Proceedings of the 2020 Annual General Donald R. Keith Memorial Capstone Conference
West Point, New York, USA
April 30, 2020
A Regional Conference of the Society for Industrial and Systems Engineering

82nd Airborne Division Soldier Fatigue Solution Design

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Abstract: Soldiers assigned to the 82nd Airborne Division specialize in performing parachute operations. To ensure success upon hitting the ground, Paratroopers exit the aircraft with all the equipment they need to fight and win. Often, this equipment can weigh more than 200 pounds. This weight, combined with hours of mission preparation, puts Paratroopers under an immense amount of physical and mental stress. This paper addresses how to reduce the physical toll that Paratroopers incur when conducting airborne operations. Specifically, the walk Paratroopers take from the parachute harness (PAX) shed to their awaiting aircraft. By developing a solution to transport Paratroopers from the PAX shed to the aircraft, the airborne timeline can be reduced, and Paratroopers will be more ready to fight and win when they hit the ground. This project was approached through the Systems Decision Process (SDP) which is a methodology used to define problems, design solutions, and recommend decisions.

Keywords: Parachute Harness Shed (PAX shed), Systems Design Process (SDP), Airborne (ABN), Immediate Response Force (IRF), Paratrooper, chalk (group of Paratroopers)

1. Background

A key component of the 82nd Airborne Division's mission is to maintain the immediate response force (IRF). At all times, a Brigade (4,000+) of airborne-qualified soldiers (Paratroopers) is kept ready to rapidly deploy in response to any national need. Paratroopers are a key part of the IRF, but rapidly organizing, outfitting, and loading a large number of troops onto waiting aircraft is a significant challenge (Pernin et al., 2016). Paratrooper fatigue exacerbates this already difficult process and can be detrimental to their effectiveness once they begin their mission. The problem of Paratrooper fatigue stems, in part, from the physical load placed on the Paratroopers as they conduct their movement to the aircraft during the final phase of the deployment timeline. This problem was identified by senior leaders at the 82nd Airborne but was left largely untreated due to a lack of a viable solution. This project identified that a vehicle capable of transporting Paratroopers from the PAX shed to the aircraft they would deploy on was the most viable option to reduce Paratrooper fatigue and lower the amount of time it takes Paratroopers to load an aircraft. The methodology construct used to analyze this problem was the Systems Decision Process (SDP). The first step in the SDP-structured analysis is problem definition, which is driven by stakeholder analysis, research, and functional requirements analysis. The second step is solution design, which resulted in four different alternatives that met the functional requirements and stakeholder needs (Henderson et al., 2011). In the final step the solutions were presented to the 82nd Airborne Division Engineer along with respective values, costs, and trade-off analysis.

This paper is submitted as part of the systems Engineering Honors Program

2. Methodology

2.1 Analysis Assumptions

2.1.1 Solution Design Assumptions

The Paratrooper planning weight was determined to be 380lb. Towing capacity for each prime mover was taken from manufacturer specifications (NMC Wollard, n.d.). Trailer weight was taken from manufacturer specifications (BigTex Trailers, 2020). Turn radius was estimated using known values from a 40-foot truck trailer. Each Paratrooper was assumed to take up two feet of trailer length per side of the trailer.

2.1.2 Cost Analysis Assumptions

The prime mover cost was determined from off-the-shelf market values (Eagle Tugs, 2020). Modifications to the payload such as seats and supports were determined from estimated material costs, labor costs, and the length of the trailer. Lifecycle costs were calculated using a one-time maintenance cost at year five equal to 25% of the initial cost, and a disposal cost at year 10 equal to 15% of the initial cost. Life cycle costs were converted to present value assuming an 8% interest rate.

2.2 Stakeholder Analysis

Stakeholders interviewed included the division engineer and his staff, civilian contractors who manage logistical processes at the Arrival/Departure Airfield Control Group (A/DACG), and the 82nd Airborne Advanced Airborne School leadership. The key recommendations taken from these interviews are shown below (Table 1).

