fratricide (U.S. Department of the Army. 2012).

Construction of survivability positions is dependent on completion of steps one, two, and three. Once those are complete the engineer in charge of earthmoving assets must coordinate their efforts with the maneuver element to complete step five. A breakdown in communication between these two stakeholders can result in rework, which costs time.

The issue that arose occurred because the 326th BEB attempted to anticipate what the Infantry Battalions would request before they requested it. 2nd Platoon's leadership often found itself

constructing survivability positions without a representative from the infantry units (the customer) verifying that the location selected was suitable. When questioned about this approach, the B Company Commander often defaulted to the “this is an order, not a request” style of leadership. With only four days allocated to prepare a defense for a Brigade of 3,600 Soldiers, the 326th BEB’s leadership understood it needed to maximize the quantity of survivability positions produced. In light of this, the Company Commander’s approach was understandable although inefficient.

Table X: Rotation 16-06 Project Site 5 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
5	2100-0430	2 x T5	4 x HDPs	0.53HDP/HR	45	15

The four HDP constructed were part of the defensive plan developed for the city of Dara Lam. HDPs constructed for Project Site 4 provided over-watch for the primary engagement area. Due to intelligence gathered on movement of enemy forces, the Brigade leadership planned for a defense in depth to blunt the attack in two areas in the event its hold on the first defensive line became tenuous. Project Site 5’s HDPs were constructed as part of the final defensive line to hold the city of Dara Lam.

Table XI: Rotation 16-06 Project Site 6 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
6	2100-0100	1 x T5	2 x HDPs	0.5HDP/HR	12	4
	2100-0100	1 x HMEE	2 x fighting positions	0.5FP/HR	12	4

As mentioned in the description about Project Site 4, the possibly of rework became part of the work program assigned to 2nd Platoon. Upon completion of Project Site 5, 2nd Platoon received orders to return to Project Site 4. Upon their arrival the infantry platoon leader requested the construction of two additional HDP in a location that provided better over-watch based on the capabilities of his M2 BFVs. The fighting positions constructed provided survivability for the M2 BFV’s dismounts.

For the purposes of this study, a focus of Just-In-Time production was the elimination of waste. Failing to wait for the project’s primary stakeholder consumed time, the primary resource spent in

military troop construction. In military construction concern for labor costs were non-existent, concern for POL costs were minimal, but time was always a critical factor. Constructing a project on-time in a combat environment often meant the difference between life and death. The rework needed for Project Site 6 meant less HDPs and fewer meters of berm constructed for the final defensive line of Dara Lam.

Table XII: Rotation 16-06 Project Site 7 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
7	1200-1400	2 x T5	4 x HDPs	2HDP/HR	8	4

Project Site 7 entailed the construction of additional HDPs for the Infantry Company equipped with M2 BFVs to defend other Brigade Assets. The Brigade Support Area (BSA) was the central nexus for all the support elements that made it possible for Brigade to project combat power; therefore, the defense of this location was critical in ensuring the continued functionality of the Brigade as a viable combat asset to the 101st Air Assault Division.

Table XIII: Rotation 16-06 Project Site 8 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
8	1430-1700	2 x T5	600m berm	240m/HR	10	5

Friendly constructed obstacles served to alter and slow the flow of enemy troops through the engagement area, which increased the amount of time a friendly weapon system had to engage with and destroy the enemy force. 2nd Platoon constructed a 600m x 2.5m tall berm outside of Dara Lam. The soil was sandy and easy to manipulate. The obstacle served to turn the enemy force into the engagement area, and it helped the Company manning defensive positions over-watching the area to close off a main avenue of approach.

Work rates had improved by this point in the exercise; however, the data does not communicate how much Soldier equipment operator efficiency had improved over the course of the exercise. 2nd Platoon's leadership limited the number of T5 operators to their six most proficient operators after Day Two in an effort to meet the production timelines established by the 326th BEB. All six of the selected

operators worked with engineer equipment in their civilian jobs, which deprived the other 16 Horizontal Construction Engineers of the opportunity to train on survivability construction tasks.

Table XIV: Rotation 16-06 Project Site 9 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
9	0800-1200	2 x HMEE	30m ditch	7.5m/HR	20	8
	1300-1700	2 x HMEE	60m ditch	15m/HR	20	8
	0800-1200	2 x HMEE	70m ditch	17.5m/HR	20	8
	1300-1700	2 x HMEE	20m ditch	5m/HR	20	8
	0800-1200	2 x HMEE	20m ditch	5m/HR	20	8
	0800-1200	1 x Scraper, 1 x T5, 2 x Grader	45.9m <sup>3</sup> of fill removed	11.5m <sup>3</sup> /HR	64	16
	1300-1700	1 x Scraper, 1 x T5, 2 x Grader	45.9m <sup>3</sup> of fill removed	11.5m <sup>3</sup> /HR	64	16
	0800-1200	1 x Scraper, 1 x T5, 2 x Grader	53.5m <sup>3</sup> of fill removed	13.4m <sup>3</sup> /HR	64	16
	1300-1700	1 x T5, 1 x Grader	21m <sup>3</sup> of fill removed	5.3m <sup>3</sup> /HR	32	8
	0800-1200	1 x T5, 1 x Grader	24.7m <sup>3</sup> of fill removed	6.2m <sup>3</sup> /HR	32	8

Upon the conclusion of the Defense, 2nd Platoon received Change of Mission Orders from Operations Group to commence construction on FLS Berry. Information provided to 712th ESC leadership in March 2016, stated that the 36th Engineer Battalion began work on the FLS. When 2nd Platoon arrived on site they discovered the work performed was not in accordance with the SOW or the paving schedule submitted previously. The previous unit brought the 304.8m x 18.3m x (-0.46m) landing strip to grade without the use of proper compaction or aggregate types stipulated by the paving schedule (see Figure 10). Compounding matters was the nine days of rainfall Fort Polk, LA received during the exercise. The lack of compaction caused soil saturation and ponding across the runway surface, which forced the platoon to wait for a sunny day to dry out the landing strip prior to starting work.

The platoon leadership developed a revised construction plan to address draining water off the runway surface before beginning work (see Figure 16). According to the new plan, the landing strip was divided into the following three sections: Section 1 focused on digging 30.5m drainage ditches with the

HMEE to tie in with an existing drainage ditch along the southern perimeter; Section 2 focused on excavating the poorly compacted fill and aggregate with a 613B scraper and a T5 bulldozer from a 61m x 15.3m area along the southern end of the runway; and Section 3 focused on grading a slope for the purpose of drainage on a 61m x 24.4m area along the western perimeter with two graders.

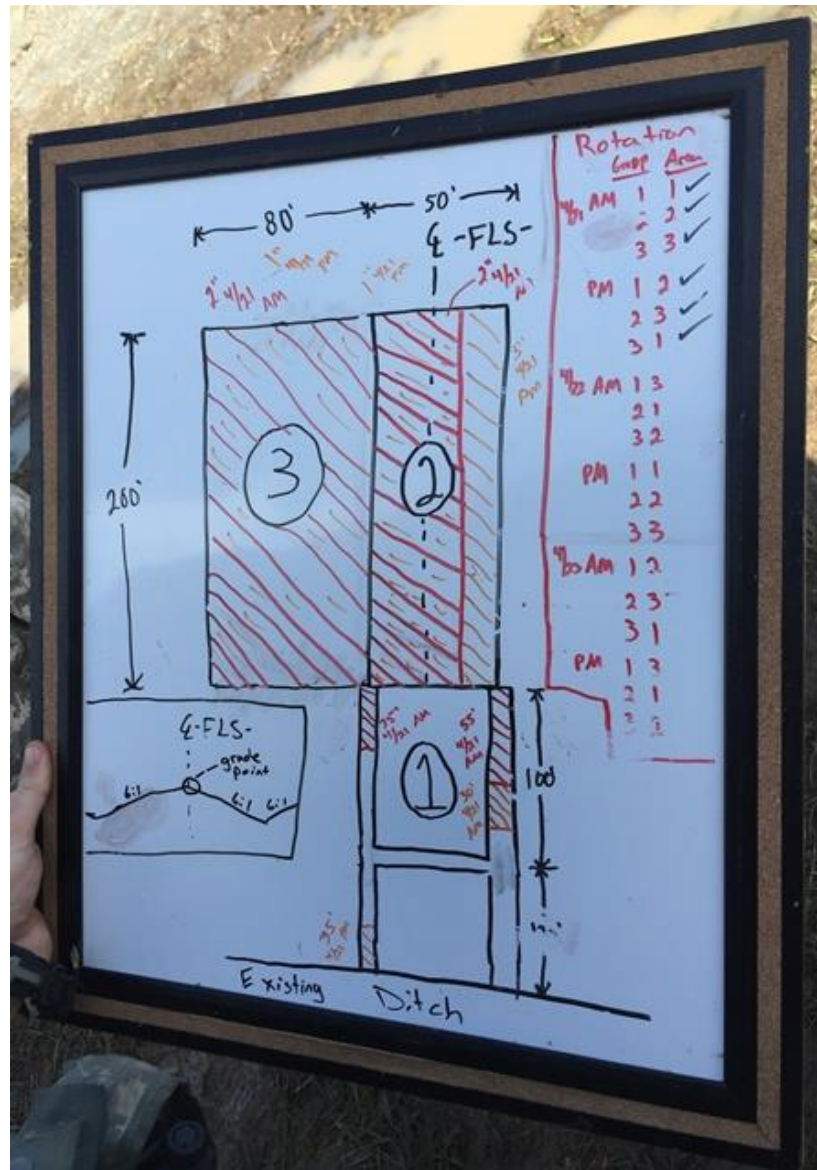


Figure 16: FLS Berry Revised Construction Plan

In conjunction with improving the drainage around the landing strip, the 48 hour period allocated to work was spent excavating the previously lain fill material in Section 2. The work of a previous unit failed to properly compact and cap the fill used in bringing the FLS to grade. This prevented the airfield

