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Alternative Troop Labor Construction

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Abstract: Current troop labor construction methods can be improved through the implementation of a new system. The USASOC SOTF Task Force identified this gap and proposed a potential solution to the problem that they believe the Army Engineer Regiment could benefit from. The proposed system for implementation is the FrameCAD machine, a cold-formed steel system with automated design features and software capabilities. The purpose of this capstone is to build a case study for FrameCAD to provide for the USASOC SOTF Task Force so they can make informed decisions and potentially utilize the findings in their pitch to the Engineer Regiment. The capstone leveraged both qualitative and quantitative analysis using the DOTMLPF model, value-modeling, and cost analysis to assess the implementation of the FrameCAD system.

Keywords: FrameCAD, DOTMLPF, USASOC, Engineer Regiment

1. Introduction

Currently, the United States Army finds itself in a multitude of new combat environments, and this has shifted the needs of the Army. The Engineer Regiment, acting as the shaping operation for all major US Army missions, has been tasked with remaining up to date on completing this task. Currently, the US Army Corps of Engineers creates structures in and out of theater through Premade structures, transporting essential building equipment, and outfitting previously built structures. Oftentimes the Engineer Regiment struggles to effectively balance scope, schedule, and cost, inhibiting mission success. While looking into alternative troop labor construction methods, members of SOTF Task Force began looking into FrameCAD, a system which effectively shapes cold-formed steel to exact building requirements input by the user. The FrameCAD system has many complexities yet could fulfill the Engineer Regiments requirements for a solution. Our capstone aimed to uncover the complexities of this system and create a business model to propose to the Engineer Regiment and US Army. This model will utilize DOTMLPF, value scoring, and cost analysis, each providing a unique perspective that will lead to the acceptance or denial of this system.

2. Methodology and Model

2.1 Qualitative Analysis

The US Army DOTMLPF model is an acquisition framework created by the Joint Capabilities Integration and Development System and commonly used in the United States Armed Forces which determines how acceptable, suitable, and feasible a proposed force design change is. The DOTMLPF model consists of Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities. While many of these parts are consistent with the implementation of some systems in the US Army, others were less applicable to this project and therefore omitted and replaced with Interoperability and Risk Management. With the US Army being a multifaceted organization, investigating the interoperability of the FrameCAD system within the Engineer Regiment as well as other combat arms branches and maintenance and logistical support units was crucial.

2.2 Quantitative Analysis

To capture the economic impact of the implementation of FrameCAD systems, the authors constructed a quantitative model that compares the FrameCAD system to another construction alternative, Pre-Engineered Buildings (PEBs). The authors built a cost model for both alternatives to assess the life-cycle costs of each. In addition to the cost model, the authors created a value model which relies on value-focused thinking to determine the worth, from the perspective of the stakeholders, of each system. The value model allows the decision maker to understand the value, not necessarily in terms of monetary value, that one alternative may provide. By including a quantitative approach detailing monetary costs in addition to the assessed value, a decision maker can assess the cost-benefit ratio associated with an alternative and choose the one most tailored to their values.

The authors aimed to construct a holistic cost model that captured the first and second-order costs associated with the implementation of one FrameCAD system building one 80 ft x 30 ft x 8 ft barracks in a one-year timespan. The purpose of constructing it this way was to allow for ease of understanding and provide a comparison between the two alternatives in a standardized scenario. However, the model can be amended to reflect more frequent building over a longer duration to produce a more realistic dollar amount. The costs included in the model were acquisition costs, operating costs, transportation costs, and implementation costs. The acquisition cost is simply the cost of acquiring the system itself. The FrameCAD model in consideration is the F325iT with the mobile factory. The operating costs included costs such as those for materials and electricity. The transportation costs were based on weight and included costs such as those for fuel. Lastly, the implementation costs consider the cost of training personnel to operate the system.