Table 1. Recommendations Matrix

Stakeholder	**Mr. Steve Wykel (A/DACG)**	**Advanced Airborne School Leadership**	**82nd Airborne Division Engineer**
Key Recommendation	Solution should have minimal impact on the existing IRF loadout procedure.	Solution is ergonomic to fully loaded paratroopers, and operates efficiently to allow for a reduced airborne timeline.	Solution prioritizes simplicity, flexibility, and scalability proof of concept.

Conversations with stakeholders made it clear that there has been significant thought put into the problem of Paratrooper fatigue. Possible solutions ranged from wheeled benches that could be towed from the PAX shed, to people-mover carts often found at airports and amusement parks, to reevaluating the entire process in how Paratroopers load the aircraft. A group of stakeholders also seemed to doubt the nature of the problem in general and offered that Paratroopers should just "tough it out" and that increasing the fitness of Paratroopers would reduce the impact of the movement to the aircraft. After many conversations and careful thought, however, it was determined that the client most desired a solution that involves some sort of a vehicle and personnel-carrying payload that can move Paratroopers to the aircraft, thereby reducing the physical stress endured by walking out to an aircraft.

2.3 Functional Analysis

From the stakeholder interviews and through iterative functional requirements analysis, the fundamental objective was determined: "Provide a transport solution to reduce Paratrooper fatigue." Key functions, objectives, and value measures that describe what the new system should achieve were defined and organized in the value hierarchy (Figure 1).

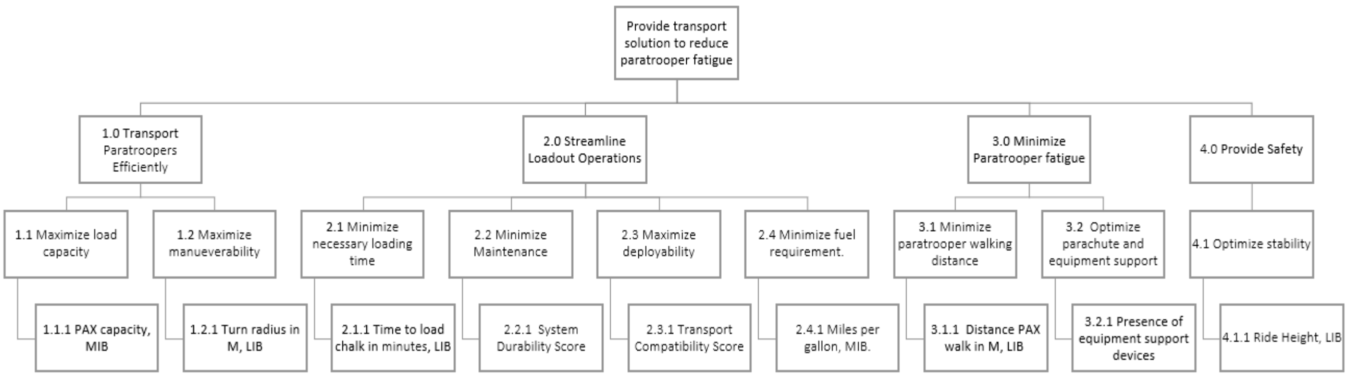

Figure 1. Value Hierarchy

Through conversations with key stakeholders and subject matter experts at the 82nd Airborne, the desired high-level functions were identified to be: 1. Transport Paratroopers efficiently, 2. Streamline Loadout Operations, 3. Minimize Paratrooper Fatigue, 4. Provide Safety. These four key functions were chosen because they address the key issues of walking-induced fatigue and inefficiency in the Paratrooper loading process. These four functions drove the creation of the design objectives, each with a corresponding value measure that allowed for measurement and scoring. These value measures ultimately drive how each alternative would be quantitatively scored based on what was important to the stakeholders and shaped the development of the solution designs.