from shedding water effectively. All the rain Fort Polk, LA received that month left the FLS saturated with water. This in turn left wheeled vehicles prone to getting stuck while maneuvering on the airfield. When measured, the average tire rut depth left from an empty 613B Scraper, which weighs 14,305kg empty, was 0.35m or approximately 14in. (see Figure 17).



*Figure 17: Depth of Poorly Compacted Soil*

Even with the construction of drainage ditches by the platoon's two HMEEs in Section 1 (see Figure 19), the site conditions restricted work productivity. The 613B Scraper required one x T5 Bulldozer to provide push assistance (see Figure 18) until the scraper blew a hydraulic hose. Without a means of procuring a replacement part, the scraper remained non-mission capable for the remainder of the exercise. A vibratory roller with a sheep's foot tamping attachment was brought to the construction site; however, the ground's moisture content eliminated the usefulness of this asset.



*Figure 18: Drainage Ditch from Section 1*



*Figure 19: 613B Scraper Receives T5 Dozer Push Assist*

During two days of construction the focus shifted from completing the landing strip construction to training Soldiers on their equipment. While this limited output it served the purpose of improving the operator skillsets of 22 Horizontal Construction Engineers, six Horizontal Construction Supervisors, six



Support personnel, and two officers. A long term gain demonstrated through the 356 man hours of experience earned through executing construction operations. Upon conclusion of the 48 hours allocated, the platoon excavated 191m<sup>3</sup> of fill from the FLS in Section 1 and completed 200m of linear ditching.

Table XV: Rotation 16-06 Fuel Consumption

VEHICLE	BUMPER #	14APR2016	16APR2016	18APR2016	20APR2016	22APR2016
SCOOP LOADER	PS 04					45gal
SCRAPER	NH 004					43gal
HMEE	E242	18gal		27gal		27gal
HMEE	E243	26gal		23gal		25gal
GRADER	NE 021					43gal
GRADER	NE 025					45gal
10T DUMP	E 222					24gal
10T DUMP	E 122					33gal
10T DUMP	E 321					31gal
10T DUMP	P 409					27gal
LMTV	P 554	24gal		21gal		22gal
BOBTAIL	E 170					
HMMWV	P 263	17gal		13gal		12gal
HMMWV	P 876	18gal		14gal		14gal
DOZER	ND 8		53gal			57gal
DOZER	ND9		54gal			
916	P 111	41gal		17gal		22gal
916	P 419	23gal		19gal		35gal
	<b>TOTAL</b>	<b>167gal</b>	<b>107gal</b>	<b>134gal</b>	<b>No Report</b>	<b>505gal</b>

Complete fuel consumption data was not recorded outside of the 48 hour period of time allocated to work on FLS Berry. Refueling occurred every other day. An allotment of 500 gallons of diesel every other day was coordinated for during exercise planning sessions with 326th BEB.

Table XVI: Rotation 16-06 Equipment Readiness Rate

Vehicle Downtime	Hours down	Total Equipment Hours	Vehicle Readiness Rate%
1 x T5	3		
1 x Scraper	8		
1 x Grader	8		$281.50 / (281.50 + 19)$ = 0.937
Total	19	281.5	94%

Vehicle and equipment breakdowns are a common occurrence in military construction. In the US Army Reserves this can be attributed to several factors. Not all equipment assigned to a unit is stored in the unit's motor-pool, which prevents it from being used during monthly training events. This is due to a lack of space and the desire to maintain sets of equipment available for other Army Reserve units to train on at military installations. A second reason for breakdowns stems from the requirement to store some equipment on military installations at equipment collection sites. These sites conduct routine services on the equipment, but they do not exercise it. Exercising equipment would entail taking a bulldozer to a dig pit. The last reason equipment often breaks down can be attributed to operator inexperience. Neophyte operators often push equipment too hard, which can result in broken equipment.

The high operational tempo of Rotation 16-06 led to the breakdown of three vehicles despite performing daily preventive maintenance checks. Breakdowns of all the equipment listed in Table XV occurred during construction on FLS Berry. This limited the negative effects on the platoon's overall mission in supporting 326th BEB and 1st BDE, 101st Air Assault Division

#### 4.2 Rotation 16-07 Results

Table XVII: Rotation 16-07 Project Summary

<b>Project Site #</b>	<b>Scope of Work</b>
1	21st Brigade Engineer Battalion (BEB) Assembly Area- Grey Water Pit: 3m x 3m x 2m for Mobile Food Kitchen
2	21st BEB Assembly Area - Construct 1 x Q36 Radar Berm (three sub-assemblies) 78.5m <sup>2</sup>
3	21st BEB Assembly Area (AA) - 200m x 2.5m Perimeter Berm
4	Position Area for Artillery (PAA)4, 320th Field Artillery (FA), A CO. - Emplaced 500m x 2m Berm, 1X Q36 Radar Berm, Crew Serve Fighting Positions, Survivability Pits, Removed Existing Berm
5	PAA4, 320th FA, B CO. – Deconstruct Fighting Positions and Q36 Radar Berm
6	180m Anti-Tank Ditch, 8 x Hasty Fighting Positions
7	75m Anti-Tank Ditch

Table XVII: Rotation 16-07 Project Summary

<b>Project Site #</b>	<b>Scope of Work</b>
8	Construct Berm, Anti-Tank Ditch, FA Positions, and Q36 Radar Positions for 21st BEB and 32nd FA
9	FLS Berry – Removal of 200cubic meters of fill, Installation of 200m <sup>3</sup> of aggregate, grading and compaction of 183m x 30.5m of runway, construction of 5 x 10m drainage ditches
10	Training Area Recovery – 4 x Soldiers with 2 x T5s filled in all fighting positions and knocked down all berms.

1st Platoon, 712th Engineer Support Company deployed to JRTC in support of 3rd Brigade Combat Team, 101st Air Assault Division from 08-28MAY2016. The platoon was comprised of 39 Soldiers. A total of ten missions were executed while executing training during the 12 days of operations. A brief summary of each mission assigned while deployed to JRTC was provided in Table XV. A company of M1A2 Abrams Tanks was at JRTC; however, the 21st BEB used an internal horizontal asset to construct VFPs for the armored vehicles.

Each of the following tables reviews nine of the ten projects assigned the platoon during its 12 days of training. A table for Project Site 10 does not exist because the project consisted of undoing all survivability construction from Project Sites 1 – 8. The Horizontal Construction Supervisor in charge of Project Site 10 did not maintain an accurate record of work rates while executing the task. Similar to Rotation 16-06, the task work rates are calculated by dividing the quantity of construction by the duration of a shift. Man hours per project include the operators and the supervisors directing the equipment. JRTC safety standards require a minimum of one supervisor during day time and two supervisors during night time operations. Equipment hours are calculated by multiplying the total pieces of equipment in use by the duration of a shift.

When attached to support another unit, the unit often vetted the attachment's capabilities through a series of minor projects. The 21st BEB elected to vet 1st Platoon by tasking them to execute three projects close to the Battalion Headquarters, which facilitated increased oversight. Construction of a 200m Berm (ref. Table XX and Figure 21 below), A Q36 Radar protective positions (ref. Table XIX), and

the grey water pit (ref. Table XVIII below) allowed the Battalion Executive Officer and Operations Officer to effectively evaluate the skillset 1st Platoon brought to their operation.

Part of the Lean World Class Manufacturing lessons covered the increased focus on customer value. The 1st Platoon Officers regarded the 21st BEB as their primary customer during the initial infiltration of the training area. By discussing possible mission sets available with the Battalion Operations Officer, the officers understood the Assembly Area missions close to the BEB allowed them to best learn the BEB's, their customer's, definition of value. Additionally the platoon leadership was able to begin analyzing the platoon's construction practices for signs of waste.

