ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #36118

SIMULATION MODELING LAYOUT PROCESS DESIGN FOR THE JET ENGINE LIFT MANUFACTURING SYSTEM

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BIOGRAPHICAL SKETCH - Abayomi Ajayi-Majebi, PhD, PE, CMfgE, CQE, CRE.

Dr. Abayomi Ajayi-Majebi, PE, is a full time Professor and past Chairman of the Manufacturing Engineering Dept. at Central State University (CSU) where he teaches undergraduate engineering students in the four (4) year ABET Accredited Manufacturing Engineering Program. He has an earned doctorate degree in Engineering from The Ohio State University in Columbus, Ohio and is a Summer 2021, 2016, 2014, 2011 and also 2010 National Aeronautics and Space Administration (NASA) Summer Faculty Fellow at the NASA Glenn Research Center in Cleveland, Ohio. For over 36 years, he has supported the professional development of over 300 graduate Manufacturing Engineers and over 600 CSU STEM and non-STEM student graduates who are now serving as Plant Managers, Senior Executives, Supervisors, Quality Control Engineers, etc., these graduates are all supporting Manufacturing and allied industries and businesses in the U. S and across the World.

He was an Air Force Research Laboratory (AFRL) Summer 2013 Faculty Fellow at the Eglin Air Force Base in Eglin, Florida and a Summer 2018 AFIT/WPAFB Research Faculty. He has served as Board Alternate and a program planning committee member of the University Clean Energy Alliance of Ohio (UCEAO). As a member of the National Science Foundation Partners for Innovation team, he has served as Director of the Minor in Nuclear Engineering program at Central State University and oversees the development and implementation of the program. He is a Permanent Member of ASEE, a Life member of the National Society of Black Engineers (NSBE), a Senior and Endowed Member of the Society of Manufacturing Engineers (SME) and a Senior Member of the American Society for Quality (ASQ), he is a Life Member of the American Nuclear Society (ANS).

Dr. Ajayi-Majebi, is a recent 2021 Recipient of the Distinguished CSU Presidential Award for Excellent in Service and a past recipient of the Central State University (CSU) Distinguished Faculty Excellence Award for Research and also for Community Service, he is a recent recipient of the Outstanding Faculty of The Year Award in the CSU College of Science and Engineering and the past recipient of the Outstanding Faculty of The Year Award in the College of Business and Industry at Central State University. He is a Life-Time member of The Ohio State University Alumni Association. He is a member of numerous Christian Organizations in various part of the World & subscribes to the higher values. He is a Science Fair Judge for the Engineering and Science Foundation (ESF) of Dayton, Ohio, he is a Dayton Public Schools and West District Science Fair Judge for the Montgomery County and the Miami Valley of Ohio.

He has had significant and dynamic involvement with numerous research and/or engineering projects executed for over thirty (30) organizations over a span of thirty-seven (37) years, including General Electric, National Aeronautics and Space Administration (NASA), Great Lakes Center for Truck Transportation Research (GLCTTR), Federal Aviation Administration (FAA), The Boeing Co., McDonnell Douglas Corporation, the US Army Tank-automotive Command (TACOM), United States Agency for International Development (USAID), etc. Through these research and project interactions, he has served as Principal Investigator, attracting approximately $2 Million dollars to Central State University and working in collaboration with other researchers and project managers, he has attracted in excess of $ 4.5 Million dollars to Central State University. In February 2015 he was honored by the White House as a Champion of Change in HBCU Higher Education by the President Barack Obama Administration.

Dr. Ajayi-Majebi is a registered Professional Engineer (PE) with the State of Ohio and is a Certified Manufacturing Engineer, so certified by the Society of Manufacturing Engineers (SME). He is also an American Society for Quality (ASQ) Certified Quality Engineer (CQE) and is also an ASQ Certified Reliability Engineer (CRE). He is a faculty adviser for both the CSU Student Chapter of the National Society for Black Engineers (NSBE) and the CSU chapter of the Society of Manufacturing Engineers

(SME). He has for approximately thirty (30) years served the State of Ohio Residents as a Notary Public being duly registered with the Greene County Clerk of Courts in discharging the duty

SIMULATION MODELING PROCESS LAYOUT DESIGN AND OPERATION OF THE JET ENGINE LIFT MANUFACTURING SYSTEM

A STUDY OF THE MARMAC COMPANY, XENIA, OHIO HYDRAULIC DIFFERENTIAL COLUMN CYLINDER LIFT OPERATIONS

By:

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Mr. Dan Mangan, President, MARMAC Company, Xenia, Ohio
Mr. Bryce Combs, Vice President, MARMAC Company, Xenia, Ohio
Mr. Addison Carter, B. S. Manufacturing Engineering, CSU, Wilberforce, OH
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DESIGN PROJECT SUMMARY

A process layout design simulation study involving the engineering operational factors that affect the factory production and efficiency performance of an Ohio local manufacturing company has been studied. The layout process design project involves the conceptual development of three alternative layout configurations of the jet engine lift production system and evaluation of these alternatives using simulation modeling.to optimize the jet engine lift production system operation. Modern manufacturing systems evaluation tools including simulation modeling using ARENA and experimental design technologies (Using Design of Experiments Professional – DOE PRO) have been utilized in guided attempts to improve the jet engine lift manufacturing process layout operations. A production performance regression model was developed along with specified goodness of fit estimates. Trades-off relative to cost, maintainability, reliability, serviceability, design for the environment, safety, health and welfare of society and the effect of globalization as well as the effect of offshore manufacturing on the US economy in relation to the jet engine lift process layout design have been considered through a multi-attribute evaluation matrix analysis.

BACKGROUND

The MARMAC Company was established in 1954 by Emeritus President Mr. Bob (deceased) and Margaret McCreery and later the company was run by the succeeding President, Mr. Gary Walthall. The new company owner and President is Mr. Dan Mangan, and the Vice President is Mr. Bryce Combs who both run the custom manufacturing job shop and company, which produces an array of custom designed and built manufacturing artifacts that meet the needs of the industry and society including Hydraulic Draw Bridges, Jet Engine lift, etc. The MARMAC Company manufactures the hydraulic lift of the Jet Engines to support the manufacturing operations of the Pratt and Whitney Canada and Pratt and Whiney West Virginia Operations. The US operations is close to the Morgantown Airport in West Virginia. The operational capacity of the Jet Engine lift is 4000 lbs. and it utilizes Hydraulic Oil and Lubricating Oil.

Historically, the MARMAC Co. is a custom design and manufacturer of industrial hydraulic lifts and material handling equipment. The company specialize in partnering with customers and engineers to solve difficult problems. The company has two 25 feet giant lathes machines, a 52 feet giant Vertical Turret Lathe and a large cylinder testing capabilities The company has in the past served customers by manufacturing or testing lifts, cylinders, truck, hydraulic, telescopic, service pump platform, single and double acting cylinders, train hydraulic components, heavy lift tables, lift stages, special railroad platforms, material handling systems, maintenance, lift trucks, heavy handling machinery, forklifts, heavy duty box cars, buses, draw bridges, hydraulic lifts, cylinders, hoists, stage lifts, material handling elevators, loading platforms, railroad crossover bridges

Figure 1: Areal view of the Frontage of the MARMAC Company in Xenia, Ohio, designer and manufacturer of the Jet Engine Lift for the Pratt and Whitney Company in Morgantown, West Virginia and the Ontario, Canada

Figure 2: Three Jet Engine Lift manufactured in Xenia, Ohio for the Pratt and Whitney Company

METHODOLOGY

The performance characteristics of a system could be evaluated rather tediously using queuing system theory expressed in mathematical constructs for an identified customer, service systems, channel configuration and resources arrival mechanisms. This could lead to complex recursive, analytical model derivations that may be difficult to solve numerically. The mathematical model could admit an arrival distribution and a service distribution for entities. To get around the mathematical tedium, a simulation design and analysis could be deployed to enable estimation of the measures of performance or measures of effectiveness (MOP / MOE) for the system being modeled. To study the complexity of the manufacturing system, under study to reflect the dynamic characteristics of a stochastic process, a discrete-event based simulation model could be developed using available simulators such as ARENA, PROMODEL and/or SIMPROCESS. The ARENA simulation modeling system was chosen for this study

SIGNIFICANCE

This study imparted critical process layout design job skills to senior student, while simultaneously leveraging the confidence of the senior engineering student in making fact-based decisions and coherent technical presentations

ENGINEERING SPECIFICATIONS: SPECIFIC AIMS

Study the factory layout and achieve a production level specification of 4 to 10 per year consistent with customer demand, i. e. build 1 per 11 weeks with variable production schedule

Justify how and why the project meets the complex engineering problem requirement of abet criterion 3 outcome 1 - 3

Implement a process design simulation modeling of the manufacturing system

Optimize the system to achieve stated production goals

Choose the best process design project layout and options

THE COMPLEXITY OF THE PROCESS LAYOUT DESIGN PROJECT: -

The project meets the design complexity requirements for the following reasons:

1. Process Design Project has numerous important technical issues such as optimization that are not easy to be solved manually or mentally and require a more sophisticated tool such as simulation that capture the interactions and intricacies of the many complex variables involved.