2.4 Value Modeling

After final approval from the 82nd Airborne Division Engineer, the value measures were modeled using value functions. Minimum, maximum, and ideal values were determined by the Division Engineer and his staff. All value functions were subject to final approval before being used to evaluate each solution design. After each value measure was defined by its respective function, they were rank-weighted using a swing-weight matrix. The value measure with the highest importance and highest variability— "Time to load chalk onto an aircraft"—was given the highest swing weight of 100. The remaining value measures received a swing weight on a scale of 100 to 0, corresponding to their respective importance and variability. The value measure 3.2.1 ("presence of equipment supports") was not included because it was deemed essential and was included in every solution design. The final swing weight matrix, which was approved by the Division Engineer, is seen in Table 2.

Table 2. Swing Weight Matrix

		Level of Importance		
		High	Moderate	Low
Level of Variation	High	Time to Load Chalk (100)	Pax Capacity (80)	Miles per Gallon (40)
	Moderate	Distance Pax walk (90)	System Durability (70)	Ride Height (20)
	Low	Transport Compatibility (60)	Turn Radius (50)	

To determine each value measure's relative importance, each swing weight (number in parenthesis in Table 2) was converted to a global weight by dividing it by the sum of the swing weights (normalization). These numbers were used to convert each solution's "raw data score" in each value measure category to a total value score that represents how well the solution met the needs, wants, and desires of the 82nd Airborne. "Time to load chalk onto an aircraft" had the highest global weight of .2, or 20%. This means that when evaluating each candidate solution, a maximum of 20% of the overall score the solution receives is based on "Time to load chalk onto an aircraft." This reflects the importance that the 82nd Airborne Division placed on loading airplanes quickly, getting at the root cause of Paratrooper fatigue. The value measures, their corresponding swing and global weights, and minimum/maximum values are located in Table 3.

Table 3. Value Measure Comparison

Value Measure	Swing Weight	Global Weight	Minimum/Maximum Acceptable Value	Ideal
Time to Load Chalk into Aircraft	100	0.20	16 minutes	10 minutes
Distance Pax walk	90	0.18	400 meters	0 meters
PAX Capacity	80	0.16	35	104
System Durability	70	0.14	1	5
Transport Compatibility	60	0.12	1	5
Turn Radius	50	0.10	30 meters	1 meter
Miles per Gallon	40	0.08	2	50
Ride Height	20	0.04	48 inches	6

2.5 Solution Design

Four candidate solutions were created to represent a wide range of feasible solutions: “Budget,” “General-Purpose Diesel,” “Specialized,” and “General-Purpose Electric.” Each was created with a specific goal in mind and has a unique combination of design parameters. These parameters were developed through research of existing transportation solutions and conversations with stakeholders. Ultimately, all alternatives utilize some configuration of a vehicle (prime mover) and a payload designed to carry the Paratroopers. A detailed view of each solution design is shown in Table 4.

Table 4. Design Alternatives and Parameters

Design Alternatives								
	Vehicle Type	**PAX Payload Type**	**Personnel Capacity**	**Powertrain**	**Seat Type**	**Parachute/Ruck Support**	**Safety Features**	**Total weight**
Budget	HMMWV	12' Flat-bed trailer	8	Diesel	Wooden seat	Parachute=integrated, Ruck=removable	Troop strap	4340 lb
General-purpose Diesel	MB4 Tow Tractor	24' Flat-bed trailer	24	Diesel	Aluminum seat	Parachute=integrated, Ruck=removable	Troop strap	13,120 lb
General-purpose Electric	Eagle RTT-50 Tug	36' flat-bed trailer	36	Electric	Aluminum seat	Parachute=integrated, Ruck=removable	Troop strap	20,180 lb
Specialized	Eagle USATS-6 Tug	(2x) 36' flat-bed trailer	71	Diesel	Canvas web seat	Parachute=integrated, Ruck=integrated	Grab handle & Troop strap	44,980 lb