To create an accurate value model, it was vital that the authors had input from the stakeholders. In collaboration with the USASOC SOTF Task Force, eight value measures were identified as important. The identified value measures include speed of construction, material availability, skills requirement, versatility, waste factor, ease of storage, labor, and mobility. Clear definitions of each value measure were developed to ensure consistency and units were assigned for each. Some value measures' units were purely objective such as the number of days or personnel while others were scored subjectively based on a rating on a scale from 1-10. Once the value measures were identified, the USASOC SOTF Task Force assisted us in assigning weights to each value measure based on their experiences and expertise (MSG M. Ueltzen, personal communication, 2022). Figure 1 defines each value measure used in the model and displays the ratings assigned for each.

Speed of Construction (Days)	Mean	SD
FRAMECAD	20.5	2
PEB	26.0924	2.6092

Speed of Construction is the number of days it takes to build the framing of a 80 x 30 x 8 ft barracks building given a material.

Ease of Storage	Rating
FRAMECAD	10
PEB	5

Ease of storage rates, as from the perspective of stakeholders familiar with the alternatives, the ability to store materials and inventory.

Versatility	Rating
FRAMECAD	10
PEB	8

Versatility is material's ability to be used in many different kinds of structures and designs. The higher the rating, the more versatile the material is.

Material Availability	Rating
FRAMECAD	10
PEB	4

Material Availability is a rating of the speed of which materials can be transported to a job site from their point of origin. The higher the rating, the greater the material's availability.

Labor	Number
FRAMECAD	8
PEB	12

Size of Crew is the number of workers needed to build the framing of a 80 x 30 x 8 ft barracks building given a material.

Mobility	Rating
FRAMECAD	10
PEB	5

Mobility is the material's ability to be transported from one site to another. The higher the rating, the more mobile the material is.

Skills Requirement	Personnel
FRAMECAD	4
PEB	8

Skills Requirement is a rating of the amount of skilled laborers required on-site to complete a project given a material. The higher the rating, the greater number of skilled laborers required.

Waste Factor (%)	Most Likely	Low	High
FRAMECAD			
PEB	5	3	10

Waste Factor is the amount of material left over upon the completion of a project, expressed as a percentage of the amount of material ordered.

Figure 1. Definitions of and Ratings for Value Measures

3. Analysis and Results

3.1 DOTMLPF

3.1.1 Facilities

The FrameCAD system will be utilized both in garrison and OCONUS locations. A tour of OffsiteK's facility, a civilian construction company that currently uses FrameCAD in Charlotte, North Carolina shed light on the type of building that would provide an optimal amount of space, layout, and accessibility in garrison. OffsiteK used a large warehouse containing the FrameCAD machine while providing additional space for storage of supplies, such as rolls of cold-formed steel, and areas for the assembly of frames. A large, warehouse-style building with oversized entryways would allow for easy transportation of the FrameCAD machinery and any of its products in and out of the building. However, the Mobile Factory provides climate-controlled housing if necessary. In a deployed environment, the Mobile Factory will be essential as the 40-

foot shipping container can travel anywhere by semitruck and provide a self-contained steel frame production facility (FrameCAD, 2017). This system can become fully operational within 24 hours of placement (FrameCAD, 2017).

3.1.2 Interoperability

Although not organic to the DOTMLPF model, assessment of interoperability ensures that the decision maker considering the systems acquisition has a broader depth of information. The authors focused on the interoperability between the Engineer Regiment and other units organic to US Army Brigade Combat Teams and similar Department of Defense (DoD) units, Red Horse (USAF), and Seabees (USN). To achieve this, the system must deploy interoperable systems, noting that "joint concepts, standardization, and integrated architectures will be used to the maximum extent possible to characterize the exchange of data, information, materiel, and services to and from systems, units, and platforms to assure all systems effectively and securely interoperate" (Office of the Under Secretary of Defense for Acquisition and Sustainment (OUSD(A&S)), 2020). The most applicable interoperability focus for the FrameCAD system will enable all branches of the United States Military and US Army to share resources, leading to decreased project costs, project overlap, project time, and effort. This can be done in both Garrison and training or deployed environments, as the Engineer Regiment is responsible for both combat and construction projects associated with brigade and division level assets.