2. Standards and codes are important and their provisions need to be implemented within the context of the system optimization problem, this project addresses these challenges adequately
3. Design process layout project represents an industry grade problem with inputs from many actors
4. Project requires data from several sources, such as the MARMAC Company.
5. The project has many component parts such as the cylinder ram, the cylinder valve, the cylinder casing, the welding processes and the time they take to be accomplished, etc. and all these needs to be considered and integrated.
6. Project incorporates mechanical, systems and processes and the utilization of engineering software and codes to guide the process layout design project.
7. Project is complex because the process design helps add value to the company and the customer.

JUSTIFICATION OF DESIGN COMPLEXITY REQUIREMENT OF SENIOR DESIGN PROJECT AS REQUIRED BY ABET CRITERION 3 OUTCOMES 1 to 3

Engineering students executing senior design projects are required to tackle complex engineering problems and apply the skills they have learnt over a four (4) year period of their engineering training in accomplishing this complex engineering problem solution objective. This design project represents a complex engineering problem for many reasons: it studies many stochastic variables whose dynamics, affect a manufacturing or production system or process and attempts to provide a solution of the same; this complex design project opportunity, problem or challenge, is much higher than a textbook grade problem and has many inputs and many outputs that are not well understood and their effects are not readily predictable unless complex engineering tools are deployed to perform an optimization of the entire system using for their solution, simulation modeling. Furthermore, the incidence of breakdowns of machines, addition and removal of workers, introduction of new machines on the shop floor all add additional layers of complexity to the design problem; indeed, the complex engineering processes and variables involved help to define a complex engineering problem, which in turn provide important consequences for manufacturing productivity and profits. Many variables on the factory floor change over time and their effects are persistent and significant in affecting manufacturing productivity and manufacturing machinery uptimes and downtimes and these variables impacting the processes all help to make the strong case of complexity for this process design project supporting the two (2) manufacturing engineering senior students involved in this process design project study.

PROCESS DETAILS AND HISTORICAL DATA IN SUPPORT OF THE DESIGN PROJECT LAYOUT SIMULATION MODELING STUDY:

At the MARMAC Company, it takes three months for building two (2) cylinders but using simulation the possibility for building more cylinders can be determined – Unit Cost $78,000 approx. per cylinder but with inflationary trends and the challenging times, and market uncertainties, the current costs can be considerably higher.

4 or 5 units can be ordered every 10 years but a lot more can be built on short notice, predicated on customer demand.

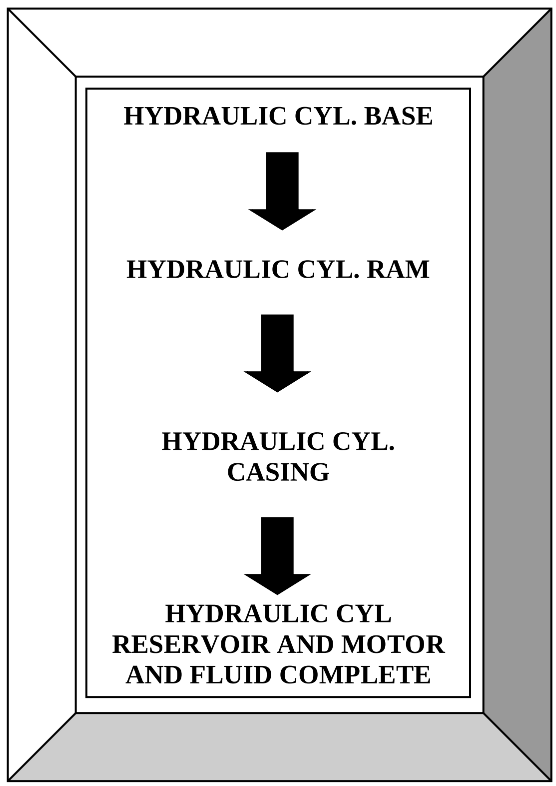
Unit Consists of Base Plate, Ram, Casing, Motor & Pump, Valve &Piping Assembly and Linings

Jet Engine Lift Service Life is about 50 years, Refurbishing Cycle 20 – 30 years

Jet Engine Lifts are used in Jet Engine Testing and Assembly Facilities or in Research and Development Aircraft Manufacturing Organizations

MANUFACTURING PROCESS PLAN FOR JET ENGINE LIFT ASSEMBLY

Figure 3 Process Plan



OPERATIONAL STATIONS AND FLOW PATTERNS IN SUPPORT OF MANUFACTURING OPERATIONS ARE:

As prescribed by the MARMAC company President, Mr. Dan Mangan, who is also the President of TDL Tool – a separate machine tool company also in Xenia, Ohio), to the CSU Team consisting of a manufacturing engineering professor and two of his manufacturing engineering senior students, the processing stations and operational flows to consider in the process and layout design simulation modeling project for the jet engine lift manufacturing operation include:

1. Receiving Material Disposition
2. Tool Room Operation
3. Welding Dept. Operations
4. Giant Lathe Finishing Operations
5. Assembly Operation
6. Inspection and Testing Operations
7. Painting Operation
8. Packaging and Shipping Operation

ARENA SIMULATION MODELING TOOL

Discrete event simulation is the process of representing dynamic systems interactions on a digital computer using logical and mathematical constructs to describe the behavior of the system and its processes, including its unique, specific set of events, over extended periods of real time. These flexible, activity-based models embodied in the simulation codes, are effectively used to simulate almost any process. For over 30 years, ARENA, developed initially by Systems Modeling Corp. and now by Rockwell Automation, has been among the World's leading discrete event simulation software in the class of AUTOSIMS, SIMSCRIPT, SIMFACTORY, GPSS, GASP, WITNESS, PROMODEL, SIMPROCESS, SIMNET, ETC.

ARENA is a discrete event simulation and automation software that captures the complexity of system interactions and was developed by Systems Modeling Corporation (SMC) and acquired by Rockwell Automation in 2000. ARENA uses the SIMAN processor and simulation language to codify and capture the complex and dynamic interactions of a manufacturing, business or industrial system. As of 2020, it was in the 16th version of incremental development operations.

Few business decisions are straightforward. Changes in one area of a business impacts other areas, often in ways not anticipated. Business process simulation software such as ARENA are highly effective methods or approaches for evaluating the full implications of manufacturing and business decisions before they are implemented in practice as a result of which simulation helps to reveal hidden problems before they occur and it serves as a catalyst for saving funds that would have been sunk into disturbing production operations due to performing disruptive tests on existing production systems as costly as these uninformed or unwise decisions could be. Simulation therefore helps to avoid the inherent risks of failure while servicing as a tool to address the challenges of intricate and / or complex engineering design processes and better yet, optimizing the process layout design project embarked on in this senior design project.