The most important parameters defining each solution were the prime mover (vehicle type in Table 4) and PAX payload type because these two parameters were responsible for a large portion of the variation between solution designs. All solution designs used a flatbed trailer payload modified to carry Paratroopers with seating, ruck and parachute supports, and safety devices. This was determined to be the most efficient and feasible way to carry the up-to 104 combat-equipped Paratroopers to each aircraft (Bolkcom, 2007). Other key parameters for each design were the payload capacity, which was limited by the trailer length, and the type of prime mover. As each paratrooper can be assumed to weigh 380lb fully equipped, the gross weight of the payload became a limiting factor during the alternative generation. Three of the four solutions were designed to use aircraft tugs for prime movers, which were identified for their superior towing capacity. The fourth utilized a High Mobility Multi-Purpose Wheeled Vehicle (HMMWV), which is a vehicle in widespread use across the army. The use of different types of prime movers along with different payload lengths gave the stakeholder an idea of the range of solutions that existed within the design trade space. Representing the extreme ends of the range of designs, the "Budget" solution utilized a HMMWV and 12' trailer to maximize maneuverability and minimize cost, while the "Specialized" solution sought to maximize payload capacity and chalk loading speed by utilizing an electric aircraft tug and two 36' trailers. The two other solutions fell in-between the extremes represented by these two designs and sought to balance maneuverability and payload capacity in different ways.

2.6 Value Scoring and Costing

After defining weights, value functions, and numerical scores for each solution, the candidate solutions were evaluated by comparing their total value scores, estimated cost, and feasibility. Raw data for each solution was generated from market research and, when necessary, estimated. Value scores were determined using the value functions and were converted into weighted value scores by multiplying the value score for each measure by its corresponding global weight. The sum of the weighted value scores gave a total value score that represents how well the solution met the priorities of the stakeholder. A breakdown of the total value score for each solution along with the improved and ideal scores can be referenced in Figure 2.

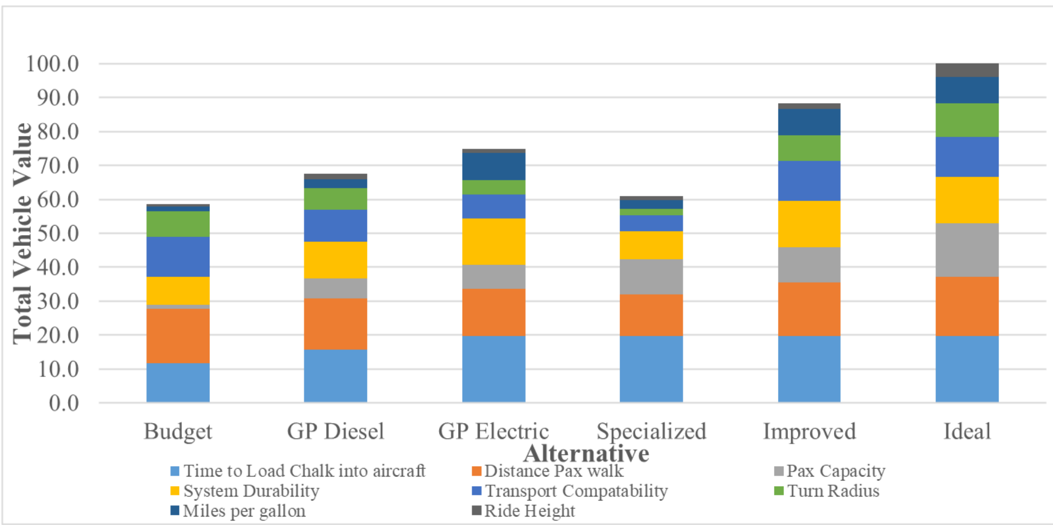

Figure 2. Value Stacked Bar Chart

The "General-Purpose Electric" design provided the highest value score, while the "Budget" design provided the lowest. The high overall score of the "GP Electric" design can be attributed to its high score in the "System durability" "Miles per gallon" and "Time to load chalk into aircraft" value measures. This design performed well in these value measures due to its use of an efficient and robust electric tug as the prime mover, and its ability to load the aircraft quickly by carrying 36 paratroopers at one time. The "Budget" design performed well across many value measures but suffered in the "Time to load chalk into aircraft" value measure due to its small 8-paratrooper capacity, and the reduced durability of the HMMWV used as the prime mover. Ultimately, the "General-Purpose Electric" solution provided the highest overall value score which shows that it best met the desires of the stakeholder.

