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Layout Analysis using Discrete Event Simulation: A Case Study

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Robbie Holt, Lucas Simmons, Clay Walden, Glenn Dennis, Travis Hill
MSU CAVS-Extension
Canton, MS 39046

Abstract

This work focused on relaying out an assembly line, which is primarily responsible for the assembly and installation of utility truck beds and booms, into an expanded section of the plant. The assembly operations were analyzed and multiple layouts were developed along with other process improvement recommendations to increase line efficiency and throughput (e.g., point of use storage, line balancing, and improved material handling). Simulation models were developed using Flexsim for each layout to determine the most effective option. Multiple staffing scenarios were developed to determine the optimal configuration for maximum throughput. The analysis of the simulation results yielded a two-phase layout strategy. The first phase accomplished short term production goals, while the second phase encompasses future equipment purchases to reach long term production objectives.

Keywords
Simulation, Layout Analysis, Process Improvement, *Flexsim*

1. Introduction
Relocating equipment can be an expensive and time-consuming endeavor. In addition, determining whether a potential new layout will perform better than the current layout is difficult to determine until the new setup is complete. If the new layout does not provide adequate improvement then a lot of time and money is wasted. The ability to test the layout before moving equipment or purchasing new equipment is desirable. Simulation models allow for the evaluation of several different layouts with different staffing requirements over long periods of time that would take years to gather the data otherwise. This paper is a case study on the use of simulation modeling to differentiate between several layout options and numerous personnel scenarios to help determine the optimal solution.

2. Problem Overview
Mississippi State University's Center for Advanced Vehicular Systems Extension (CAVSE) was invited to help a small rural manufacturing company. The company produces utility trucks with hydraulic loaders. A recent facility expansion provides additional space to re-layout the loader assembly area. The objectives of the project were to:

- Design a more efficient flow of the entire assembly area including a balanced and less congested loader assembly line.
- Determine number of people required to run the loader assembly line and loader installation to achieve one truck per day throughput.
- Determine number of loader installation areas needed.
- Determine maximum achievable throughput based on fully staffed assembly area.

While considering the following:

- Spatial constraints of the building expansion.
- Limited positioning options of potential new wash and paint booths due to existing floor drains.
- Existing and projected demand.

3. Layout and Process Analysis

This section will discuss the overall approach taken to analyze the current system and design a new layout of the loader assembly line. A brief discussion of the current system is given, followed by an in depth look at the issues with that system, and the requirements to be addressed with the recommendations stemming from this project.

3.1 System Description

The loader assembly line, which is the focus of this project, runs one shift per day at eight hours per shift. Raw materials arrive at the rate needed to assemble one loader per day. Chassis arrive at an average rate of one per day. However, the current assembly line is not producing the desired throughput of one completed truck per day.

Figure 1 shows the loader assembly line. Raw materials are distributed to the sub-assembly areas for the boom, outriggers, and grapple. Materials are also taken to the loader assembly line where the pedestal is assembled and the valves and handles are installed. Once the pedestal exits the assembly line, it enters a staging area where the boom is installed onto the pedestal to complete the hydraulic loader.

Referring to Figure 1, a rolling chassis enters into “Chassis Prep 1” to add various weldments for attaching equipment later in the assembly process. The chassis then enters “Chassis Prep 2” to run electrical wiring for hydraulic hoses and various components. After this station, the chassis is sent to “Wash and Paint” in a separate building. Once painted, the chassis goes to “Loader Installation” to install the loader, outriggers, grapple, and body. The completed truck is tested outside and approved for delivery to the customer.