Table XVIII: Rotation 16-07 Project Site 1 Details

<b>Site #</b>	<b>Shift Time</b>	<b>Equipment Used</b>	<b>Work Complete</b>	<b>Work Rate (per hour)</b>	<b>Man hours</b>	<b>Equip. hours</b>
1	1845-2100	1 x HMEE	1 x (3m x 3m x 2m) Grey Water Pit	1PIT/2.25HRS	4.5	2.25

When deployed to the field Army units use several methods available to them for feeding their troops. The most common method of feeding is the Meal Ready to Eat (MRE), which is a prepackaged meal comprised of vacuum sealed food packages. Another method of feeding Soldiers in the field is the Mobile Kitchen Trailer (MKT), which is a portable cooking facility capable of preparing hot meals for Soldiers. The MKT (ref Figure 20) requires a grey water pit to dispose of all water used during meal preparation.



Figure 20: Mobile Kitchen Trailer

Table XIX: Rotation 16-07 Project Site 2 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
2	1630-2000	2 x T5	1 X Q36 Radar Berm	1 x Q36/3.5HRS	14	7
			Q36 HMMWV (5.3m x 4.7m x 2.5m)	1.1HRS	4.3	2.2
			Q36 Generator (6.7m x 4.7m x 2.5m)	1.4HRS	5.6	2.8
			Q36 Antenna Array (4.7m x 4.7m x 1.5m)	1HRS	4.1	2

The Q36 Radar is a piece of equipment used to detect and calculate the point of origin for incoming enemy artillery rounds. It is comprised of three parts as see above in Table XVII. The HMMWV stores the antenna and hauls the generator, which is mounted upon a trailer. This is the first of five Q36 Radar berms constructed during the Rotation.

Table XX: Rotation 16-07 Project Site 3 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
3	1950-2400	2 x T5	200m Perimeter Berm	48m Berm/HR	16	8



Figure 21: 21st BEB Assembly Area Project Site 3 Berm

Table XXI: Rotation 16-07 Project Site 4 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
4	1300-1730 2100-0100	1 x T5	500m x 2.5m Berm	59m/HR	17	8.5
	1730-2100	1 x T5	1 x Q36 Radar	1 Q36/3.5HRS	7	3.5
	1300-1700	2 x HMEE	Removed 100m Berm	25m/HR	16	8
	1700-2200	2 x HMEE	4 x Fighting Positions	0.8FP/HR	20	10
	2200-0100	2 x HMEE	3 x Survivability Pit	1 Pit/HR	12	6

Upon successful completion of the Assembly Area, 1st Platoon received a mission to construct survivability positions for B/320th FA. Once again the first thing the platoon leadership did

during link up operations with the FA unit was to establish what the customer wanted in order to minimize waste. The locations of one Q36 Radar, one 1000m long x 2.5m tall berm, eight fighting positions, four 105mm Howitzer positions, and six survivability pits were established and work commenced. Survivability pits were open top protective positions meant to shield dismounted Soldiers from enemy mortar and artillery fire. However, a position transfer of ownership between A Company and B Company/320th FA changed the mission requirements. A Company/320th FA wanted to move the location of the Q36 Radar protective position, the fighting positions, and the survivability pits. They canceled the order for the four 105mm Howitzer positions because occupation of that position was temporary. As a result of the original order, only the work annotated in Table XIX was completed.

Instead of constructing three separate compartments for the Q36 Radar protective position (see Figure 22), 1st Platoon's leadership determined that a non-compartmentalized protective position would better suit B Company/320th FA's needs. The officers tested treating the project site like a focused factory in an effort to streamline workflow and limit the waste of transportation and motion. Each T5 bulldozer crew executed its own construction mission. Due to the limited capacity of the HMEE, the two pieces of equipment were paired to increase productivity as a group technology cell. This approach increased the T5 work rate from 50m at Project Site 3 to 60m per hour.



*Figure 22: Project Site 4 Q36 Radar Position*

Table XXII: Rotation 16-07 Project 5 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
5	0100-0200	2 x T5	Removed Q36 Radar Berm	1 x Removal/HR	4	2
	0615-0715	2 x HMEE	4 x Fighting Positions filled in	1FP/0.25HR	4	2
	0615-0715	2 x T5	3 x Survivability Pits filled in	1 Pit/0.33HR	4	2

Project 5 entailed undoing some of the work constructed for B Company. While working on Project 5, 1st Platoon and A Company/320th FA came under simulated indirect fire (enemy field artillery) attack resulting in the “death” of six Soldiers from 1st Platoon, to include both officers and one Horizontal Construction Supervisor. Project 5 was abandoned to preserve the remaining lives and equipment of 1st Platoon and A Company/320th FA, which prevented the construction of additional survivability positions from occurring. All six Soldiers were “revived” after a 24 hour period. This project was one of two instances when construction was interrupted by any enemy attack.

Table XXIII: Rotation 16-07 Project Site 6 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
6	1430-1700	2 x T5	188M Anti-Tank Ditch (NOTIONAL)	75M/HR	10	5
	1430-1700	1x HMEE	8 x Hasty Fighting Positions	1Position/0.31HR	5	2.5

Execution of Project Site 6 occurred on the final day of the Defense. All construction conducted was in preparation of a major enemy attack. 1st Platoon’s leadership sat down with the C Company Commander, 506th Infantry Battalion to determine how and where to deploy their assets to support defensive preparation of their position. Using their expert map reading and terrain analysis skills during negotiations, the platoon’s leadership determined exactly where the C Company Commander wanted to



plan an Anti-Tank Ditch. They then tasked the HMEE to follow an escort along the perimeter of the battle position to dig hasty fighting positions for dismounted infantry. Using the HMEE in this manner facilitated a rudimentary *Kanban* or pull system that gave the customer exactly what they wanted one at a time without performing unnecessary work in the process.

Work rates for both the Anti-Tank Ditch and Hasty Fighting positions required some explanation. At Fort Polk, LA, excavation of soil by equipment was not allowed to occur within 15m of a tree. C Company, 506<sup>th</sup> Infantry Battalion's battle position was located in the middle of a heavily forested area. A direct result of this environment led to the construction of the Anti-Tank ditch to consist of two T5s and their crews on the side of a road idling for a period of time based on the equipment's standard work rate. Figure 23 (see below) clearly showed how dense the trees were and how the T5s were deployed while constructing the Anti-Tank Ditch. Once the time it would take to execute elapsed, the obstacle was replicated with white construction tape wrapped around trees. The HMEE's dig depth was restricted to 0.5m due to the same 15m rule tree rule.



*Figure 23: T5 Digging a Notional Anti-Tank Ditch*

Project Site 6 was the location of the second enemy attack experienced by enemy forces. The attack was poorly adjudicated by the on-site Observer/Coach-Trainers (OC-Ts) which initially affected work rates. Damage caused in the attack was negated due to the enemy aircraft acting outside the bounds of its weapons' capabilities.

Table XXIV: Rotation 16-07 Project Site 7 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
7	2100-2200	2 x T5	75M Anti-Tank Ditch (Notional)	75M/HR	4	2

Project Site 7 involved the construction of another notional anti-tank ditch, and the work rates provided will not be used in the final analysis.

Table XXV: Rotation 16-07 Project Site 8 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
8	0400-1100	2 x T5	700M x 2M Berm	100M/HR	28	14
	1000-1100	2 x T5	100M V-Ditch	100M/HR	4	2
	0600-0930	2 x T5	3 x Q36 Radar Berms (Partial: No Berm for Antenna Array)	0.86Q36/HR	14	7
	1200-1800	2 x T5	5 x 60M x 2.5M Howitzer Protective Positions	50M/HR	24	12

Following the conclusion of the Defense and a refit period, the Offense began. 1st Platoon received a change of mission order to begin work on FLS Berry similar to Rotation 16-06, unlike 16-06 21st BEB retained the two T5 Dozers and their crews of four Soldiers total (2 x Construction Supervisors and 2 x Construction Engineers). This detachment worked independently of the two personnel who trained in LWCM methodologies. Despite the fact the crews spent the past five days working with the Lean techniques, their lack of formal training on the subject reduced the viability of including their work on Project Site 8 in the overall analysis.