PROCESS DESIGN PROJECT LAYOUT ALTERNATIVE EVALUATION FOR JET ENGINE LIFT ASSEMBLY OPERATOINS

A Schematic of the Process Design Flow of the Jet Engine Lift Assembly:

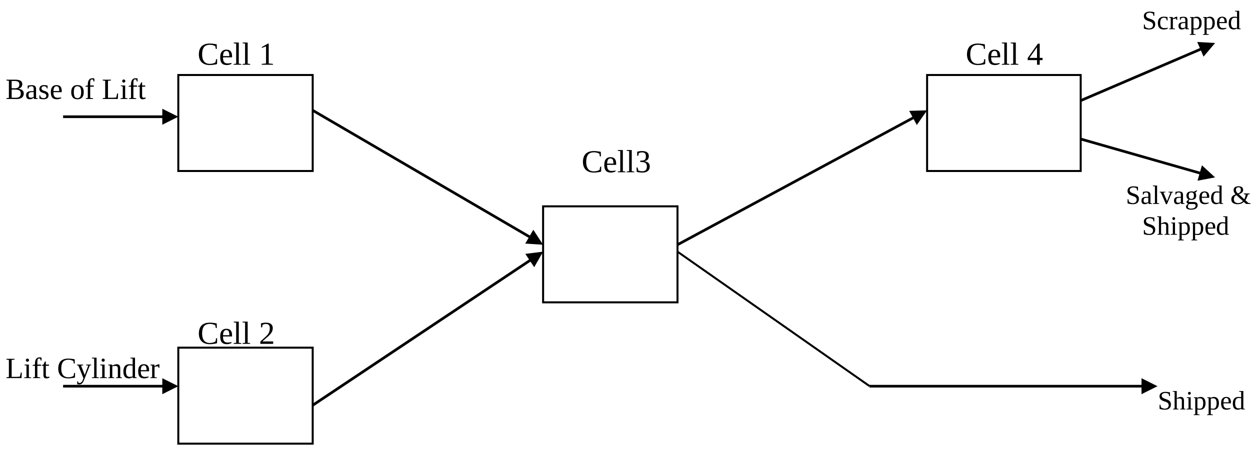


Figure 4: Conceptual Process Design Flow of The Jet Engine Lift Assembly

In Figure 3, the cells have the following designation:

Cell 1 is the location where Base are made and prepared for assembly
Cell 2 is the location where the lift cylinder is prepared for assembly
Cell 3 is the location where the two components are assembled, inspected and tested
Cell 4 is the location where the materials are inspected, accepted or rejected having come from cell 3 from where they have been rejected for rework and sent to station 4 to be reworked and re-inspected.

At each station depending on the layout plan, one, two or three servers are available to process the various components passing through the station, depending on the task to be executed:

THE TASK SCHEDULE FOR THE LAYOUT PROCESS DESIGN ARE AS FOLLOWS:

1) Study the characteristics of the MARMAC Company Hydraulic Lift manufacturing operations at a judiciously chosen service system and identify measures of performance.

2). Develop measures of performance effectiveness of the manufacturing system.

3) Specify the model input factors for the layout process design in support of the design project simulation modeling

4) Specify the model output responses for the simulation modeling project.

5). Specify the systems performance metrics for the simulation modeling and design for the jet engine manufacturing system study

6). Specify the evaluation metrics for the study,

7). Specify the constraints for the study

8) Find out the applicable engineering standards that govern the simulation modeling operations

9) Study the requirements and characteristic of the project that qualify it to be a complex engineering project as required by ABET Criterion 3, student outcomes 1 - 3

10) Study, purchase and learn to use the ARENA Simulation Modeling System to capture the complexity of the manufacturing operations.

11) Specify the existing layout of the manufacturing operations and develop two alternative layouts for the comparative operations to move toward an optimized layout

12) Develop a preliminary version of the simulation model for a chosen layout to provide a verification of the feasibility of the modeling approaches.

13) Using collected or data obtained from the shop floor codify a simulation model of the existing operations using either the PROMODEL or ARENA or SIMPROCESS packages for discrete event simulation modeling. Compare the three models and select one for deployment.

14) Deploy the Design of Experiments (DOE) tool to study the operational parameter sensitivities of the developed design project layout alternatives. Utilize the 2^3 Full Factorial Design to implement the factor sensitivity study and make recommendations resulting from the study results.

15) Perform a comparative evaluation of the results obtained from the three alternative layout study for the simulation models developed. Provide lucid explanations for the resulting differences that you may observe.

16) Learn and deploy the MS Office and Power Point Systems for the study and provide documentation of the results.

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17) Prepare PowerPoint presentation of results and Microsoft word report of the work done. Other presentation methods to convey information to audiences may be developed.

PROCESS LAYOUT ENGINEERING DESIGN PROJECT COMPLEXITY JUSTIFICATION IN RELATION TO THE EAC/ABET DESIGN PROJECT COMPLEXITY REQUIREMENT

This project incorporates many factors and elements that cannot be effectively analyzed manually and/or mentally which places the project out of the realm of the simple day-to-day or even cook book problems or the realm of the more challenging typical textbook problem and into the realm of a complex and challenging engineering design project where there are no fixed inputs and outputs and the objective is to maximize the performance of the complex system under specified systems operating parameters that are identified in this senior design project. Moving parts arriving at different stations that are being processed by machines and operators and moving to the next processing stations until they are fully processed and exit the system., capture the stochastic and dynamic nature of a complex manufacturing system. These considerations make the project meet the requirements of complexity for a senior design project.

TECHNICAL APPROACH

1. Developed process design layouts schematics
2. Built process design simulation in ARENA using three (3) alternatives
3. Checked model design to ensure error-free codification
4. Simulated model for 3 months (90 days) and collected statistical data
5. Ran various combinations of modeling scenarios for 22 full factorial design using four simulation model replicates
6. Evaluated the simulation models for output factor effects

TESTING AND EVALUATION

Developed arena simulation models and tested various combinations of variables

Variables tested are arrival rates, queue capacity and processing times. These are tested to predict output production in terms of number of jet engine lifts produced over 90 days (3 months)
Ran ARENA simulation model using various combinations of 23 full factorial design

Evaluated output of simulation model and obtained effects of selected input variables on output production responses.

DESIGN OF EXPERIMENTS (DOE) TESTING DATA MATRIX FOR INPUT AND OUTPUT PROCESS FACTORS MATRIX DEVELOPED ARE PROVIDED BELOW:

A 2^3 or 2 x 2 x 2 full factorial experimental design was executed for the three layouts shown in Figures 5 to 10, featuring eight (8) experimental runs and three replications The experimental design template inputs variables selected were station arrival rates, queue capacity and station service rates which were the same for each layout studied. The results of the ARENA process simulation model runs were executed for each layout developed. The full factorial experimental design matrix used to study each layout identified for the senior design project is presented in

Table 1. The input variables effects were analyzed using the DOE PRO experimental design software code developed by Air Academy Associates in Colorado Springs, Colorado as indicated in Table 2. The results of the three (3) alternative design layouts evaluated are presented in Figures 11 through 15. The three identified variables main effects and their interaction effects are highly significant relative to the hydraulic jet engine lift productivity as presented in Table 3.

TABLE 1: FULL FACTORIAL DESIGN OF EXPERIMENTS (DOE) TESTING MATRIX SHOWING VARIABLES MAIN EFFECTS AND INTERACTIONS.