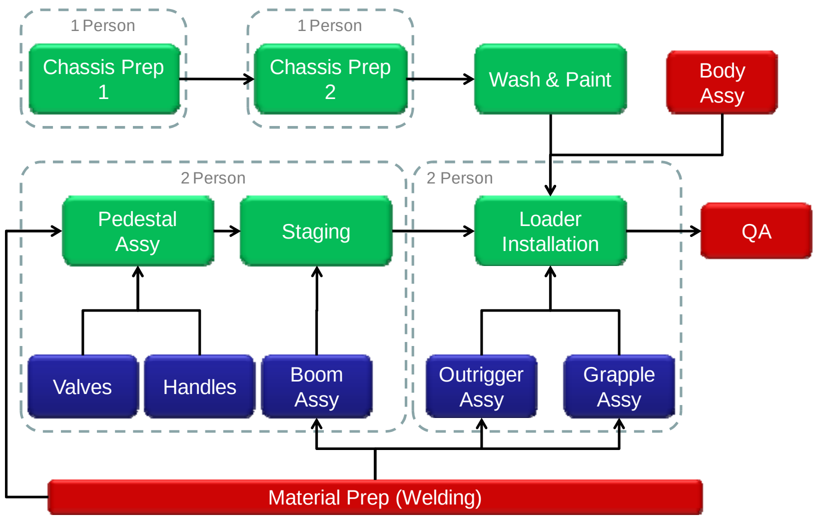

Figure 1: Loader Assembly Production Flow

Figure 2 shows the current loader assembly line. The current layout is confined to a small area that constrains the production and overall throughput of the line. One workstation is setup at the beginning of the roller bed. At that workstation, the loader is assembled and the valves and handles are installed. The loader is unloaded by crane at the end of the roller bed and the boom arms are installed.

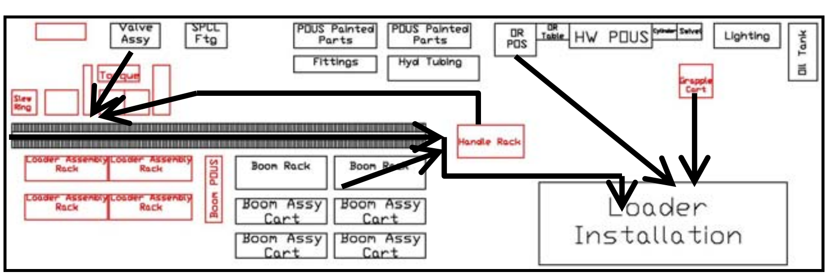

Figure 2: Current Loader Assembly Line Layout

The current layout of the loader assembly production area is displayed in Figure 3. Green arrows show the flow of the chassis and finished trucks as they move through the system. The chassis enters the plant from the top and backs into “Chassis Prep One”. The chassis then pulls out and backs into “Chassis Prep Two”, when finished the chassis is taken outside to an external building for “Wash and Paint”. After painting, the chassis comes back into the building and backs into “Loader Installation.”

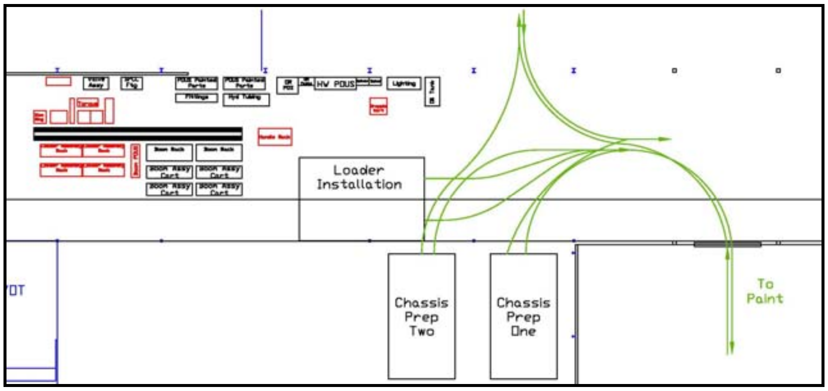

Figure 3: Current Loader Assembly Production Layout

3.2 System Analysis

The current loader assembly line is congested and setup for only one person to perform all of the assembly functions at the far left of the roller bed as seen in Figure 2. In addition, the storage of hardware needed to assemble the loader is contained in racks spread throughout the production area. The hoses are stored on the wall next to “Chassis Prep One” and “Chassis Prep Two”. Another concern is that the pedestal is taken off the roller bed and set on the floor to install the booms and complete the loader before being picked up again to install on the chassis. This is indicative of double handling; part of one of the seven wastes discussed in lean. As discussed by Hines et al. “the third waste, transport, involves goods being moved about. Taken to an extreme, any movement in the factory could be viewed as waste and so transport minimization rather than total removal is usually sought. In addition, double handling and excessive movements are likely to cause damage and deterioration with the distance of communication between processes proportional to the time it takes to feedback reports of poor quality and to take corrective action.” [1]

Figure 4 shows the proposed layout for the loader assembly line. The conveyor assembly line has been extended to provide additional working space on the line and allow for boom/pedestal assembly without removing the pedestal from the conveyor. The extension of the assembly line will address one of the major problems with the current layout, which is the inability of one workstation to produce at the desired throughput rate. After time studies were performed and analyzed, three separate workstations were set up to balance the work in order to reach the minimum throughput of one truck per day. The sub-assembly areas were moved and set up to feed the appropriate workstations. To eliminate double handling, a ball transfer table was added to allow the pedestal to be reoriented without the use of a crane so that the boom can be installed on the conveyor.