3.1.3 Risks

The authors conducted an initial risk assessment for implementing FrameCAD and determined the most important risks are as follows: communication, environment, and budgeting. In accordance with the US Army Risk assessment matrix and process, the authors attributed likelihood and severity to each of the risks listed above. Budget, being frequent in probability and catastrophic in severity as project budgeting is an essential piece to implementing and maintaining the FrameCAD system. DOD and US Army budgeting restrictions are often a product of national debt, inflation, and congressional allocations, which have been known to fluctuate from year to year. The authors assessed communication risks as very frequent and critical in severity, as communication is essential to all actions and parts surrounding the FrameCAD system's implementation, use, transportation, and maintenance. Although most communication risks and errors can be negligible in their severity, constant miscommunication can cause significant issues regarding the project throughout its life. Environmental risks, as the authors assessed them, are a product of the placement of the unit. These locations being Garrison and training/deployed environments. It is also reasonable to assume that adverse weather conditions and terrain will pose major threats to the system's use. Likely probability and critical severity classify this as an extremely substantial risk. Some of these environments being tropical, desert, and tundra. Tropical environments are likely to disrupt electronics and begin rapid deterioration of the steel products produced. Extreme cold temperatures affect battery life and the production of materials, as tests and manufacturing have only occurred in ambient temperatures of 0-40 degrees. Desert sands and winds erode products as well as the system itself. All environments outside of garrison are catalysts for the destruction of this system and its products.

3.1.4 Personnel & Training

The FrameCAD system is a reliable system that can be implemented to help support the Army's operations. Depending on the amount of labor it takes to operate this new system, the army will have to evaluate the number of soldiers in the Echelon Above Brigade (EAB). The construction company within an EAB is organized into a company headquarters, two general construction platoons, a horizontal construction platoon and a maintenance section. With the implementation of FrameCAD, the engineer unit could keep the same structure with two general platoons to support the system with a construction and maintenance section. The FrameCAD system personnel could change whether the system is operating in a combat zone since this can change the training requirements of the soldiers that reinforce the system. In the future, FrameCAD is planning to extend its capabilities by adapting to the vertical and horizontal constraints of the specific project and site. These latest changes could potentially change the Army's perspective on alternative troop labor construction which could reduce the number of soldiers the army puts down range.

The Army has effective training methods in place currently; however, implementation of FrameCAD will require changes to the training program for Engineer soldiers, both enlisted personnel and officers, with assistance from civilian contractors. The FrameCAD system is an advanced construction technology and has many applications. The integration of the FrameCAD system may cause changes and additions to Army doctrine and tech manuals that must be overseen and approved by TRADOC to be implemented. Prior to training members of the Engineering Regiment, civilian contractors from FrameCAD would create a program that follows the "train the trainer" framework. Warrant officers can complete the required courses to effectively control and operate the FrameCAD system where they can be the experts on the system for their units. The FrameCAD system uses world-leading technology and manufacturing equipment, meaning there will be training for the operation of the system and on its maintenance. Maintenance of the FrameCAD system is extremely important as it can extend the lifespan of the system and prevent unplanned downtime that could disrupt the manufacturing process. Having soldiers trained in the maintenance of the FrameCAD system can continue to run without interruption to ensure that projects get completed on time. Therefore, during the training process key leaders and soldiers will also need to specialize in the maintenance of the FrameCAD system to quickly troubleshoot and resolve issues that may cause interruption of the system. Utilizing the 120A Construction and Facilities Engineers can be a major part of training and operating FrameCAD in the Engineer Regiment. The FrameCAD system helps deliver steel, however, machinery to reinforce a construction project such as forklifts, cranes, or transportation will be needed to support the system. Due to this, the addition of the FrameCAD system may also build on the doctrine and training manuals of Army Engineers and other MOS working alongside the system. Being aware of the FrameCAD system can be helpful for others when functioning in their occupation although they are not directly operating the system.