Table XXVI: Rotation 16-07 Project Site 9 Details

Site #	Shift Time	Equipment Used	Work Complete	Work Rate (per hour)	Man hours	Equip. hours
9	0800-1900	2 x HMEE	4 x 7.5m long Drainage Ditches	2.7m <sup>3</sup> /HR	44	22
21MAY	0800-1900	2 x Grader, 1 x Vibe Roller, 1 x Scoop Loader	57.3m <sup>3</sup> soil excavated	5.2m <sup>3</sup> /HR	88	44
22MAY	0800-1230	2 x Grader, 1 x Vibe Roller, 1 x Scoop Loader	19.1m <sup>3</sup> soil excavated	4.2m <sup>3</sup> /HR	36	18
	1231-1900	2 x Grader, 1 x Vibe Roller,	57.3m <sup>3</sup> aggregate laid/compacted	8.8m <sup>3</sup> /HR	39	19.5
	1231-1900	2 x T5	38.2m <sup>3</sup> soil excavated	5.9m <sup>3</sup> /HR	26	13
	1231-1900	4 x 10Ton Dump, 1 x Scoop Loader	57.3m <sup>3</sup> aggregate transported	8.8m <sup>3</sup> /HR	65	32.5
23MAY	0800-1900	2 x Grader, 1 x Vibe Roller	95.8m <sup>3</sup> aggregate laid/compacted	8.7m <sup>3</sup> /HR	66	33
	0800-1200 1201-1900	2 x T5	38.4m <sup>3</sup> soil excavated 4,572m <sup>2</sup> drainage work	9.6m <sup>3</sup> /HR 653m <sup>2</sup> /HR	44	22
	0800-1900	4 x 10Ton Dump, 1 x Scoop Loader	95.8m <sup>3</sup> aggregate transported	8.7m <sup>3</sup> /HR	110	55

1st Platoon moved to FLS Berry to resume the work started by 2nd Platoon during Rotation 16-06. 2nd Platoon's leadership provided 1st Platoon's leadership with a brief of work they completed, site conditions, essential equipment for construction, and duration leadership should expect to have allocated for construction. When 1st Platoon arrived at FLS Berry, the landing strip's moisture content was high although the drainage work from 16-06 eliminated the majority of ponding. The platoon did not have a T5 for the first 36 hours of construction, nor did it have a Scraper for the entire duration of construction.

Initial construction of the FLS focused on the creation of additional drainage ditching along the eastern perimeter of the landing strip and the removal of the poorly compacted fill. Excavation operations

lasted only 36 hours, after which the 1st Platoon leadership organized a site visit for the Operations Group Engineer. The return of their T5s and a directive to use available fill material for the paving schedule occurred during the site visit. By organizing the site visit, the platoon leadership received the customer's value statement.

The return of the two T5 bulldozers led to a construction site reorganization into cells of equipment inspired by the tenets of group technology cells. A Dump Truck Cell, comprised of four 10Ton Dump Trucks and one Scoop Loader, focused on bringing fill material to the FLS Berry. This cell treated the Grading Cell, comprised of two Graders and one Vibratory Roller, as its primary downstream customer. Constant feedback was exchanged between cell crews to constantly improve the processing of where and how thick to layer the fill when depositing the material. The Excavation Cell, comprised of the two T5s, focused on cutting the loosely compacted fill and adjusting the grade of the landing strip's shoulders to improve drainage off the surface.

Before the return of the T5s, the Graders and Scoop Loader performed soil excavation (see Figure 24). The technique used was very innovative. The vibratory roller with sheep's foot attachment on rolled down the water saturated landing strip. A grader followed behind creating 0.3m high windrows that a scoop loader would then pick up and deposit into a dump truck (see Figure 25).



*Figure 24: Grader Excavation Work*



*Figure 25: FLS Berry Windrow Excavation*

With three days of construction available, 1st Platoon limited its focus to a 183m x 18.3m section of FLS Berry. The amount of equipment available for construction allowed the platoon to simultaneously focus on construction and training with minimal impact to work-rates. 25 Horizontal Construction Engineers, ten Horizontal Construction Supervisors, two Support personnel, and two officers improved their respective skillsets. A long term gain demonstrated through the 518 man hours of experience acquired through executing landing strip construction operations. Upon conclusion of the 72 hours allocated, the platoon excavated 153m<sup>3</sup> of fill, compacted 153m<sup>3</sup> of aggregate, constructed 30m x 20m of drainage ditching, and graded 4,572m<sup>2</sup> along the western and eastern perimeters for drainage.



*Figure 26: FLS Berry 20MAY*



Figure 27: FLS Berry 23MAY

Table XXVII Rotation 16-07 Fuel Consumption

VEHICLE	BUMPER #	14MAY2016	15MAY2016	20MAY2016	22MAY2016	23MAY2016
SCOOP LOADER	PS 04				47gal	46gal
VIBRATORY ROLLER	NH 004				38gal	22gal
HMEE	E242	20gal		20gal	44gal	28gal
HMEE	E243	30gal	18gal	11gal	37gal	28gal
GRADER	NE 021	33gal		8gal	53gal	32gal
GRADER	NE 025	40gal			65gal	55gal
10T DUMP	E 222	9gal		13gal	33gal	
10T DUMP	E 122				27gal	
10T DUMP	E 321				40gal	
10T DUMP	P 409				27gal	
LMTV	P 554	15gal		19gal	33gal	
BOBTAIL	E 170				14gal	
HMMWV	P 263	18gal		8gal	11gal	5gal
HMMWV	P 876	16gal		10gal	20gal	

Table XXVII Rotation 16-07 Fuel Consumption

VEHICLE	BUMPER #	14MAY2016	15MAY2016	20MAY2016	22MAY2016	23MAY2016
DOZER	ND 8		19gal			55gal
DOZER	ND9		24gal			57gal
916	P 111	45gal				43gal
916	P 419	20gal				46gal
	<b>TOTAL</b>	<b>228gal</b>	<b>61gal</b>	<b>89gal</b>	<b>489gal</b>	<b>417gal</b>

Table XXVII displayed a partial fuel usage of 1st Platoon during Rotation 16-07. The high operational tempo of the exercise prevented accurate record keeping of fuel consumption during the Joint Forcible Entry Operations (JFEO) and the Defense. Fuel consumption on 14MAY occurred before the platoon began executing missions. 22-23MAY were days the platoon executed construction on FLS Berry. Comparisons of fuel consumption with Rotation 16-06 were limited to construction on FLS Berry.

#### 4.3 Experiment Analysis

##### 4.3.1 Work Rates and Work Shifts

Work rates were directly affected by when work shifts occurred. Rotation 16-06 executed four projects during periods of low visibility and night. Additionally it rained during three of those four projects which further degraded overall work rates. Working under NODs during nighttime conditions degraded productivity by 52% to 65% while constructing 2.5m tall berms. Construction of fighting positions with the HMEE experienced similar drops in productivity. Project Site 1 saw a decrease in productivity of 51% to 72% when construction occurred during nighttime hours. Although skewed by Project Site 8's soil workability, the average work rate for berm construction was 56.7m/hr. The average work rate for fighting position construction was 1.26 positions per hour, and the average work rate for HDP construction was 0.88 HDPs per hour.

Rotation 16-07 executed three projects during periods of low visibility and night. Project Site 3 work occurred entirely at night, and Project Site 4 work happened during both daytime and nighttime hours. When compared to Project Site 4, Project Site 3's work rates showed 18.6% degradation in productivity. Rotation 16-07's work rates were consistently better than Rotation 16-06's due to no rain

fall during work, lower operational tempo, and increased moon illumination levels during nighttime operations. Q36 Radar productivity rates varied depending on the level of protection needed by the customer or the number of T5s available to construct it. Work rates for fighting positions varied due to customer needs or JRTC dig restrictions placed on the HMEE crews. Disregarding work rates from the shallow fighting positions constructed at Project Site 6 led to an average work rate for fighting positions of 0.8 positions per hour. The average work rate for berm construction was 53.5m/hr (Project Site 8 work rates are omitted from this average).

Different equipment sets were used during construction of FLS Berry by each Rotation, and each platoon received a different span of time to execute construction. This affected the overall work rates and productivity of each platoon. To reiterate the SOW called for 712th ESC to construct a 305m long x 18.3m wide FLS at Drop Zone Berry to support RQ-7 Shadow UAS launch and recovery sites. 712th ESC submitted a pavement schedule, which was approved by JRTC's Operations Group, requiring four layers of different types of aggregate. Upon arrival, the work executed by a previous unit forced each platoon to execute rework operations instead of making forward progress on construction.

In a 48 hour period, Rotation 16-06 excavated 191m<sup>3</sup> of fill from a 61m x 15.3m section of the landing strip. To compare overall work rates effectively the final total of excavation by Rotation 16-06 was reduced by 40% to compare it to Rotation 16-07. A total of 114.6m<sup>3</sup> of fill was excavated from a 183m x 18.3m section of the landing strip during Rotation 16-07. No methodology was developed to factor in different equipment sets being used to execute excavation operations on the landing strip. However, the Rotation 16-07 work rate of two T5 bulldozers excavating was 7.8m<sup>3</sup> per hour versus the rate of 130G grader and scoop loader approach of 5.8m<sup>3</sup> per hour demonstrated the greater efficiency realized when using equipment designed for large scale excavation work.