#NAME?													
NO	Run Order / Avg. Quantity Produced	A= Arrival Rate	B= Queue Capacity	C= Station Service Rate	AB	AC	BC	ABC	Y1	Y2	Y3	Mean= Y Bar	StdDev= Y Bar
5		-	-	-	+	+	+	-					
6		-	-	+	+	-	-	+					
7		-	+	-	-	+	-	+					
8		-	+	+	-	-	+	-					
1		+	-	-	-	-	+	+					
2		+	-	+	-	+	-	-					
3		+	+	-	+	-	-	-					
4		+	+	+	+	+	+	+					
	Dbar(-)												
	Dbar(+)												
	Dbar(+) - Dbar(-)												
	(Dbar(+) - Dbar(-))/2												

A = Arrival Rate (Lo, Hi); B = Queue Capacity (1, 3), C= Statio Serive Rate (Lo, Hi)

TABLE 2: FACTORIAL DESIGN OF EXPERIMENTS (DOE) TESTING MATRIX USING DOE-PRO DEVELOPED FOR INPUT AND OUTPUT PROCESS VARIABLES SHOWING MEAN AND STANDARD DEVIATION OF FACTORIAL DATA COLLECTED FOR ILLUSTRATIVE DESIGN LAYOUT NO. 1

	A	B	C	D	E	F	G	H	I	J	K	L
2	Row #	Arrival Ra	Queue Ca	Station Se	rvice Rate	Y1	Y2	Y3	Y4		Y bar	S
3	1	2	1	1		36	36	33	35		35	1.414214
4	2	2	1	2		15	16	15	15		15.25	0.5
5	3	2	2	1		37	38	36	37		37	0.816497
6	4	2	2	2		29	29	27	29		28.5	1
7	5	4	1	1		50	51	48	51		50	1.414214
8	6	4	1	2		21	19	19	19		19.5	1
9	7	4	2	1		72	71	73	72		72	0.816497
10	8	4	2	2		33	30	33	32		32	1.414214

The effects of the material arrival rate at the stations, queue capacity and station service rates were evaluated. The effects of the process variable one-way and two-way interactions were also evaluated, i. e. the effects of the first order and second order interactions were evaluated at the 5% level of significance. The output response variables, replicated three (3) times included:

Average Queue Size
Quantity Produced
Product Make Span

TABLE 3: RESULTS OF MAIN EFFECTS AND INTERACTION EFFECTS EVALUATION USING THE DOE PRO FACTORIAL DESIGN OF EXPERIMENTS (DOE) ANALYSIS OUTPUT RESULTS FOR ILUSTRATIVE LAYOUT NO. 1

Y-hat Model		Jet_Engine_Lift			
Factor	Name	Coeff	P(2 Tail)	Tol	Active
Const		36.156	0.0000		
A	Arrival Rate	7.219	0.0000	1	X
B	Queue Capacity	6.219	0.0000	1	X
C	Station Service Rate	-12.344	0.0000	1	X
AB		2.406	0.0000	1	X
AC		-5.281	0.0000	1	X
BC		0.21875	0.2694	1	X
ABC		-2.594	0.0000	1	X
	R^2	0.9968			
	Adj R^2	0.9959			
	Std Error	1.0945			
	F	1082.2919			
	Sig F	0.0000			
	F_{LOF}	NA			
	Sig F_{LOF}	NA			
	Source	SS	df	MS	
	Regression	9075.5	7	1296.5	
	Error	28.8	24	1.2	
	$Error_{Pure}$	28.8	24	1.2	
	$Error_{LOF}$	0.0	0	NA	
	Total	9104.2	31		

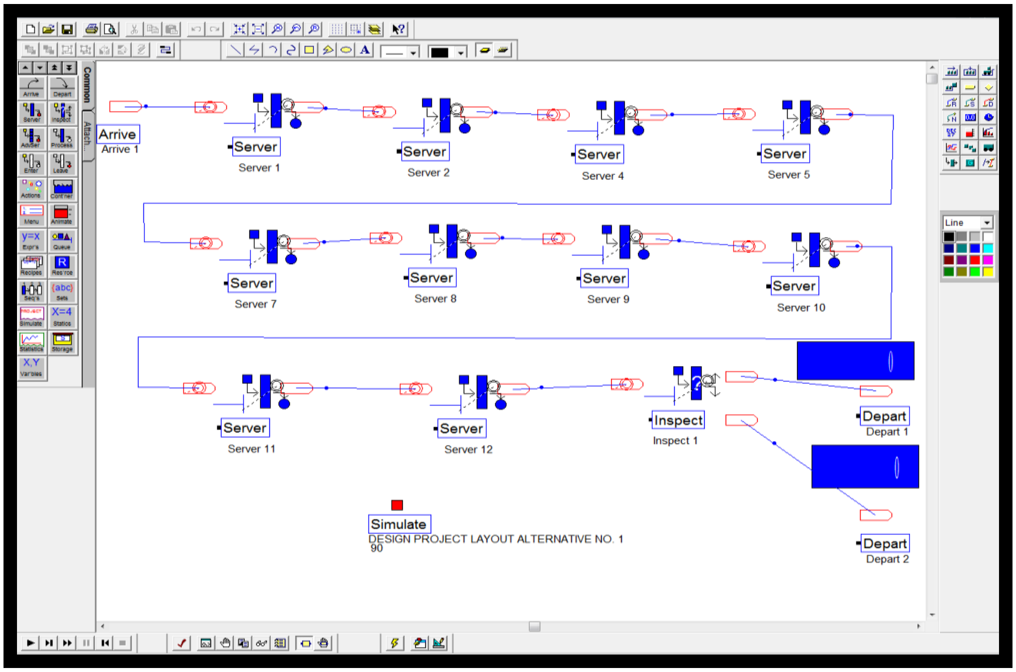
Prod Qty = 36.156 (AR) + 6.219 (QC) – 12.344 (SSR) + 2.406 (AR x QC) – 5.281 (AR x SSR) + 0.219 (QC x SSR) – 2.594 (AR x QC x SSR) (R^2 = 0.9968, Adj (R^2) value= 0.9959)

Where Prod Qty = No of jet engine lifts manufactured during the simulation, AR = Station arrival rates, QC = Queue capacity, SSR = Station service rate.

PROCESS DESIGN LAYOUT DESIGN APPROACHES UTILIZED

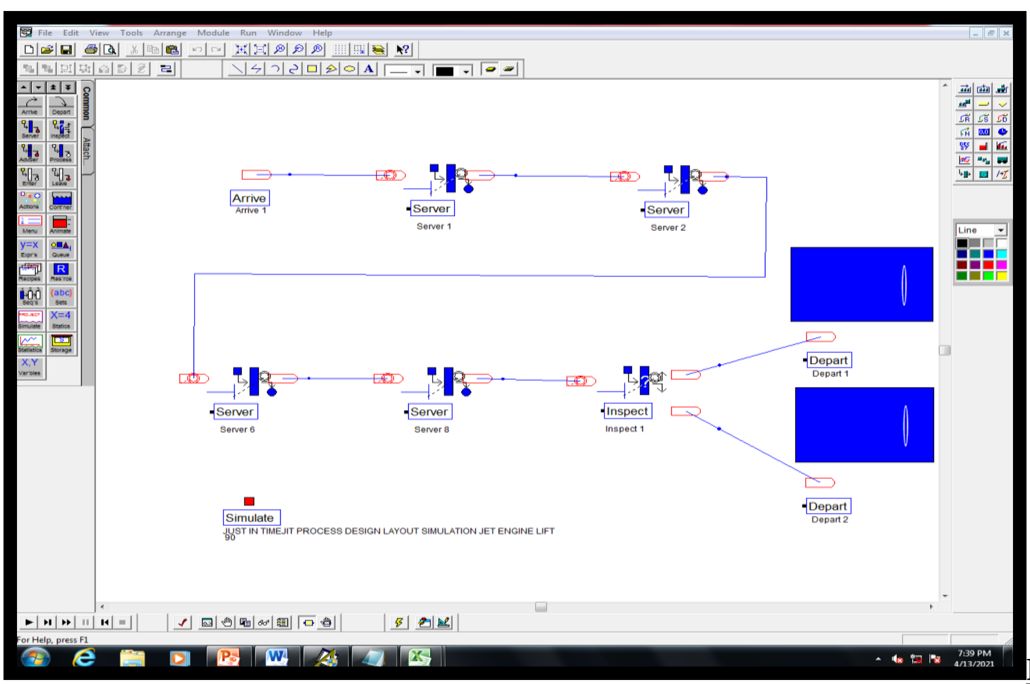
Layout Design 1

Figure 5 Process Design Alternative Layout 1 Simulation for Jet Engine Lift Assembly