3.1.5 Doctrine

USACE has been utilizing a Computer-Aided Design and Drafting (CADD) system for almost thirty years, with multiple platforms compatibility (U.S. Army Corps of Engineers, 1994). The Army acknowledges the potential of cost reductions and shorter design schedules while increasing design productivity and overall product quality (U.S. Army Corps of Engineers, 1994). However, the SOTF Task Force has argued that cost is not always the driving factor in their decision making. USACE doctrine needs to reflect this and establish new guidance as to what the most key factor should be given a variety of circumstances. FRAMECAD has a higher lifecycle cost than other alternatives due to the acquisition cost of the machine and other required equipment. The USACE Center of Standardization (COS) is responsible for the development of Army specifications and standard designs (U.S. Department of the Army, 2009). The USACE COS ensures that project standard designs meet the functional requirements and are consistently applied in construction projects by all USACE geographic districts (U.S. Department of the Army, 2009). These designs are housed in an online database, the Joint Construction Management System (JCMS). Units can pull these designs from JCMS and build them without needing technical engineers to review or validate the designs beforehand, expediting completion of the project. FRAMECAD has their own software suite, which allows users to design structures to later be manufactured by the machine. This software does not allow the operator to manufacture a design unless the software first proves it to be structurally sound. Utilizing this software would eliminate the need for the COS to develop and approve each design that a unit wants to build and upload it to JCMS, which can take upward of nine months for a single design. The COS should change its doctrine to allow units to design and build their own facilities using this software, rather than requiring the use of JCMS designs. This would allow for a much easier integration with the Army Engineer Regiment.

3.1.6 Materiel

The FRAMECAD machine is the primary piece of equipment used in the manufacturing process. The SOTF Task Force has identified the F325iT machine as the optimal system for the Engineer Regiment's needs, as it allows the user to accomplish basic and simple tasks without being too specialized (“FRAMECAD F325iT,” 2020). The machine is used with a Mobile Factory, a steel container that houses it and necessary tools for operating (“FRAMECAD Mobile Factory,” 2017). The main raw material used is 0.95 BMT x 185mm cold-formed steel. The Army Engineer Regiment has yet to adopt alternative methods of troop labor construction, but Air Force Rapid Engineer Deployable Heavy Operational Repair Squadron Engineer (RED HORSE) squadrons have been testing and implementing cold-formed steel (CFS) manufacturing systems for five years. They have gathered information on the extraneous equipment and material necessary to properly utilize FRAMECAD, such as a "T-Rex" crane, concrete pad, plywood sheeting, roof and siding panel machine, aluminum or steel exterior walls, electrical wiring, lights, doors, drywall, HVAC, insulation, and plumbing fixtures (Speck, 2018). The largest benefit of FrameCAD in terms of material is that it removes supply chain delays (Speck, 2018).

3.2 Cost Model

The FrameCAD data used in this cost model was provided by OffsiteK, a manufacturing prefabrication company that utilizes FrameCAD, while the authors obtained the PEB data from USASOC SOTF Task Force building plans and JCMS (D. Morgan, personal communication, July 7, 2022). Table 1 below shows the cost to construct a single 80 ft x 30 ft x 8 ft barracks building for each alternative. The cost model found that the acquisition cost of a single FrameCAD machine and Mobile Factory, to include delivery, is $395,923. However, FrameCAD was willing to offer a military discount of $66,734, resulting in an overall acquisition cost of $329,189. There is no acquisition cost for PEBs since this alternative has already been implemented.