Following the value scoring, a conservative 10-year lifecycle cost was estimated for each candidate solution and was used in the cost versus value analysis which can be referenced in Figure 3. From this analysis it was determined that the "Specialized" design was dominated by "General-Purpose Electric", meaning the "General-Purpose Electric" solution provided more value at a lower cost. It is also evident that the "Budget" design provided the most value per dollar spent, indicating that the "Budget" solution may have value as a low-risk proof of concept design that could be implemented with little cost. However, the "General-Purpose Electric" solution provides the best performance across the stakeholder-defined values and was less expensive than the "Specialized" solution, making it the recommended alternative. Additionally, system cost was not a critical factor defined by the stakeholder, who was more concerned with overall quality and performance than cost. A breakdown of

ISBN: 97819384961-8-9

each solution's total value score and 10-year life cycle cost can be referenced in Table 5. Assumptions made for the 10-year life cycle cost can be referenced in section 2.1.

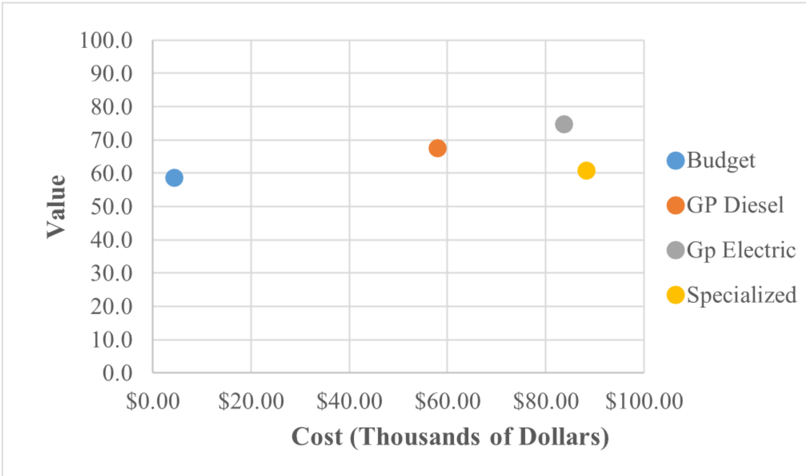

Figure 3. Cost versus Value Chart

Table 5. Cost vs. Value Breakdown

Cost and Value Analysis		
	Life Cycle Cost	**Total Value Score**
Budget	$4,314.69	58.6
GP Diesel	$57,894.19	67.6
Specialized	$88,225.84	60.8
GP Electric	$83,717.95	74.7

2.7 Recommendation and Key Takeaways

Ultimately, the "General-Purpose Electric" solution design was recommended because it provided the highest value score and came the closest to meeting the ideal values given by the stakeholder. In addition, it offers flexibility and ease of implementation by using an aircraft tug which is a system already in use in the airborne loading process. The "Budget" solution offered the best value per cost ratio but suffered from a lack of scalability and overall performance due to limited (8 person) carrying capacity. The "Specialized" solution design carried the most Paratroopers but suffered in other performance measures due to its larger and more complicated design. Both "General-Purpose" solutions were more balanced designs that performed higher across the full range of value measures, but the "General-Purpose Diesel" was outperformed due to the durability and efficiency benefits offered by the electric prime mover of the "General-Purpose Electric" design. After the analysis and final recommendation were presented, the stakeholder agreed that the "General-Purpose Electric" Solution is the most feasible and best meets the needs of the 82nd Airborne Division.

The first key takeaway from this analysis was that the solution design must be able to balance payload capacity with maneuverability and the speed at which it can carry a chalk of Paratroopers. These two design parameters were the two most important factors in each solution design and determined a large portion of the total value score. The second key takeaway was the viability of the prime mover and payload concept. Each of the four solution designs exhibited this concept in different forms and showed that a solution that carries paratroopers on a modified flatbed trailer payload pulled by some sort of vehicle can help solve the problem of paratrooper fatigue faced by the 82nd Airborne Division.

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