ORIGINAL

Modeling of Automobile Assembly Line Performance Using ARENA Simulation Software

Modelización del rendimiento de la línea de montaje de automóviles mediante el software de simulación ARENA

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ABSTRACT

Due to the intense competition in today's business environment, companies must continuously analyze and enhance their existing manufacturing systems. Discrete event simulation, which is especially helpful for simulating queuing systems, involves describing the system as it evolves. The building and study of a simulation model of an existing production line are the main topics of this paper. The findings demonstrate that the current system's throughput is low due to bottlenecks, extended processing times at workstations, and inefficient resource utilization, all contribute to productivity losses in automotive assembly lines. This paper aims to evaluate the efficiency of the production line performance of automobile assembly lines using Arena modeling and simulation. Data provided by the company's management is utilized to calculate the processing time and standard time for each step in the production line. Additional information is gathered through direct observation of the assembly line. A car assembly manufacturing line was selected as a case study, and Arena 16.0 software was employed for basic modeling and analysis to achieve these objectives.

Keywords: Computer Simulation; Assembly Line; Arena; Bottlenecks; Modeling; Throughput.

RESUMEN

Debido a la intensa competencia en el entorno empresarial actual, las empresas deben analizar y mejorar continuamente sus sistemas de fabricación existentes. La simulación de eventos discretos, especialmente útil para simular sistemas de colas, consiste en describir el sistema a medida que evoluciona. La construcción y el estudio de un modelo de simulación de una línea de producción existente son los temas principales de este artículo. Los resultados demuestran que el rendimiento del sistema actual es bajo debido a los cuellos de botella, los tiempos de procesamiento prolongados en las estaciones de trabajo y la utilización ineficiente de los recursos, todo lo cual contribuye a las pérdidas de productividad en las líneas de montaje de automóviles. El objetivo de este trabajo es evaluar la eficiencia del rendimiento de las líneas de montaje de automóviles mediante el modelado y la simulación Arena. Se utilizan datos proporcionados por la dirección de la empresa para calcular el tiempo de procesamiento y el tiempo estándar de cada paso de la línea de producción. Se recopila información adicional mediante la observación directa de la cadena de montaje. Se seleccionó una cadena de montaje de automóviles como caso de estudio y se empleó el software Arena 16.0 para la modelización y el análisis básicos con el fin de alcanzar estos objetivos.

Palabras clave: Simulación por Ordenador; Línea de Montaje; Arena; Cuellos de Botella; Modelado; Rendimiento.

INTRODUCTION

In today's rapidly and dynamically changing economic conditions, manufacturing industries face considerable difficulties as manufacturing technology continues to advance in the age of globalization. For instance, they are ensuring customer satisfaction, predicting product demand for the market, increasing factory efficiency, fierce market competition, technological advancements, etc. Manufacturing company managers and engineers are actively looking for ways to deal with significant issues in production lines. These difficulties include problems with inefficiency, long waits, and processing times at workstations, all of which harm production and raise costs. The simulation technique known as discrete-event system simulation is used to study, analyze, and optimize manufacturing systems.[1] The objective of this paper is to give the industry a comprehensive set of tools, techniques, and procedures to allow examination of current worker and machine performance systems using a consequent simulation system model that could be used before an existing system is altered or a new system is built, to reduce the likelihood of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under- or over-utilization of resources, and to optimize Simulated events might be discrete or continuous. The system's state is constantly changing throughout time under a constant model. However, in a discrete model, changes can only occur at specific moments. In this study, the performance of workers and machinery at The General Company for the Automotive Industry is modeled using discrete event simulation. An essential step in ensuring that the firm's operations are running smoothly is to simulate the firm's activities using a discrete event simulations program, such as the Arena software, analyze the results of the simulation, and continually seek out and implement solutions to optimize the experimental model and to ensure efficient use of the available resources.[2]