The operating cost for the FrameCAD system is $20,797 compared to $17,948 for PEBs. While the steel cost is over fifty percent lower for FrameCAD, the annual costs for software and service visits quickly make up the cost that was saved with the cold-rolled steel. The transportation cost is directly proportional to the weight of the materials being delivered. FrameCAD required 12,403 pounds of cold-rolled steel for a single barracks building, while PEBs required 9,332 pounds of steel. Therefore, the transportation cost was about twenty-five percent higher for FrameCAD compared to PEBs. Lastly, FrameCAD has an associated training cost required for the full implementation of the system. This cost encompasses the price for a FrameCAD technician to travel to Ft. Leonard Wood, Missouri and spend 48 hours training 120A personnel at the Army Engineer School on how to use the system.

Overall, the total cost for one FrameCAD system, the F325iT and the Mobile Factory, to build a single barracks building in a single year is $370,630, compared to a cost of $30,546 dollars to construct an identical PEB. While this seems like a great discrepancy, FrameCAD can overtake PEBs as the least expensive system depending on the number of machines acquired, the number of buildings being constructed, and the number of years over which these buildings are constructed. This is due to the money saved with lower steel costs for FrameCAD. Based on our recommendation that FrameCAD be implemented at the EAB level and the ten-year service life of a FrameCAD machine, the authors modeled how many buildings per year, for ten consecutive years, each FrameCAD system would have to build to have a cost equal to that of PEBs. Our cost model found that twelve FrameCAD machines would have to build ten buildings per year, which is a realistic tempo for a vertical construction platoon, for ten years to be more cost-efficient than constructing with PEBs. Table 2 below shows the total cost to build ten buildings per year for ten years for each alternative.

Table 1. Baseline Cost Model (Single Building in a Single Year)

Acquisition Cost		
	FrameCAD	**PEBs**
Acquisition Cost	**$329,189.00**	**$0.00**
Machine	$282,150.00	$0.00
Mobile Factory	$101,773.00	$0.00
Delivery	$12,000.00	$0.00
Military Discount	-$66,734.00	$0.00

Building Cost		
	FrameCAD	**PEBs**
Total Annual Cost	**$41,441.15**	**$30,545.53**
Operating Cost	$20,796.83	$17,948.00
Transportation Cost	$16,744.32	$12,597.53
Implementation Cost	$5,000.00	$0.00
Military Discount	-$1,100.00	$0.00
Total Cost	$370,630.15	$30,545.53

Table 2. Goal-Seeking Cost Model (Multiple Buildings over Multiple Years)

Inputs	
Number of Desired Machines	12
Number of Desired Buildings	1200
Number of Years	10

	FrameCAD	**PEBs**
Total Cost	$36,651,070.67	$36,654,630.00

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4. Conclusion

After assessing the implementation of the FrameCAD system into the Army Engineer Regiment through the DOTMLPF framework, the authors identified strategies to allow for its optimal utilization. Coupling the FrameCAD 325iT machine with the Mobile Factory would allow the system to operate as a self-contained production facility. The authors also recommend that the system be integrated into one vertical construction platoon within the existing EAB construction company structure, and for 120A Construction and Facilities Engineers to assume the role of FrameCAD operator trainers at the Engineer School. Lastly, validating the FrameCAD design software would eliminate the need to send each design through the USACE COS to be uploaded onto JCMS, increasing both cost and schedule efficiency.

The value model showed that FrameCAD scores higher than PEB for each value measure considered, which demonstrates the benefit that this system provides to Army construction units. The cost-analysis revealed that the FrameCAD system has a much higher life cycle cost compared to PEBs because of the acquisition cost of the machine. However, because the acquisition cost is only incurred every ten years and FrameCAD has a lower material cost, there is potential for FrameCAD to be as cost-efficient as PEBs depending on the frequency of its use. Implementing the FrameCAD system would require a significant investment; however, the value added as a result is significant enough that it should be considered a viable alternative to PEBs.

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