#### 4.3.2 Fuel Consumption

Record keeping for fuel consumption was inconsistent throughout the Defense and JFEO. The cause for this was two of the following reasons: 1) the officers tasked to keep track of this information had multiple competing priorities, and 2) the platoons were often split to support separate missions



making fuel consumption tracking difficult. Work on the FLS provided the best opportunity for comparative fuel consumption of each platoon. Rotation 16-06 consumed a total of 505 gallons of fuel after working for a 48 hour period. Rotation 16-07 consumed a total of 906 gallons of fuel over a 72 hour period. Rotation 16-07 consumed 179% more fuel than Rotation 16-06. Those numbers include all equipment and vehicles brought to the FLS.

The total number dropped to 240 gallons for six pieces of equipment during Rotation 16-06 and 734 gallons for 12 pieces of equipment during Rotation 16-07 after subtracting all equipment not used for construction. Using equipment to gallons of diesel consumed ratios for comparison generated the following results: Rotation 16-06 used 40 gallons per vehicle and Rotation 16-07 used 61 gallons per vehicle. If this figure is adjusted to only account for 48 hours of construction during Rotation 16-07, the consumption of fuel is reduced to a total of 489 gallons for 12 pieces of equipment. This brings 1st Platoon's average gallon per vehicle use down to 40.8 gallons per 48 hour period. The savings in fuel are somewhat significant when one factors in 1st Platoon's 11 hour work day during Rotation 16-07 versus 2nd Platoon's nine hour work day during Rotation 16-06.

The dump truck operations were an additional factor that offset fuel usage. Travel distances to the designated base course material stockpile and the surface course material stockpiles were respectively 3km and 13km away. The Rotation 16-07 leadership discovered there was not a stockpile at the closer location 3km away. 1st Platoon achieved the necessary California Bearing Ratio (CBR) using a 50/50 mix of excavated fill and stockpile material available at the 13km stockpile location. Each 10 Ton Dump Truck carried approximately  $5.1\text{m}^3$  per load.  $153\text{m}^3$  total aggregate was laid, and  $77\text{m}^3$  of the material came from the stockpile 13km away. 15 dump truck loads were required with an average travel time of 24 minutes one way and approximately 68 minutes round trip (includes 20 minute loading time). The time required to place and show the operator of a loaded 10 Ton Dump Truck where to place the load was not included in the travel time calculation. 2nd Platoon did not conduct dump truck operations during Rotation 16-06.

### 4.3.3 Vehicle Readiness Rate

Comparing vehicle readiness rates for the two platoons provided two results depending on one's interpretation of the data. If the readiness rate was based on operability for all equipment used for construction the rates were 94% for Rotation 16-06 and 100% for Rotation 16-07. Rotation 16-07 maintained a high operation readiness rating by ensuring all equipment needed for a mission was mission capable. All equipment issues were identified during pre and post operation checks of the equipment and fixed.

The second methodology for tracking vehicle readiness required using a ratio based on operability of all available equipment by day. A total of 28 pieces of equipment were available at the start of Rotation 16-06. One skid-steer broke down before Day 1 of training and remained unavailable throughout the duration of both rotations. One T5 broke down on Day 8 of training and was replaced by another T5. Days 11 and 12 saw the 613B scraper and grader breakdown. The average vehicle readiness rate based on this data was 93.8%.

Rotation 16-07 had a total of 30 pieces of equipment available at the start; however, only 26 of those were operational. The grader was repaired by Day 2 of training. No other breakdowns occurred that affected the operational readiness of equipment and vehicles. The average vehicle readiness rate based on this data was 89.7%. Taking away the vehicles broken during Rotation 16-06 increased the readiness rate of the remaining 27 vehicles to 99.7%.

## **Chapter 5: Conclusions, Recommendations for Future Work**

### **5.1 Conclusions**

This experiment set out to prove that applying Lean World Class Manufacturing (LWCM) principles to a construction project would yield measurable savings in time, labor, and material related costs. Traditional Army construction methods used in this experiment by 2nd Platoon during JRTC Rotation 16-06 provided a control group of sorts to compare to an organization trained in the Lean precepts of Just-In-Time Manufacturing and Total Quality Control. 1st Platoon acted as the experimental group tasked with applying Lean World Class Manufacturing training to the military construction world during JRTC Rotation 16-07.

Unfortunately, using a JRTC Rotation as the source of construction projects to implement the experiment left too many variables outside of the researcher's control. The variance between Rotation 16-06 and 16-07's work shifts during the Defense and Joint Forcible Entry was unforeseen. Construction projects were executed when received. 326th BEB tasked 2nd Platoon with more construction projects during those two phases than 21st BEB tasked 1st Platoon. The types of projects assigned varied between the Rotations. 2nd Platoon spent the bulk of its time in the defense constructing HDPs, FA Howitzer positions, and berms. 1st Platoon on the other hand, constructed "notional" anti-tank ditches and Q36 radar protective positions. While work on FLS Berry was a commonality between the two Rotations, the time allotted and conditions present during work forced each platoon to adopt two different construction strategies.

### **5.2 Limitations of the Study**

Even though 1st Platoon used LWCM strategies and outperformed 2nd Platoon by a noteworthy degree, the conditions and time prevented the results from being used as definitive evidence in support of the hypothesis. 1st Platoon improved work efficiency by obtaining the customer's desired value prior to the start of any task, which mitigated the chance of unneeded work. On FLS Berry, more overall work was completed by 1st Platoon than 2nd Platoon in regards to area excavated, compacted, and graded.

Three to five maintenance and support personnel were attached to each platoon for their respective training rotations; however, as a result of work or family conflicts the support attached to 1st Platoon dwindled from five to two. This placed 1st Platoon at a significant disadvantage when trying to repair equipment in the field. 2nd Platoon experienced a similar issue when two of its four attached maintenance personnel missed movement (on purpose) to training.

Personnel issues were further complicated by the lack of maintenance support provided to both platoons during their respective rotations. Both the Equipment Collection Site-17 (ECS) on Fort Polk and the training Brigades were supposed to provide maintenance support in the event a piece of equipment broke down. The training brigades and the BEBs the platoons supported did not offer any repair support during the rotation or at the conclusion of the exercise. Understandably the reason stemmed from the high operational tempo causing those units to focus on the task of defeating an enemy force and from working to redeploy their people and equipment back to home-station. No maintenance support was provided by ECS-17. Essentially all coordination and written agreements were ignored, and the researcher was unable to affect the conditions on the ground due to an 853 mile geographical separation.

Another issue stemmed from failing to train all of 1st Platoon on LWCM precepts and strategies. As U.S. Army Reservists a limited time each month was available to train the Soldiers participating in Rotation 16-07. Soldiers had civilian careers outside of Reserve training, which prevented them from participating in seminars or reviewing instruction material on the subject. Providing weekly lessons for only the two officers went against the Lean tenet of getting buy-in from all levels of the workforce. This top down approach prevented the experimental group from being truly experimental.

Incomplete book-keeping plagued this experiment. As mentioned in section 3.2.5 “Additional Controls,” all four officers were instructed to record work rates based on equipment and man hours, record fuel consumption, record vehicle readiness rates, and record number of shifts worked. Each platoon tracked only two/four items mentioned above consistently. Records were kept for the other two items, but the data was not daily or complete. A review of fuel consumption rates provided the best example of this short-coming.

### 5.3 Recommendations for Future Work

Conducting an experiment like this in the future would be extremely beneficial. Knowledge gained in the above experiment demonstrates the potential viability of incorporating LWCM concepts into traditional construction projects. As demonstrated by the outputs from Rotation 16-07, incorporating the LWCM concepts ensured the platoon leadership understood the customer's definition of value before beginning any construction project. This mitigated the chances for rework, which translated into time, labor, and equipment savings. 1st Platoon's leadership focused on continuous improvement through the incorporation of Total Quality Control tools into their post project analysis. Finally, 1st Platoon used approximately the same amount of fuel per vehicle despite working an 11 hours versus 2nd Platoon's nine hours daily during construction on FLS Berry.

An unexplored benefit of utilizing Lean practices in construction during this experiment includes using the Last Planner System (LPS), which enabled one project to increase its percent planned complete ratio from 83% to 93% over the course of six weeks. The LPS works best on longer projects because of the weekly work reviews and three week look-aheads it entails. Although those reviews and look-aheads can be adapted to more compressed timelines, the benefit of implementing pull system material practices decreases with shorter projects in military construction due to the military's bureaucratic heavy procurement process.

Further work in this subject must implement the following changes to be successful. First, the experiment cannot occur during a Combat Training Center Rotation at JRTC, the National Training Center, or the Joint Maneuver Readiness Center. It should occur at a location where the construction agency can control work shifts to establish work rate metrics not subject to change based on an enemy attack. Next, the experimental group needs training provided to all members of the section adopting LWCM strategies. Obtaining total employee involvement is essential. Thirdly, maintenance support must be identical in size and capability for each section working. Lastly, the researcher must be in a position to conduct frequent site visits enabling them to spot check record keeping, LWCM implementation, and work-rates.