Another major concern of the current layout is the excess travel of the operator due to the storage of necessary parts spread out across the entire production area. Loader assembly station carts have been created that enable more product family specific point of use storage (POUS). Point of use storage is a technique that ensures people have exactly what they need to do their jobs – the right work instructions, parts, tools and equipment – where and when they need them [2]. As can be seen in Figure 4 these carts have been added to the “Pedestal/Pivot/Gear”, “Hose/Valve”, and “Handle Install” stations. They contain all the nuts, bolts, hoses, etc. needed for an individual station and prevent workers from having to leave their workstation to find parts. The loader assembly station carts are loaded from a central location or supermarket close to the beginning of the loader assembly line shown in Figure 5.

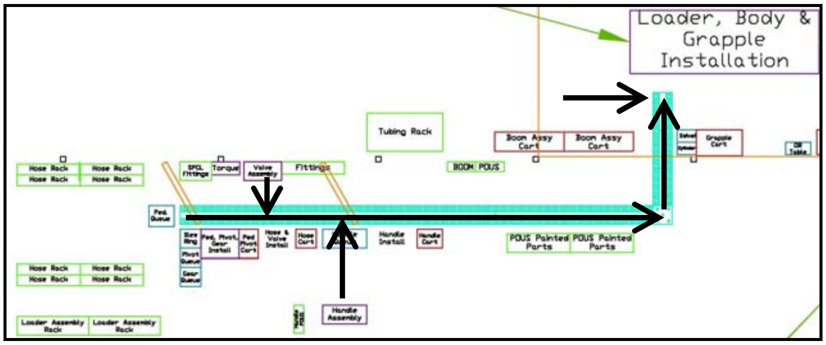

Figure 4: Proposed Loader Assembly Line Layout

Figure 5 displays the new overall layout of the assembly process. A green arrow shows the new improved flow, which eliminates having to back up the chassis. Eliminating backing up improves safety of employees, reduces possible material damage, and cuts down on handling and travel time. A wash booth and paint booth added to the building help eliminate environmental effects on quality and production. Finally, an area for testing has been established in the building, which allows the entire process to remain inside one building further reducing any environmental effects on production and cuts down on handling and travel time.

The layout shown in Figure 5 is proposed to the company as Phase 2. Due to current economic times, a Phase 1 solution that would not require the additional capital investment of adding the new “Wash Booth” and “Paint Booth” is proposed. Phase 1 would allow the company to make the changes earlier and enable them to take advantage of the other benefits of the proposed layout. Phase 1 reverses “Chassis Prep One” and “Chassis Prep Two” to send the chassis outside to the existing paint booth while still taking advantage of the improved flow not requiring the chassis to back up. After painting, the chassis enters the door below “Chassis Prep One” and continues through the process as it would in Phase 2.

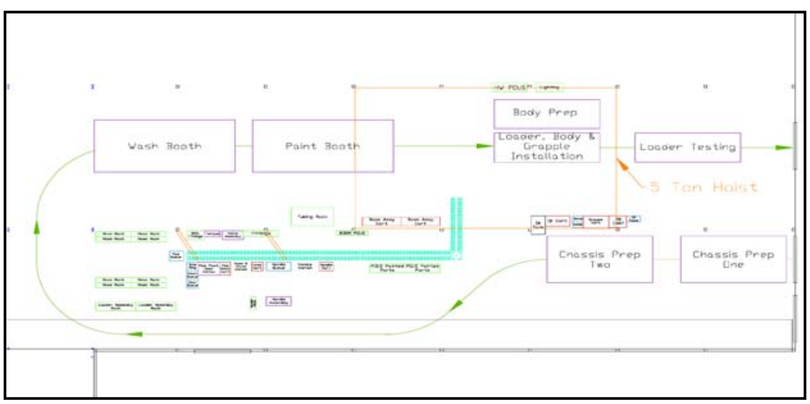

Figure 5: Proposed Phase 2 Layout

4. Simulation Analysis and Results

The simulation models used in this project are discrete, dynamic, and stochastic and will henceforth be called discrete-event simulation models [3]. Discrete-event simulation is a powerful tool for deciding on different alternatives. This section will discuss the use of simulation models to compare the current layout with the alternative layouts and will address different staffing scenarios to determine the optimal configuration for maximum throughput given the constraints.

4.1 Layout Simulation

The objective of this project was to design a more efficient flow of the loader assembly area in order to achieve one truck per day throughput. Several alternative layouts were developed and evaluated. Discrete-event simulation models using the *Flexsim* simulation package were developed to evaluate the alternatives.