Layout Design 2

Figure 6 Process Design Alternative Layout 2 Simulation for Jet Engine Lift Assembly



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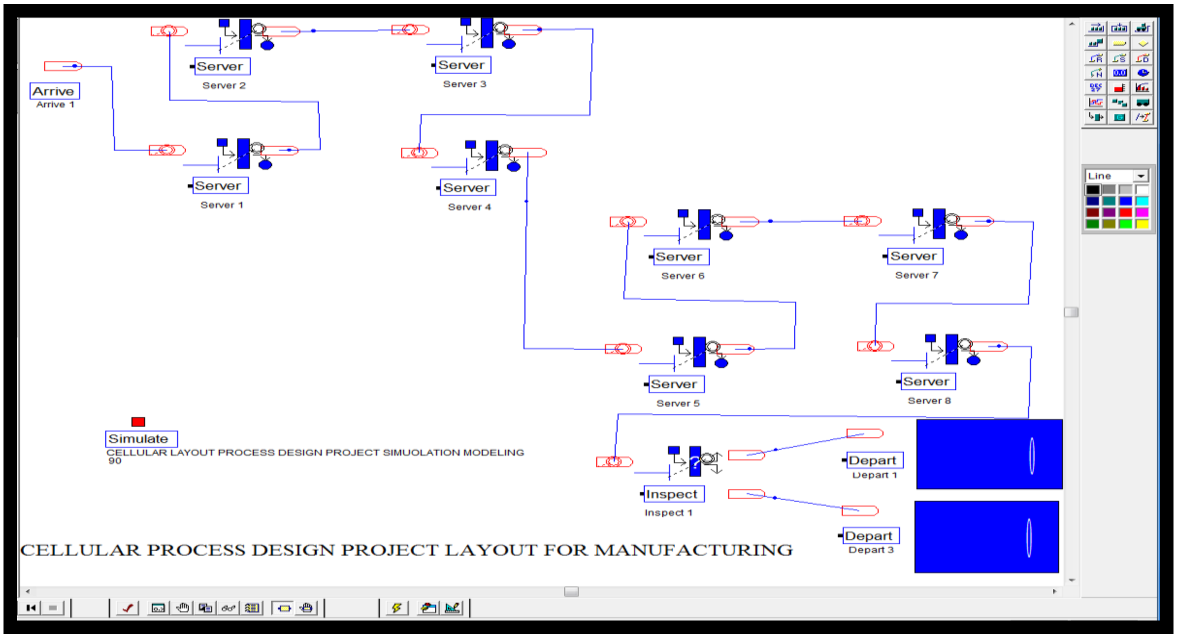
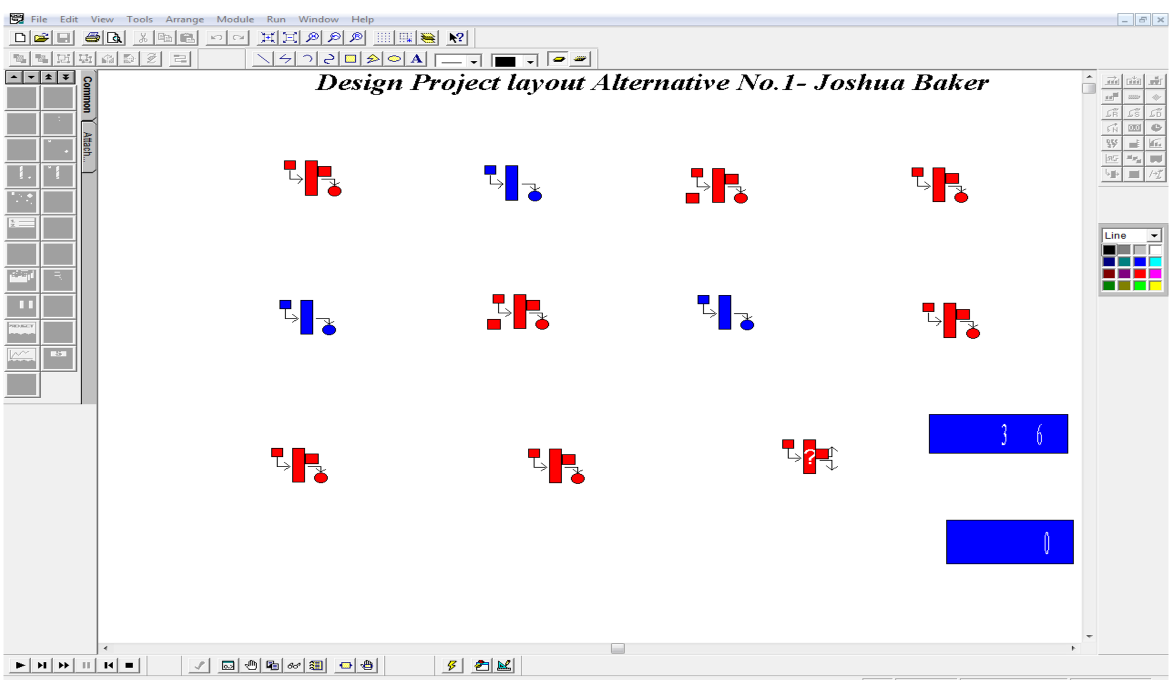
Layout Design #3

Figure 7 Process Design Alternative Layout 3 Simulation for Jet Engine Lift Assembly



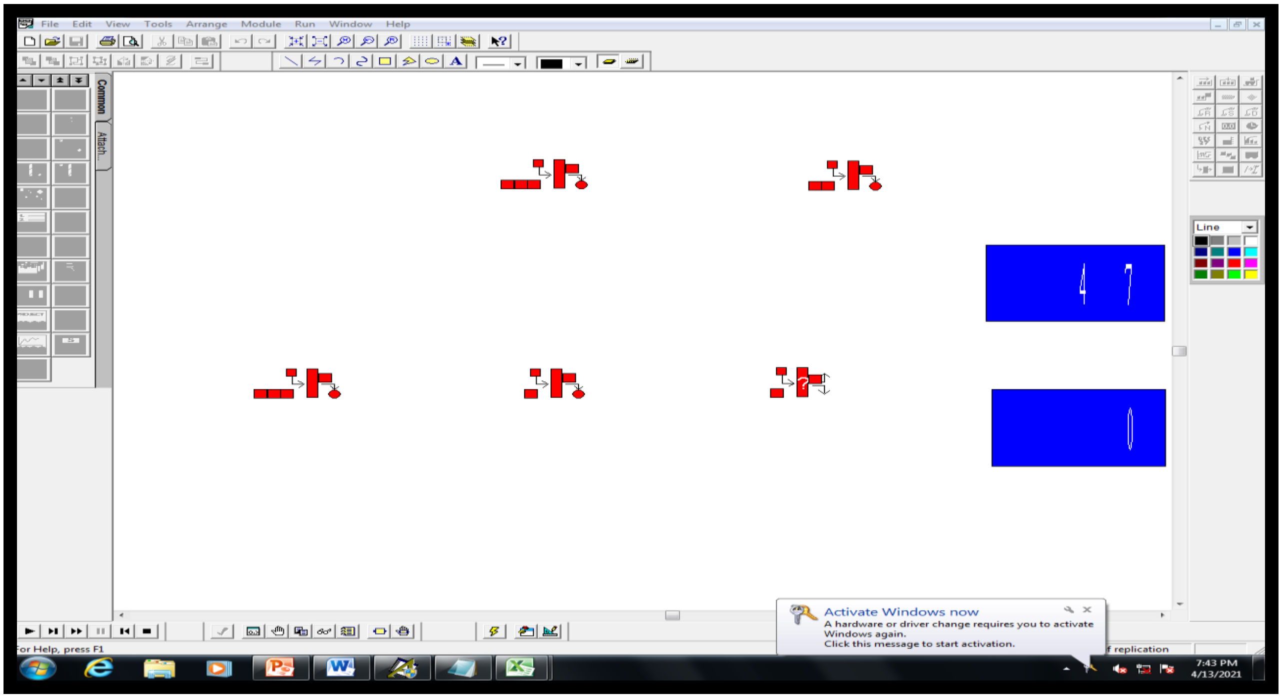
SIMULATION MODELING RUN FOR PROCESS LAYOUT DESIGN ALT 1

Figure 8 Process Design Alternative Layout 1 Simulation Run in Progress for Jet Engine Lift Assembly



SIMULATION MODELING RUN FOR PROCESS LAYOUT DESIGN ALT 2

Figure 9 Process Design Alternative Layout 2 Simulation Run in Progress for Jet Engine Lift Assembly



SIMULATION MODELING RUN FOR PROCESS LAYOUT DESIGN ALT 3

Figure 10 Process Design Alternative Layout 3 Simulation Run in Progress for Jet Engine Lift Assembly

The iterative alternative design evaluation approach was utilized to study the various process layout factors that impact the productivity of the jet engine lift layout process design.