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## APPENDICES

### Appendix A: Formulas Used

#### 16-06 Work Rates

Berm Work Rate Day vs. Night:

11.67m/hr night is 52% less effective than 24.29m/hr

$11.67/24.29 = 0.48(100) = 48\%$

$100\% - 48\% = 52\%$

Avg Berm Work Rate:

$11.67 + 24.29 + 12 + 13.64 + 38.75 + 240 = 340.35\text{m/hr}$

$340.35/6 \text{ projects} = 56.7\text{m/hr}$

Avg Fighting Positions (FP) Work Rate:

$0.67 + 1.2 + 2.43 + 2 + 1.11 + 0.88 + 0.5 = 8.79\text{FP/hr}$

$8.79/7 \text{ projects} = 1.26\text{FP/hr}$

Avg Hull Defilade Position (HDP) Work Rate:

$0.67 + 0.71 + 0.53 + 0.5 + 2 = 4.41\text{HDP/hr}$

$4.41/5 \text{ projects} = 0.88 \text{ HDP/hr}$

Project Site 1 Night vs Day Work Rate:

$1.2\text{FP/hr} / 2.43\text{FP/hr} = 0.49 (100) = 49\%$        $100-49 = 51\%$

$0.67\text{FP/hr} / 2.43\text{HDP/hr} = 0.28 (100) = 28\%$        $100-28 = 72\%$

FLS Berry:

Total Excavation on Airfield:  $45.9\text{m}^3 + 45.9\text{m}^3 + 53.5\text{m}^3 + 21\text{m}^3 + 24.7\text{m}^3 = 191\text{m}^3$

Total Work Hours 16-06

Man Hours: 769hrs

Equipment Hours: 281.5hrs

#### 16-07 Work Rates

Project Site 3 vs Project Site 4:

$48\text{m/hr} / 59\text{m/hr} = 0.85(100) = 81.4\%$        $100-81.4 = 18.6\%$

Avg Berm Work Rate:

$48 + 59 = 209\text{m/hr}$

$107/2 = 53.5\text{m/hr}$

Total Work Hours 16-07

Man Hours: 725.5hrs

Equipment Hours: 372.75hrs

FLS Berry T5 vs. Grader, Scoop, Vibe Combo:

- GSV:  $5.2\text{m}^3/\text{hr} + 6.4\text{m}^3/\text{hr} = 11.6/2 = 5.8\text{m}^3/\text{hr}$

- T5:  $5.9\text{m}^3/\text{hr} + 9.6\text{m}^3/\text{hr} = 15.5/2 = 7.75 \text{ or } 7.8\text{m}^3/\text{hr}$

**Dump Truck Work Data:**

- Gravel:  $1 \text{ yd}^3 = 2 \text{ tons}$       - Soil:  $1 \text{ yd}^3 = 1.33 \text{ tons}$
- 10Ton Dump can carry:  $10/1.33 = 7.5 \text{ yd}^3$  Soil and  $10/2 = 5 \text{ yd}^3$  Gravel
- $1 \text{ yd}^3 = 0.7646 \text{ m}^3$
- $0.7646(7.5 \text{ yd}^3) = 5.75 \text{ m}^3$  Soil   -  $0.7646(5 \text{ yd}^3) = 3.82 \text{ m}^3$  Gravel
- $153 \text{ m}^3 / 5.75 \text{ m}^3 = 26.6$  or 27 Dump Truck Loads of Soil
- $153 \text{ m}^3 / 3.82 \text{ m}^3 = 40.05$  or 40 Dump Truck Loads of Gravel

**Dump Truck Work Data (cont.):**

- Clay wet weighs 110lbs per  $\text{ft}^3$  x 27 = 2,970lbs for  $1 \text{ yd}^3$
- Clay dry weighs 100lbs per  $\text{ft}^3$  x 27 = 2,700lbs for  $1 \text{ yd}^3$
  
- Aggregate and fill was used: mix soil and rock =  $1.5 \text{ ton/yd}^3$
- $10 \text{ ton} / 1.5 = 6.67 \text{ yd}^3 (0.7646) = 5.1 \text{ m}^3$
- $153 \text{ m}^3 / 5.1 \text{ m}^3 = 30$  Dump Truck Loads
  
- 30 Dump Truck Loads transported 13km =  $30(13) = 390 \text{ km}$
- Used 50/50 gravel/clay mix from stockpile and local fill
- 15 loads of 50/50 mix were transported 13km each lift =  $15(13) = 195 \text{ km}$
  
- Time: 17.5hrs of work
- Travel Time = 24 min 1 way
- 68 min round trip (includes 20min load time) [ $68/60 = 1.13 \text{ hrs}$ ]
- $15(1.13 \text{ hr}) = 17 \text{ hrs}$

**Fuel Usage**

FLS 16-06: w/only equipment use calculated = 1 x Refuel 240gal  
 240 gallons used for 6 pieces of Earthmoving Equipment over a 48hr period  
 $240/6 = 40$  gallons per vehicles

FLS 16-07: w/only equipment use calculated = 2 x Refuel of 411 + 323 = 734gal  
 Adjusted for only 48 hours =  $734 \times (0.6666) = 489.3$  gallons  
 $489.3/12 = 40.8$  gallons per 48hrs

**Vehicle Readiness Rate**

28 Vehicles available for 16-06 (minus 1 x Skidsteer, 1 x T5)

16-06:

Ratio [ $96.4\%(7 \text{ days}) + 92.9\%(3 \text{ days}) + 85.7\%(2 \text{ days})$ ]/12 =  
 $[674.8 + 278.7 + 171.4]/12 = 1125/12 = 93.75\%$  Vehicle Readiness Rate

16-07: minus FLS = 98.75 equipment hours

16-07: with FLS = 357.75 equipment hours

30 Vehicles available for 16-07 (minus 613B, 1 x Skidsteer, 1 x T5)

16-07:

Including NMC Vics from 16-06: [ $86.7\%(1 \text{ day}) + 90\%(11 \text{ days})$ ]/12 =  $1077/12 = 89.7\%$  Vic Ready Rate

Excluding NMC Vics: [ $96.3\%(1 \text{ day}) + 100\%(11 \text{ days})$ ]/12 =  $1196/12 = 99.7\%$  Vic Ready Rate

## Appendix B: Copy of OC Evaluation Report

Rotation 16-06: 2/712 ESC

1. General: 2nd Platoon 712 Engineer Support Company participated in a Decisive Action Training Environment (DATE) rotation during JRTC 16-06. 2nd Platoon conducted mobility, counter-mobility and survivability operations throughout each phase of the operation. During the demanding rotation, the unit developed and refined their basic Soldier skills, planning and integration, and general engineering operations.

2. As 1/712 ESC returns to home station, we recommend focusing on the following areas:

a. The 712<sup>th</sup> ESC does not have a published **TACSOP**, and reverted to using a few copies of the B Co/101<sup>st</sup> TACSOP as a baseline throughout the rotation. Areas where having a company TACSOP would be beneficial have been identified by the platoon. These areas include night operations under NVGs, convoy operations, and PCC/PCIs. The platoon has recognized the need for a TACSOP and has begun development of company standards to be submitted to the CO for review.

b. Develop **PCC's and PCI's** for common operations that the unit conducts. Leaders checked on their Soldiers and vehicles before conducting a convoy, however, the lack of a PCC checklist increased the time before SP and allowed for oversight of critical checks. The knowledge for the unit to be successful is accessible within the unit, the knowledge needs to be transferred to a checklist and used by leaders.

c. **Priorities of work** were not clearly established throughout the rotation. While a work/rest cycle was somewhat utilized, the leadership was still relied on heavily. This affected leaders' decision making when fatigued. Also, while conducting shift work there was an hour of lost construction production due to the entire unit having lunch at the same time. Establishing priorities of work will greatly increase the efficiency of the unit when implemented properly. Less time will be spent with Soldiers wondering what they should be doing and more time will be focused on getting the conditions set for the unit to be successful once they arrive at the mission location.

d. **Task organization/Command Support Relationships** was a significant challenge this rotation. There was a steep learning curve for the unit on integration with an active Army unit once they were on ground at JRTC. Once they were task organized under B Co there was no additional communication with BN on priorities of engineer support. Due to a lack of specificity in the Command Support Relationship the unit struggled to understand where to request from and receive sustainment and administration support.

e. **Rehearsals** were either not conducted, or not conducted to standard. Often short timelines prevented mission specific rehearsals from taking place, but general rehearsals and battle drills were largely not conducted, even when the unit had plenty of time and was not gainfully employed. Rehearsals should be a standard part of mission prep, and when not preparing for a specific mission, should still be conducted for anticipated events like reacting to direct or indirect fire, actions on contact, vehicle recovery, actions on short and long halt, CASEVAC/MEDEVAC drills, etc. These largely did not happen and were evident when the platoon was in a situation they did not rehearse for.

f. This platoon has had several challenges with their **communications**. There was no reliable PACE plan established for operations outside of the FM bubble. The platoon also relied on the B Co comm representative to ensure they had the proper fill. Additional training on communication systems will help to improve the unit's self-sufficiency. The platoon did not establish and maintain a

communication channel with the BDE engineer. This lead to a lack of a survivability matrix and the BDE commander's priorities for horizontal construction operations. We recommend the unit creates a standardized report for construction progress to be reported higher to improve visibility on the progress toward mission completion.