The current layout was modeled to provide a base case for comparison purposes. Phase 1 and Phase 2 were also modeled to determine if they meet the minimum throughput of one truck per day. The simulation model of the current layout produced 0.85 trucks per day, which is below the one truck per day requirements. This reflected what the customer was seeing in the real system. Phase 1 and Phase 2 were both able to produce more than one truck per day. However, Phase 2 was determined to be a more desirable layout due to a higher potential throughput as a result of a reduction in overall chassis travel distance.

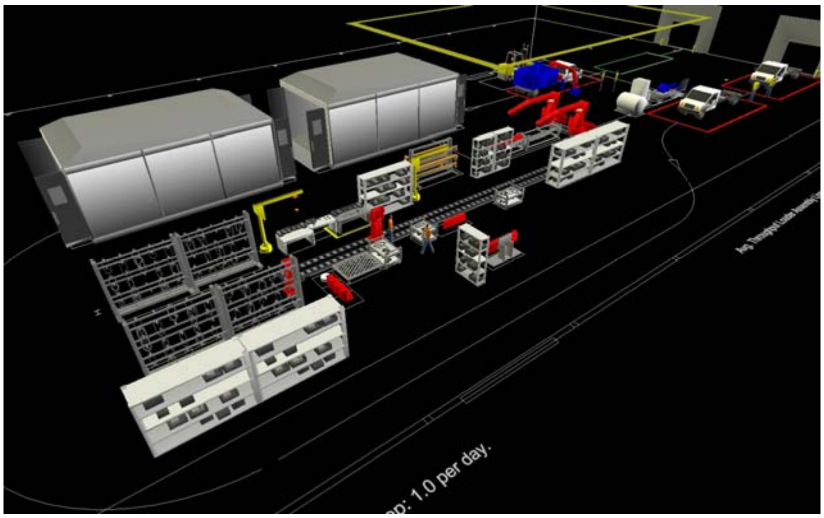

Figure 6: Final Layout Simulation Screen Shot

4.2 Staffing Simulation

After the most efficient layout had been determined, several other project objectives needed to be addressed. These objectives were the minimum number of people required to run the assembly area to achieve one truck per day throughput, the number of loader installation areas needed to achieve the required throughput, and the maximum achievable throughput based on a fully staffed assembly area. Working with the company, three scenarios based on the most efficient layout (Phase 2) were designed and tested to answer the above objectives.

Scenario 1 consists of two people on the loader assembly line and two people in the loader installation area. As can be seen in Table 1 the average system throughput was 0.96 trucks per day, which fails to meet the minimum of one truck per day. The loader assembly line is able to produce enough, but the “Chassis Prep” area is the bottleneck because of excessive work content.

Scenario 2 consists of two people on the loader assembly line and two people in the loader installation area just as in scenario 1. However, through discussion with the customer it was determined that by improving certain aspects of “Chassis Prep One” and “Chassis Prep Two” the processing times of those stations could be reduced. After reducing the processing times in those stations, Table 1 shows that the system throughput becomes 1.23 trucks per day. This scenario also shows that throughput can reach the desired one truck per day with only one loader installation area.

Scenario 3 deals with the project objective of determining the maximum achievable throughput based on a fully staffed assembly area. Table 1 shows that a fully staffed assembly area can produce 2.3 trucks per day with one loader installation area.

Table 1: Staffing Scenario Outputs

	Scenario 1	Scenario 2	Scenario 3
Chassis Prep Throughput	**.96**	**1.24**	**2.3**
Loader Assembly Line Throughput	**1.23**	**1.23**	**2.3**
Loader Installation Utilization	**45%**	**100%**	**65%**
System Throughput	**.96**	**1.23**	**2.3**

4.3 Results

The simulation models showed that Phase 1 and Phase 2 layouts could produce the minimum throughput requirement of one truck per day. However, the model proved that Phase 2 was the preferred solution because less travel distance ultimately provided a greater throughput potential. In addition, the model showed that the Phase 2 layout could produce more than one truck per day with two people working the loader assembly line and two people working in one loader installation area. If fully staffed, Phase 2 could produce a maximum throughput of 2.3 trucks per day.

5. Conclusion

In this project, a layout analysis was explored using discrete-event simulation. Several layouts were designed and tested to determine the most efficient flow that met the requirement of one truck per day throughput. Three scenarios were designed and tested to determine the minimum staffing requirements and the number of loader installation areas needed to meet the desired throughput of the system. In addition, the maximum throughput based on a fully staffed assembly area was determined.

This work demonstrates the applicability and importance of simulation modeling in plant layout design before investing time and money in equipment or additional staffing.

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