Technical Approach Considered in the Process Layout Design Project Implementation

Conceptual Design was implemented

Realistic Constraints were addressed in the design project

Alternative designs were addressed using three design alternatives

Provided at least two more alternative designs for a total of 3 alternative designs

Considered the impact on designs using the Multi-Attribute Evaluation Matrix and included the contributions of :

- Ethical responsibilities
- Economic benefits
- Health and Safety
- Societal context
- Environmental
- Global effects
-

Detailed Design were addressed as applicable (As driven by type & nature of the design project)

Systems Diagram (Interfacing, power, signals)
Materials/Mechanical System
Manufacturing & Process Planning System
Simulation / Industrial System
Thermal System
Electrical System
Computer System
Integration of Systems

Identified Engineering Standards for design project, prototyping and testing procedures

Testing Plan, Methods, & evaluations addressed to extent possible:

- Algorithm
- Tools and Materials
- Processes and Procedures (Reference Appropriate Standards, Procedures)
- Contingency Plans
- Presentation of results and Deliverables

REVIEW OF THE LITERATURE ON FACTORY LAYOUT PROCESS DESIGN AND SIMULATION MODELING

Using the simulation modeling databases and journals, a review of the literature on simulation modeling with a focus on jet engine layout design and simulation modeling driven improvement was conducted and the results is documented in the design project report to the effect that no information is indicated in the literature about jet engine process design layout. The following sources of information in the literature were reviewed. The literature review and product search databases utilized included .

Journals
Magazines
Internet

Search Engines utilized to access the journals included:

Google Scholars
Ohio Link
Dissertation Abstracts
Compendex, SciCitation, ISMEC, ABI-Inform, etc. and also
Engineering Reference Librarian's Support

Relevance of searches and summary of result:

The results of the search indicated that no study involving jet engine process layout design for the lift assembly is reported in the literature.

Project Management

The senior design project implemented project management principles including:

1.1 Work Breakdown for project members

1.2 Schedule: Gant Chart

1.3 Man Power Allocation

1.4 Activity Crashing and Time Compression Considerations to achieve timely completion.

<u>Statement of work achieved:</u>

1.5 Implemented a process design simulation modeling of the manufacturing system

1.6 Studied the factory layout and using Ad-hoc data, achieved a production level specification greater than 4 to 10 per year consistent with customer demand, i. e. build 1 per 11 weeks with variable production schedule as is currently the real life experience

1.7 Provided justification for how and why the project meets the complex engineering problem requirement of ABET criterion 3 outcome 1 - 3

1.8 Optimized the system to achieve stated production goals

1.9 Chose the best process design project layout and options (Alternative 3)

FIGURE 11 MILESTONES AND SCHEDULE OF TASKS FOR SENIOR DESIGIN PRJ.

```
                                                  1/30/2021 2/28,2021     3/31   4 /30   5/5
                  TASK                                          TIME (Weeks)
                                                  0   1  2  3  4  5  6   7  8  9  10 1112 13 14

1) Study characteristics of MARMAC Operation       x____x
2) Visit the MARMAC Company Plant                     x
3) Perform Literature Review                        x____x
4) Perform Engineering Code Review                    x____x
5) Study location & characteristics for process          x___
6) Develop data template & fit distribution to data         x____x
7) Review ARENA Simulation Model Environment                 x
8) Develop list of input factors and output responses      x________x
9) Develop simulation model of system/facility              x_____________x
10) Perform comparative evaluation of results                               x________x
11) Document process design study in M/S Word              x_________________________x
12) Document process design study in PowerPoint                   x__________________x
13) Use DOE-PRO to Analyze ARENA Results                    x_________________________x
14) Keep log of time and effort applied to tasks             x    x    x    x    x   x
15) Provide progress report on work performed                x       x       x         x
16) Provide deliverables                                     x       x       x         x
```

Table 4:Multi-attributes Evaluation For Process Layout Design Project

MULTI-ATTRIBUTES EVALUATION OF THREE DESIGN ALTERNATIVES

NO	DESIGN ATTRIBUTES SPECIFICATIONS	RELATIVE WEIGHTS	WTS ALT 1 MOTOR	WT. OF DESIGN ALTERNATIVE 1 - MOTORIZED GABTRT STS	WTS ALT2 JIT	WT. OF DESIGN ALTERNATIVE 2 - JIT LAYOUT	WTS ALT3 CELLULAR	WT. OF DESIGN ALTERNATIVE 3 - CELLULAR LAYOUT
1	Performance	5	9	45	8	40	10	50
2	Economics / (Benefit & Cost)	5	8	40	9	45	9	45
3	Aesthetics	3	8	24	9	27	9	27
4	Specifications Conformance	5	8	40	8	40	8	40
5	Serviceability	4	7	28	9	36	8	32
6	Durability	4	10	40	10	40	10	40
7	Reliability	5	10	50	10	50	10	50
8	Health	5	7	35	7	35	7	35
9	Safety	5	10	50	10	50	10	50
10	Public Welfare	5	10	50	10	50	10	50
11	Environmental Compliance	5	8	40	8	40	8	40
12	Sustainability of Process Design Solution	4	10	40	10	40	10	40
13	Design Global Impacts	5	10	50	10	50	10	50
14	Design Societal Impacts	5	9	45	9	45	9	45
15	Design Cultural Impacts	4	9	36	9	36	9	36
16	Ethical Dimension of Design	5	8	40	8	40	8	40
17	Legal Dimension of Design	5	10	50	10	50	10	50
18	Risk Profile-Design Project	5	10	50	10	50	10	50
			Combined Wt. Alt 1	753	Combined Wt. Alt 2	764	Combined Wt. Alt 3	770

GRAPHICAL REPRESENTATION OF ARENA SIMULATION MODELING RESULTS FOR THE "BEST" ALTERNATIVE 3, BASED ON THE MULTIATTRIBUTE EVALUATION OF THE THREE ALTERNATIVES (TABLE 4)

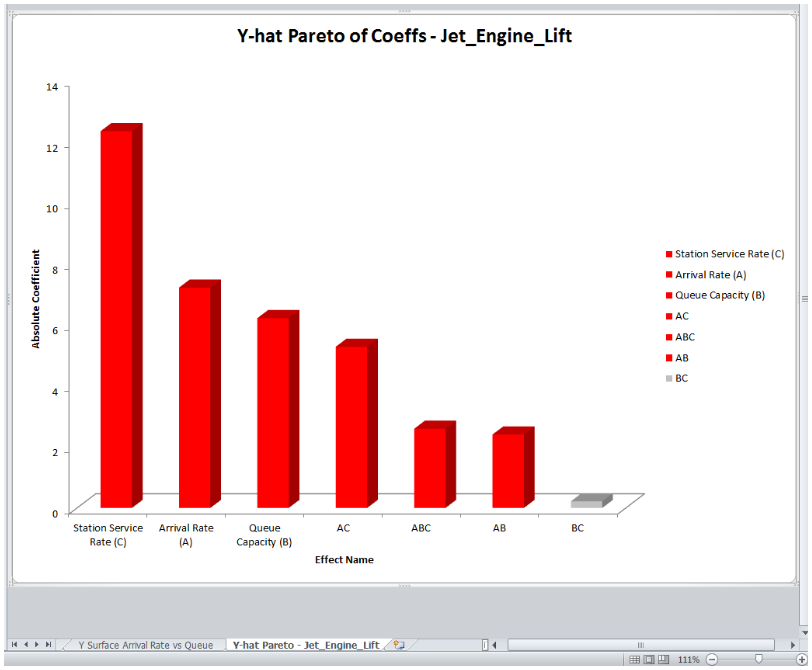


Figure 11: Pareto Diagram of Absolute Half Effect Values of Main Effect and Interaction Effect Factors influencing Production Volume, including Station Service Rates, Arrival Rates and Queue Capacity.