3. Summary. Rotation 16-06 was a building rotation for the platoon from 712 ESC. JRTC has improved the platoon's understanding of horizontal engineering in a combat environment. The OC/Ts have given plenty of recommendations and coaching to the platoon in AARs and informal conversations. We believe that the unit's leadership has an understanding of the way forward for the platoon and will succeed in the future.

4. The point of contact for this memorandum is CPT Reyn Mossman at 808-546-1032 or email [reyn.h.mossman.mil@mail.mil](mailto:reyn.h.mossman.mil@mail.mil).

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CPT, EN  
Engineer Platoon OC/T

## Rotation 16-07: 1/712<sup>th</sup> Engineer Support Company

1. General. The 712<sup>th</sup> Engineer Support Company took part in a Decisive Action Training Environment (DATE) exercise during JRTC Rotation 16-07. The Immunes mission was to deploy to JRTC for Rotation 16-07 in support of 21BEB, 3-101<sup>st</sup> to execute mobility, counter mobility, and survivability operations in order to enable combined arms freedom of maneuver. The 712<sup>th</sup> showed exceptional proficiency at all levels from individual Soldier skills to collective training during all phases of the exercise.

2. The following areas have been identified as needing further development prior to assuming future assigned missions:

a. Roles and Responsibilities: Everyone had a general understanding of their roles and responsibilities. However, there were periods throughout the exercise where some leaders felt the need to step outside of their roles in order to fill leadership gaps at lower levels. This was due to some junior leaders either not taking any initiative to fill those gaps, or not being empowered to do so. This was evident while conducting priorities of work and site management. The leadership was able to identify this, and will develop courses of action to address these issues for future exercises.

b. TACSOP: A TACSOP is a collaborative document that outlines a set of explicit instructions to successfully accomplish a specific mission. The TACSOP is also a document for improving existing SOPs and incorporating checklists for conducting PCCs and PCIs. We recommend the platoon take the lessons learned, as well as correct any shortcomings identified throughout the exercise and use them to build a TACSOP and Engineer Annex. Furthermore, creating a TACSOP working group during collective and annual training will not only aid in further development, but also give the soldiers and leadership within the platoon assisting in its creation a collective voice.

c. Troop Leading Procedures and Rehearsals: Back briefs, rehearsals and battle drills did take place throughout the exercise. However, short suspense's for "hey you" taskings; mission changes with short suspenses; and inadequate use of their assets by supported units made it a challenge for the platoon to adequately practice the one-third, two-third rule. One of the key preparation activities, as outlined in ADRP 5-0, is conducting rehearsals. Once a plan has been developed, it is the responsibility of the leadership to ensure that their subordinates, at a minimum, rehearse key portions of the plan. Even when limited on time, leaders can conduct abbreviated rehearsals that focus on critical events; especially those pertaining to their tactical and technical tasks. By doing so, leaders would be able to identify and address any shortcomings in the plan. Rehearsals also ensure that subordinates have a better concept of their responsibilities

d. Commo: Due to equipment limitations, the platoon had to rely heavily on supported elements for commo. This hindered the leadership's ability to effectively conduct mission command with their forward elements. The platoon understands the importance of having reliable communications and [with suggestions from the OC/Ts] should develop courses of action in order to address this for future exercises.

3. Summary. The Immunes experienced many challenges throughout this exercise. Even so, they displayed their ability to rapidly adapt to constant changes in their mission set, and accomplish all assigned tasks. However, this rotation has helped them to identify their strengths; weaknesses; and develop courses of action to help them to improve overall. The eagerness and receptive nature of the Soldiers and leadership in the 712<sup>th</sup> Engineer Support Company greatly contributed to this. The platoon leadership have a clear picture of their capabilities and should ensure they routinely voice those capabilities and limitations to the higher command.

4. The point of contact for this memorandum is CPT Frank Lawson at (678) 754-1770 or [frank.lawson.mil@mail.mil](mailto:frank.lawson.mil@mail.mil).

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## Appendix C: Copy of Rotation After Action Review

AFRC-EMS-AGC7

12 June 2016

### MEMORANDUM FOR RECORD

SUBJECT: Company JRTC Rotation 16-06 and 16-07 After Action Review.

1. The 712th Engineer Support Company participated in two Joint Readiness Training Center (JRTC) training exercises at Fort Polk, LA during Fiscal Year (FY) 2016. Specific tasking directed a minimum of 36 or 1 Platoon deploy ISO of each training rotation. The Company sent a total of 77 Soldiers to JRTC ISO of these training rotations. While preparing for and executing the rotations several matters worth discussion came to light.

2. Discussion Point 1.

a. Issue: Coordination for deployment to the rotations occurred between the Reserve Company and the Active Duty Brigade being supported with no involvement from the Reserve Brigade.

b. Discussion: The 926th EN BDE provided the company with a set of dates for the rotation and sent the Active Duty Rotational Training Unit (RTU) a list of the 712th's contacts. All fact finding and coordination occurred between the Company and the Brigade from that point forward. Due to the nature of the initial RFIs submitted, the majority of coordination for the rotation was conducted by the TPU Commander. The Brigade did not become involved in the coordination process with the RTU until the Company Commander sent the RTU S8 the points of contact for the 926th EN BDE equivalent position. This was to ensure funding was allocated for equipment and personnel transportation.

c. Recommendation: When tasked to support a Combat Training Center (CTC) rotation, the Army Reserve Higher Headquarters must provide the company and the RTU a list of contacts and what they are responsible for to ensure all parties are actively involved in any coordination. For Example: Funding for CBL of vehicles POC at Reserve BDE level.

3. Discussion Point 2:

a. Issue: No CTC Requirement Checklist was provided to the company prior to its deployment to the CTC.

b. Discussion: All special equipment requirements were not discerned until attending the Initial Planning Conference four months prior to execution and another company within the same Battalion began preparation for a CTC rotation scheduled at an earlier date. During the IPC the 712th was able to verify that they needed JLIST, IBAs with SAPI plates, additional AT days, BFAs, face paint, and NVG Bracket Plates. The process for acquiring these items was discovered through trial and error at the Company level. NVG Bracket Plate orders were denied when placed as Class IX in the SAMS and OCIE in Supply systems. Final approval authority rested at the BDE level. Face Paint was obtained using the BN impact card. JLIST and IBAs were acquired by going through Fort Jackson and Fort Polk CIFs.

c. Recommendation: Either the TEC or the BDE develop and provide a standard requirement checklist to a company deploying to a CTC a minimum of nine months prior to execution. This checklist must include a how to guide for procurement.

#### 4. Discussion Point 3:

a. Issue: Invalid training dates and required training days were provided to the company when Extended Combat Training (ECT) dates were provided.

b. Discussion: Original dates provided to the company did not reflect the CTC training timeline and were for a duration that was five days less than the CTC required. The error was not discovered until attending the IPC four months prior to execution. Then at no point did the Brigade or the Reserve Liaison from the CTC stipulate it was mandatory for attendance to a CTC to last 21 days. The 926th BDE did allow all SM to be placed on orders for up to 29 days three months prior to execution; however, extending the number of days was never directed. This led to changes in the training timeline one month prior to execution of the first rotation IOT accommodate a FORSCOM mandate to extend the training timeline. The impact of such a last minute change affected the SM's civilian occupation and planning considerations for family care.

c. Recommendation: Ensure all CTC deployments reflect the correct training dates and duration.

#### 5. Discussion Point 4:

a. Issue: 21 days is an insufficient period of time to have a Reserve unit deploy to a CTC.

b. Discussion: 21 days is an insufficient amount of time for preparing to deploy into a CTC training area. With two days dedicated to travel, this leaves the unit a maximum of 19 days to go through RSOI and Reserve RSOI. Even with an ADVON and Trail party to receive and return equipment, this does not address the need to go through MILES equipment draw, PREPO fleet equipment draw, Exercise Rules of Engagement training, and participate in RTU live fire events. Drawing equipment from MILES and PREPO is dictated by the work schedule of civilians who work only Monday-Friday and 0800-1600. An issue 712th ran into was sending an ADVON out four days prior, but their arrival to the CTC on a Thursday meant they only had the Friday to draw equipment from PREPO, which conflicted with their ability to receive vehicles arriving to the base. Additionally, drawing equipment from an ECS faces the same timeline constraints as the PREPO or MILES yards.

c. Recommendation: Make it mandatory for SM to be put on 23 day orders when supporting a CTC Rotation. Two days are lost to travel, which allows the training unit sufficient time to go through the RSOI and Reverse RSOI process. Ensure ADVONs and Trail parties are on the ground IAW a timeline that facilitates working with civilian run organizations like PREPO, MILES, and ECS.

