Technical Report

OAKLAND UNIVERSITY

Industrial and Systems Engineering

Optimization of a Paint Production Process

Submitted by: Pamela Najjar

Prepared for: Professor Michael Polis

April 2009

U.S Army TARDEC
6501 E. 11 Mile Road
Warren, MI 48397

UNCLASSIFIED: Dist. A Approved for Public Release

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 APR 2009**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Optimization of a Paint Production Process**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Pamela Najjar**		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000**		8. PERFORMING ORGANIZATION REPORT NUMBER **19823**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) **TACOM/TARDEC** 11. SPONSOR/MONITOR'S REPORT NUMBER(S) **19823**
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES **The original document contains color images.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**5**	

Project Description

The project will be conducted for the U.S. Army TARDEC Survivability Group. The main objective of this project is to integrate a pixilated camouflage paint pattern into the production process for the Future Combat Systems (FCS). Currently, military systems are coated with a single color of Chemical Agent Resistant Coating (CARC) for the entire vehicle. However, when the previous generation of camouflage was applied, it was done by hand, using pattern templates only as a guide (which led to variation and overspray from color to color), and each color could be applied over the previous one(s). The new camouflage pattern requires that a minimal amount of paint be applied (i.e. different colors should not be coated over others). In addition, the paint process will be almost entirely robotic (with the exception a few minor details (i.e. touch ups)). In order to incorporate the new camouflage pattern on to a vehicle, this project will need to obtain the following:

- Paint specifications from the manufacturer in order to spec out application hardware (i.e. spray guns, nozzles)
- FCS vehicle assembly information from the Project Management Office (PMO) to determine where in the assembly process the painting step will fit.
- Assess the viable methods for painting the pattern (i.e. removable templates, robotic "on-off" spray pattern, etc.)
- Generate an optimized solution based on time, cost, material and labor from the input data

This is a real-world scheduling problem of deciding how many production facilities to construct, and how to schedule these facilities. *The overall objective will be to minimize overall cost.*

Assume that the manufacturing process will take place five days a week, 50 weeks in the year which results in a total of 250 working days. Due to the requirements of the manufacturing paint process, the Army must force heat dry the vehicles. The requirements are set in place because at the time of the paint application the vehicle is not fully assembled. Therefore, the vehicle is not drivable. Air bearings are placed beneath the vehicle on the platform which allows the vehicle the capability of being able to roll to the vicinity where the paint will be force cured. Once the paint is force cured, the vehicle is later completely assembled. If the vehicle were to be completely assembled at the beginning of the paint process, the employees would need to manually "tape-off" much of the interior of the vehicle which would require a significant amount of time. By force curing the paint, idle time is cut and money is saved.

The Army proposes a line item budget to Congress, Congress gives the Army a budget for the requested project , the Army gives FCS a budget to manage based on Congress' quantity requirements for the FCS program, the Program Manager (PM) of FCS then manages technical acquisition requirements in order to meet the timeline of the program's production schedule. This process of budget delegation is shown in *Figure 1*. The PM FCS budgets the allotted money for each fiscal year to build the vehicles, equip them and paint them. The goal of the FCS PM is to field one Brigade Combat Team at a time with the number of vehicles needed.

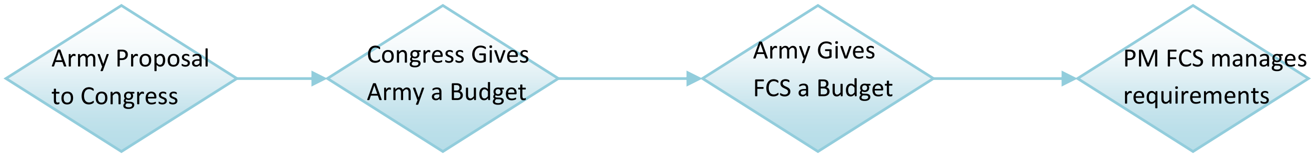

Figure 1: Budget Delegation Process

The U.S. Army will request that Contractor A be responsible for the robotic paint application process. Contractor A must ensure proper paint mixing while maintaining speed and accuracy. This would assure an increase in quality, that employees be exposed to fewer chemicals, a decrease in material waste and optimized color patterns (digital pattern programming).

The number of vehicles to be painted varies by each fiscal year. This is due to the low rate of initial production. Contractor A must do test-runs. Once the test runs are approved by Congress, additional funding is allocated.

The notional production schedule for the FCS Core Program is to be determined. Once the production values are established, a table can be displayed with information including the following:

- The vehicle numbers and the number of vehicles being produced each fiscal year (FY) from FY13 to FY28
- The sum of each vehicle number being produced from FY13 to FY28
- The sum of the number of vehicles being produced each fiscal year from FY13 to FY28
- The total number of vehicles being produced

The total cost to paint each vehicle was calculated using total vehicle area (sq. ft.) and is shown in *Table 1*.

Table 1: Area of Manned Vehicles (sq. ft.) and Cost to Paint Each Vehicle Completely

Manned Vehicles	Area	Price to Paint Each Vehicle	Cost to Paint Full Vehicle
Vehicle No.	**(Square Feet)**	**(Per Square Foot)**	**(U.S.D.)**
1	706.49	$158.00	$111,625.42
2	699.63		$110,541.54
3	708.56		$111,952.48
4	708.56		$111,952.48
5	801.43		$126,625.94
6	693.08		$109,506.64
7	662.41		$104,660.78
8	662.41		$104,660.78
9	647.79		$102,350.82

There are intermediate constraints which require a certain number of each vehicle to be produced by the requested date for each Army organization. These numbers will be integers, greater than or equal to zero. The intermediate number of vehicles needed is currently unknown.

The production scheduling process shown in *Table 2* will require the following times (in hours) for each vehicle:

Table 2: Production Schedule Tasks and Times (in hours)

Booth	Task	Time (hours)
1	wash	0.5
2	pretreat	0.5
3	dry	0.5
4	primer	2.5
5	force cure	1
6	paint	4.5

At the start and end of each work day, 15 minutes will be added on to process time for setup/cleanup. This includes but is not limited to the following: moving vehicles in and out, cleaning up excess paint and taping-off the necessary features of each vehicle. A vehicle must go through booths 1 through 5 in the same day. Also, a vehicle must go through booth 6 in the same day. Booths 1, 2 and 3 must be separate. However, booths 4, 5 and 6 may be combined into one booth. This would decrease the capital investment by eliminating 2 booths and robots. The setup/cleanup time will not be a variable because a given vehicle will be driven in and a given vehicle will be driven out each work day.

There is a possibility of scheduling more than one shift or adding hours on overtime. Variable "S," the number of shifts being worked, will be an integer value, where S = 1, 2 or 3. Alternatively, if the addition of employee overtime hours is considered, this would result in further production costs.

Binary variables (y_i) will be utilized to determine whether paint booths 1, 2, 3 and/or 4 will be built. This is shown in *Table 3*.

Table 3: Binary Variables per Paint Booth

y_i	Paint Booth	Binary Variables	
y_1	1	0	1
y_2	2	0	1
y_3	3	0	1
y_4	4	0	1

The startup costs are to be determined. However, based on whether the paint booths are built, the startup costs will vary depending on the result of the binary variable for each paint booth (1 through 4).

If the binary variable is 1, the startup costs will be accounted for because paint booth y_i is being built. If the binary variable is 0, there are no startup costs for the given booth $y_{i.}$

Objective function:
Z = total costs for the paint production process for all vehicles + startup costs