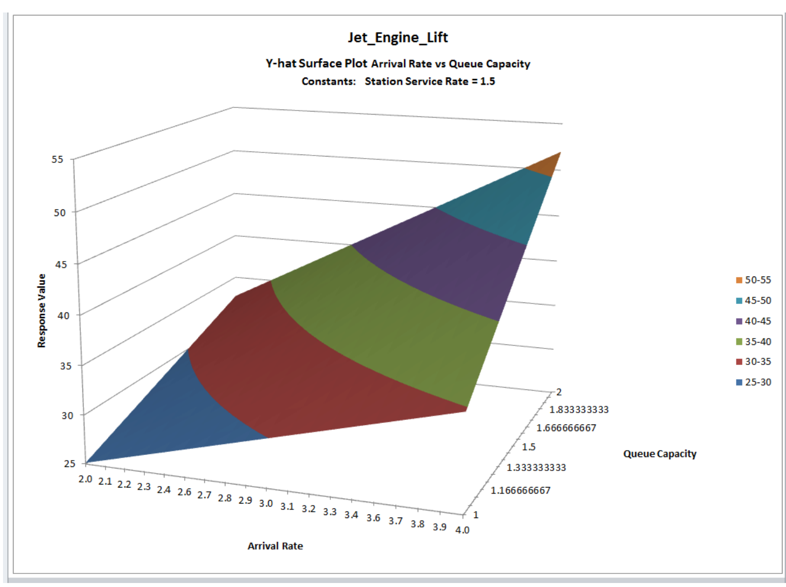


Figure 12: 3-D Response Sirface Plot of Production Volume, influenced by Arrivel Rates and Queue Capcity for a defined Service Rate

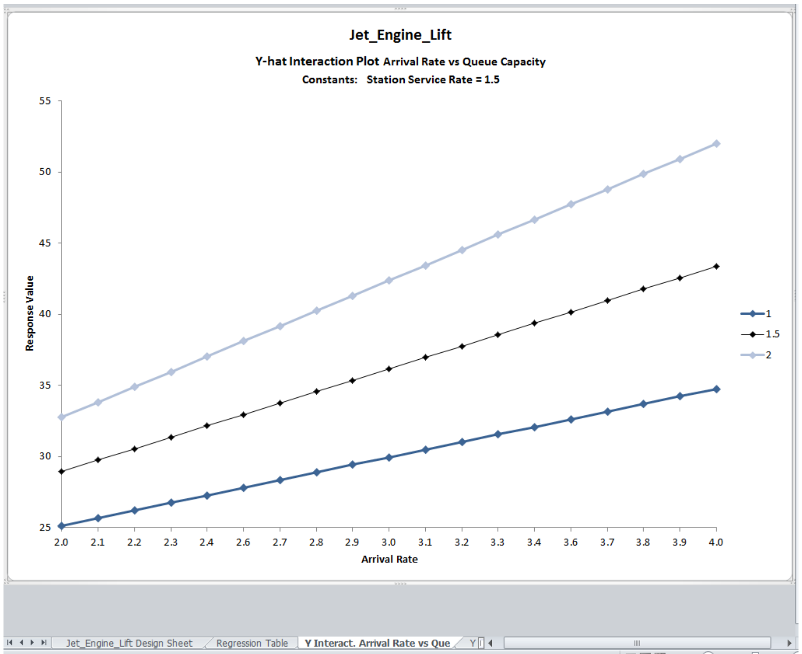


Figure 13
2-D Plot of Production Volume, influenced by Arrivel Rates for a defined Stn. Service Rate

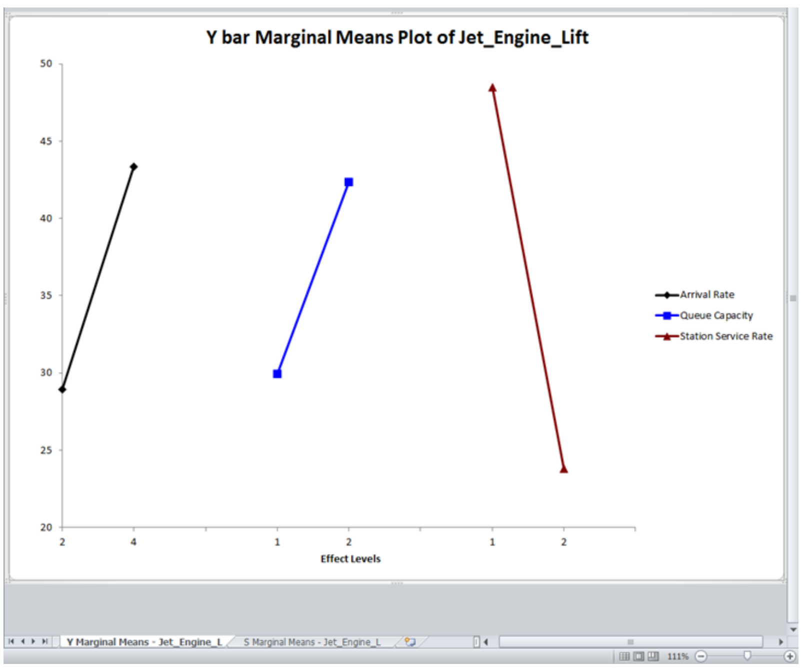


Figure 14
Marginal Means Plot of Factor Effects Levels on Production Volume, in particular Arrival Rate, Queue Capacity and Station Service Rate

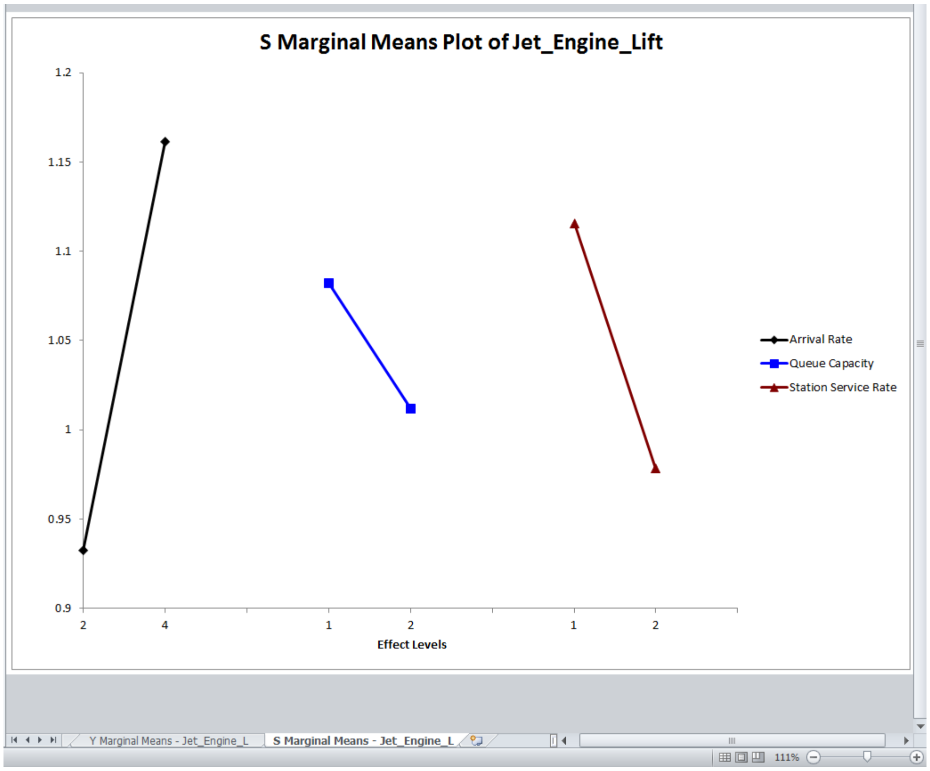


Figure 15

Std. Deviation of Marginal Means Plot of Factor Effects Levels on Production Volume, in particular Arrival Rate, Queue Capacity and Station Service Rate.