#### 6. Discussion Point 5:

a. Issue: No Blue Force Trackers (BFT) , Joint Capability Release (JCR) or Forms of Communication outside of FM radios were made available.

b. Discussion: During training the unit was unable to communicate with the Active Duty units whenever FM Radio issues occurred. This meant the PACE plan was limited to FM radio and runner. The unit was not issued BFT or JCR units. Vehicles drawn from the CTC PREPO fleet do not come equipped with BFT or JCR units. The RTU was not able to provide its augmentees with the equipment.

c. Recommendation: Units deploying to a CTC need to be issued JCR units to support PACE plans.



#### 7. Discussion Point 6:

a. Issue: Tasking a Company deploying to a CTC to provide Guest Observer/Controllers-Trainers (OC-T) to support the same Rotation.

b. Discussion: The 712th ESC was tasked to support two CTC rotations which depleted its number of available leadership. A tasking came down for the 712th ESC to provide 5 x Guest OC-Ts for both Rotations. The requirement was for 1 x O-3, 1 x E-7, and 3 x E-6s. A company commander cannot validate his own formation objectively. If a commander deploys as a Guest OC-T, even if assigned to observe a different unit this prevents him/her from providing reach back support to the force in the field. During both rotations, the 712th Commander was contacted via cell phone to address coordination issues by the platoon leadership.

c. Recommendation: Ensure USARC or the TEC do not task the same Company being deployed to a CTC to provide Guest OC-Ts.

#### 8. Discussion Point 7:

a. Issue: Tasking one Company to support two platoon sized rotations instead of deploying the whole company.

b. Discussion: When issuing the request to attend a CTC for its FY16 ECT, the 712th ESC Commander expressed a willingness to support two x platoon level rotations if a company level rotation was unavailable. Between the lack of support from Higher Headquarters in coordinating the event and demand placed on the staff of the 712th to coordinate with two separate Active Duty Brigades, this is an untenable approach to ECT tasking for a company. As the commander, I highly discourage placing this burden on a Reserve company in the future.

c. Recommendation: Do not task a company to support two platoon sized CTC rotations in the same FY.

#### 9. Discussion Point 8:

a. Issue: Zero coordination occurred between the 926th EN BDE and Operations Group or DPW on Fort Polk, LA to find horizontal construction missions for the platoon after the defense concluded.

b. Discussion: A key part of attending ECT is providing an opportunity for specialty MOS SM to execute tasks in their MOS. For a unit comprised of 12N Earthmoving Equipment operators this means executing horizontal construction projects. During a CTC, the horizontal asset demand diminishes upon the conclusion of the defense, which concludes after training day 7 or 8. To maximize training value for a CTC rotation, secondary missions must be coordinated for between the BDE and the base. The Commander of 712th coordinated with Operations Group, Fort Polk, LA to procure a Forward Landing Strip construction mission. A similar coordination could have easily occurred between the owning BDE and the installation. Additionally minimal sustainment support was provided once the unit broke away from the RTU's training mission to execute construction. This could possibly have been avoided if the BDE coordinated for mandatory sustainment support from the RTU or the installation. The 712th Commander coordinated for support from the RTU and Brigade Engineer Battalion (BEB); however, that coordination fell through because of the BEB's more pressing priorities during the Offense.

c. Recommendation: When tasked to support a CTC ensure units with specialized MOS base (horizontal, ESC, or vertical) have additional construction missions coordinated to maximize training on

the ground. Coordination must include sustainment support. For example Fort Polk, LA had a Unmanned Aerial System Forward Landing Strip construction mission available at Drop Zone Berry.

#### 10. Discussion Point 9:

a. Issue: No sustainment support was provided to the Company by Fort Polk, LA based entities such as ECS-17 or nearby reserve units.

b. Discussion: When tasked with supporting two platoon sized CTC rotations that occurred in April and May 2016, the 712th decided to send one set out equipment that could be used for both rotations. The 712th coordinated with ECS-17 and the RTU for sustainment support in the event equipment was broken or damaged. Each rotation was augmented with a two to four SM maintenance section to facilitate basic repairs. During Rotation 16-06, the unit had a scraper (613B) go down due to a dry-rotted hydraulic hose. A grader went down due to a dry rotted O-ring on the blade's hydraulic line. A T5 went down due to an issue with the tracks. Of note all these pieces of equipment are stored at ECS sites in South Carolina and North Carolina. The SMs on the ground generated 2404s that they submitted to the 712th who then reached out to the Rotation 16-07 RTU and ECS-17 for maintenance support to fix this equipment. Rotation 16-07 platoon received zero support from either entity. This degraded the platoon's equipment operational readiness posture for the defense and later work on the FLS.

c. Recommendation: When tasking a Company to provide a platoon sized element as RTU augmentees develop a method for holding the RTU accountable for providing maintenance support. If possible reach out to the ECS on site or a nearby reserve unit and ensure they are provided with a line of accounting/funding code that makes them more likely to provide maintenance support for a training unit.

#### 11. Discussion Point 10:

a. Issue: The 712th ESC went from Training Readiness 02 status to deploying ISO a CTC Rotation without a sufficient amount of time for an effective train-up.

b. Discussion: At the FY16 Yearly Training Brief Conference (YTB occurred three months before I assumed command), I pushed BDE to provide my company the opportunity to deploy to a CTC for an ECT. 712th ESC was notified of being selected for two platoon sized CTC rotations seven months prior to execution. This is not a sufficient period of time to effectively prepare a unit for a CTC Rotation regardless of the ambition of an incoming Company Commander. Training for this event was constrained by other administrative readiness factors to include: Medical, administrative readiness, Individual Weapons Qualification, and mandatory training. An effective train-up should have included an ECT that allowed the unit to focus on Engineer specific tasks that will be performed during a Decisive Action Training Environment (DATE) scenario. For an ESC this includes Survivability tasks of laid out in ATP 3-37.34 Survivability Operations, Mobility tasks (non-explosive obstacle breaching and route sanitation), and Counter-Mobility tasks (Berm and Anti-Tank Ditch Construction). The company was unable to conduct any equipment training under NVGs due to a schedule conflict at a dig location on FT Jackson and lack of NVG Bracket Plates to mount the NVG to the ACH. The skull crusher included in the NVG COEI is made for the Kevlar not the ACH. The short preparation cycle prevented the company from conducting an M2 .50 cal range prior to deployment. This prevented the company from sending anything larger than a M249 to with the platoon deploying to the CTC, which in turn prevented them from being able to move about the battle field autonomously.

c. Recommendation: A unit selected for a CTC deployment must be provided a minimum of 18 months prior notice to adjust its training schedule to accommodate training requirements.

## 12. Discussion Point 11:

a. Issue: ECS equipment coordinated for draw ISO training was either not available or non-mission capable (NMC).

b. Discussion: The 712th coordinated for nine pieces of equipment from ECS-17 on Fort Polk, LA. When the ADVON arrived for Rotation 16-06 it was discovered that the Water Buffalo and 2 x M172 trailers were NMC. The 6 x SINCGARs, 2 x M1165s, and 2 x Cargo Trailers were not available. The company was able to procure these items from the PREPO yard, but the platoon would have been without transportation and water had those items been unavailable. Additionally this caused the company to execute a last minute coordination to CBL 2 x M172 trailers from ECS-125 Fort Bragg, NC. The trailers arrived in time to support the platoon attending Rotation 16-07. However, this meant Rotation 16-06 was forced to rely on the RTU for equipment moving support instead of having enough organic assets to move its own equipment.

c. Recommendation: In addition to holding an ECS accountable for failure to provide support, provide/coordinate for funding to allow a unit to bring a baseline of equipment from home-station to support its mission.

## 13. Discussion Point 12:

a. Issue: Understanding Mayor Cell requirements for reserving billeting was unknown until arrival.

b. Discussion: The unit could not reserve billeting until a roster with all personnel and their sensitive items on it was provided to the Mayor Cell. 712th had this information on separate documents, which created a problem of finding a venue to compile it onto one document to procure billeting upon arrival. Knowing the format prior to arrival would have save time during execution because automation access was limited at Fort Polk.

c. Recommendation: Find out who the POC is for the CTC Mayor Cell to ensure all billeting requirements are outlined for the training unit a minimum of 30 days in advance.

14. Point of contact for this memorandum is CPT Jacob Randles 803.684.6048.

--Original Signed--

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