Evidence of Team cohesiveness

Worked cooperatively at various times to ensure project progress is maintained

Worked on project together to address requirements provided by MFE dept.

Visited the MARMAC Company in Xenia, Ohio on Feb 17, 2021 from 3 pm to 5:15 pm, on personal time to obtain information in support of the process design layout model development

Agreed to sign a non-disclosure agreement which was signed and delivered to Mr. Dan Mangan, the MARMAC company President

Worked on the report preparation In MS Word, and in MS PowerPoint, Using the Central State University (CSU) One-Drive located in the Cloud

Utilized Google Docs originally and switched to Office 365 with a view to using the Cloud to work jointly on the reports sections but did not have enough information technology (IT) privilege to make the file-sharing and collaborative, as well as cooperative, final report development strategic plan, to work as efficiently and effectively, as was originally planned.

During undergraduate engineering training, learned to perform statistical analysis of data using DOE-PRO, SPSS, MINITAB and MS. EXCEL

Risk Management Considerations (5 Types of Risks)

There are five (5) types of risks that were considered for this project:

1) Manufacturing / Production, 2) Market, 3) Institutional, 4) Personal and 5) Financial Risks.

Effort was made to compare the MARMAC company risk profile with that of other similar organizations for effective process design and project implementation and the company ranks higher compared to others relative to design and manufacturing practices.

Also due to the practice at the MARMAC Company of only making equipment of very high margin of design safety, with a design and manufacturing factor of safety of five or more, they more than exceed the ISO Standards, in addition, many of their client designs require a PE stamp of approval to safeguard and / or ensure professional safety, quality and accountability.

COST ESTIMATION (STUDENT DESIGN AND ENGINEERING TOTAL COST)

Cost Estimation for Senior Design Project :
Materials $600+$575 = $1175 (ARENA + DOE) Software)
Machining $ 0.00 (No machining activity or cost incurred for this senior design project)
Design & Innovation Details $ 1500 ($15 x 100)
Overhead Costs $ 200
Labor Cost 3 months of work from 2 students totaling 200 hours at $ 15 per hour $3000

TOTAL COST OF MFG, DEV. AND REPORTING FOR STUDENTS $10,775

COST ESTIMATION FOR MARMAC CO. OPERATION ON JET ENGINE LIFTS

Cost Estimation for Jet Engine Manufacturing on the Job:
Materials Machines cost $ 25.0k - 50.0k to build a lift system
Machining $70- $78,000
Design & Innovation Details $ 37,000
Overhead Costs - $15,500
Labor Cost 3-4 months of work from 5 Staff member - $22,500

TOTAL COST OF MFG, DEV. SALES- $170,000 (Approx.)

EXPECTED PROBLEMS AND HOW THEY HAVE BE RESOLVED:

1. The simulation model developed may not run. To solve or avoid this problem building the simulation model incrementally. The simulation will run without any problems but due to the factory size some of the parts have to be shipped to other factories and due to the COVID-19 pandemic effects and delays, it could take weeks to get the parts back.

2. The simulation model may blow up due to using a limited educational version. To get around this problem, purchase the full academic version that is full scale to perform a successful model of the system from Systems Modeling Corporation in Sewickley in Pennsylvania

3. The experimental combination chosen for the experimental design may not be feasible. Redesign the system layout to accommodation the proposed changes in the system.

RESOURCES UTILIED TO SUPPORT PROJECT:

Two (2) key resources were utilized for the support of this project. The ARENA educational version software license and the MARMAC company facilities in Xenia, Ohio. The ARENA Simulation Modeling System academic version had the system entity size limitation of 150 which imposed a limitation on both the size and complexity of the simulation model and also the simulation modeling entities (<= 150) that could be accommodated during a simulation run without the model crashing. Judicious choice of variables sizes and feasible combinations provided a walkaround for this restriction leading to the successful completion of the project.

ARENA SIMUATION MODELING RESULTS

Measures of Effectiveness (MOEs) or the Measures of Performance (MOPs) of the system identified for study were analyzed and the results are presented in graphical and / or tabular form as indicated in Figures 5 to 11 and in Tables 1 to 3. The batch arrival rates, the station capacity and the station processing times have all been found to significantly affect the production rate at the 5% level of significance. The interaction effects have also been found to be significant at the 5% level.

DISCUSSION OF STUDY EXPERIENCES AND SIMULATION MODELING RESULTS

After running the simulation with ARENA 3.0 and executing the project, we have learned the value of developing a project plan and adhering to the specified schedule as a key to effective project management and implementation. We achieved and implemented the process design simulation modeling of the manufacturing system, as well as studied the factory layout using ad-hoc data. Justification is provided for how and why the project meets the complex engineering problem in support of the ABET outcomes assessment criterion 3 and outcomes s 1 to 3.

The best process design layout alternative, based on the Multi- Attribute Evaluation of the design alternatives, as presented in Table 4, is the process design alternative 3. Teamwork enabled success predicated on an informational and data gathering visit to the MARMAC Company in

Xenia, Ohio on February 17 2021 from 3 pm – 5 pm to obtain information in support of the model development. The Microsoft Word processing and editing system as well as the Google Docs system was used to document the study results. The model was debugged over several days within a couple of weeks, after which reasonable, defensible and reliable results were obtained.

SCHEDULE AND PROGRAM IMPLEMENTATION SAFE GUARDS

The weekly schedule utilized by the students, during each week of the semester in support of the senior design project are presented as follows:

Monday- 12pm- 2:30pm
Tuesday- 12pm- 4pm
Wednesday- 12pm – 4pm
Thursday- 12pm – 4pm
Friday- 12pm -4pm

CONCLUSIONS:

A challenging process layout project design project has been undertaken and executed in such a way that it addresses the intents of the ABET standards for design project execution including consideration of multiple alternative design solutions, multiple optimum solution specification, incorporation of uncertainty, risk, global engineering factors using a multi-attribute evaluation analysis and ranking. The modeling results indicated that the arrival rate, the processing time and the station capacity are all significant factors that influence the production rate at the 5% level, by which it is meant that if the experiment is repeated continuously under randomized but replicated, yet identical analysis experimental design trial conditions, only rarely, indeed as rare as five times or less out of 100 trials, would a different result, i.e. non-significance variable effects result, contrary to that already concluded, be observed.

RECOMMENDATIONS:

Purchase a Professional Site License as may be necessary, i.e. the ARENA Professional Simulation model software license as opposed to the Academic Site License that was used, to avoid the use of the entity-size-limited ARENA educational version site license.

Utilize the professional version and prevent the limited educational version ARENA model from crashing due to the limitation of no more than 150 entities allowed for the educational version.

For the next set of senior students interested in executing a process layout design simulation project, this project could be refined by collecting motion time measurement (MTM) data or time and motion data on the manufacturing operations to provide a more accurate, realistic and representative simulation of the jet engine lift manufacturing process.

FUTURE PLANS:

The future plans are to make a presentation of our project to the Industrial Advisory Committee (IAC) of the manufacturing engineering department and to obtain their feedback for improvement of the process design jet engine lift assembly project for the next sets of senior engineering students. This would be followed by the presentation of the results of the factory or manufacturing simulation study, at a future ASEE regional or national conference.

Future plan for the MARMAC Company in Xenia, Ohio the company that supported this process layout design engineering project includes the plan to grow the employee-base and expand the talent pool to a level it once was before the recession, which was around 25 employees.

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