Related Works

Production can be defined as the systematic transformation of one material form into another through chemical or mechanical processes to generate or improve the product's utility for the end user. Therefore, production constitutes a process that adds value.[3] At every phase of processing, there is an incremental increase in value. Discrete-event simulation may be helpful in various disciplines because it enables projects to be studied and their feasibility to be determined without making significant investments. Identifying waste, improving the layout, and working on the line balance for optimizing resources helped improve the productivity of the assembly line.[4] There is a lot of literature on applying simulation to manufacturing systems. Han et al. have used DES models to show the advantages of using VSM as a lean technique. Use simulation to address the issue of quality inspection.[5] A computer simulation analysis was conducted to model production process efficiency, perform product life analyses of the production line, and address the allocation of intermediate buffers.[6] A TV assembly/production line's performance was measured to meet the study's objective. A detailed analysis revealed that the production line had bottlenecks, which were queuing the stations.[4] The research demonstrated the integration of critical lean tools, such as Value Stream Mapping (VSM), with the simulation of a batch production system's current and future states in the leather industry.[7] The study focuses on Simulating the automobile repair shop firm's activities using Arena software to analyze the result.[8] The repair shop's capacity is primarily influenced by the possibility of an event that designates a specific number of vehicles to each intervention category[9] focused on line balancing in a textile business using simulation and optimization approaches. The study aimed to streamline material flows within the company, maximize labor capacity utilization, minimize cycle times and material requirements for processes, and eliminate bottlenecks for efficient capacity utilization.[10]

METHODOLOGY

The research's methodology explained in Figure 1 illustrations. The details of each section of the methodology flow chart are provided in the following paragraphs.

The State Company for automobile assembly manufacturers of SAIPA saloon cars, Selecting the company and production line which correlates with the objective of the study is one of the important aspects in conducting the study.

Data Collection

For simulation and verification, real-world operational data are required. The information was gathered by keeping an eye on the line. Entities per arrival, line configuration, and machine process types comprise the data collected. The company's management provided the processes and standards for each line's operations. The model built into ARENA software is discussed in regular meetings with the center's engineer.
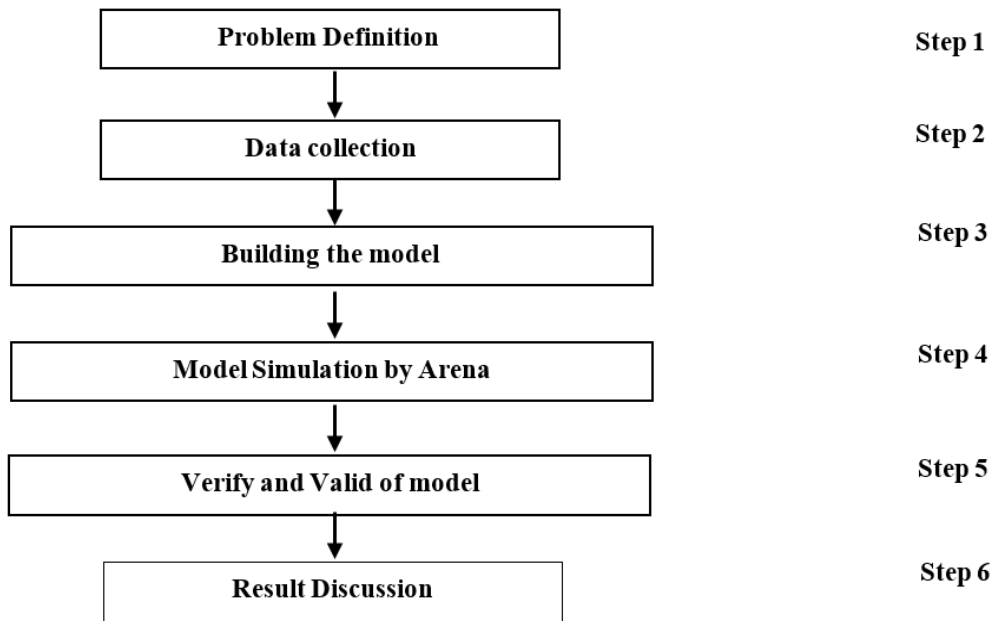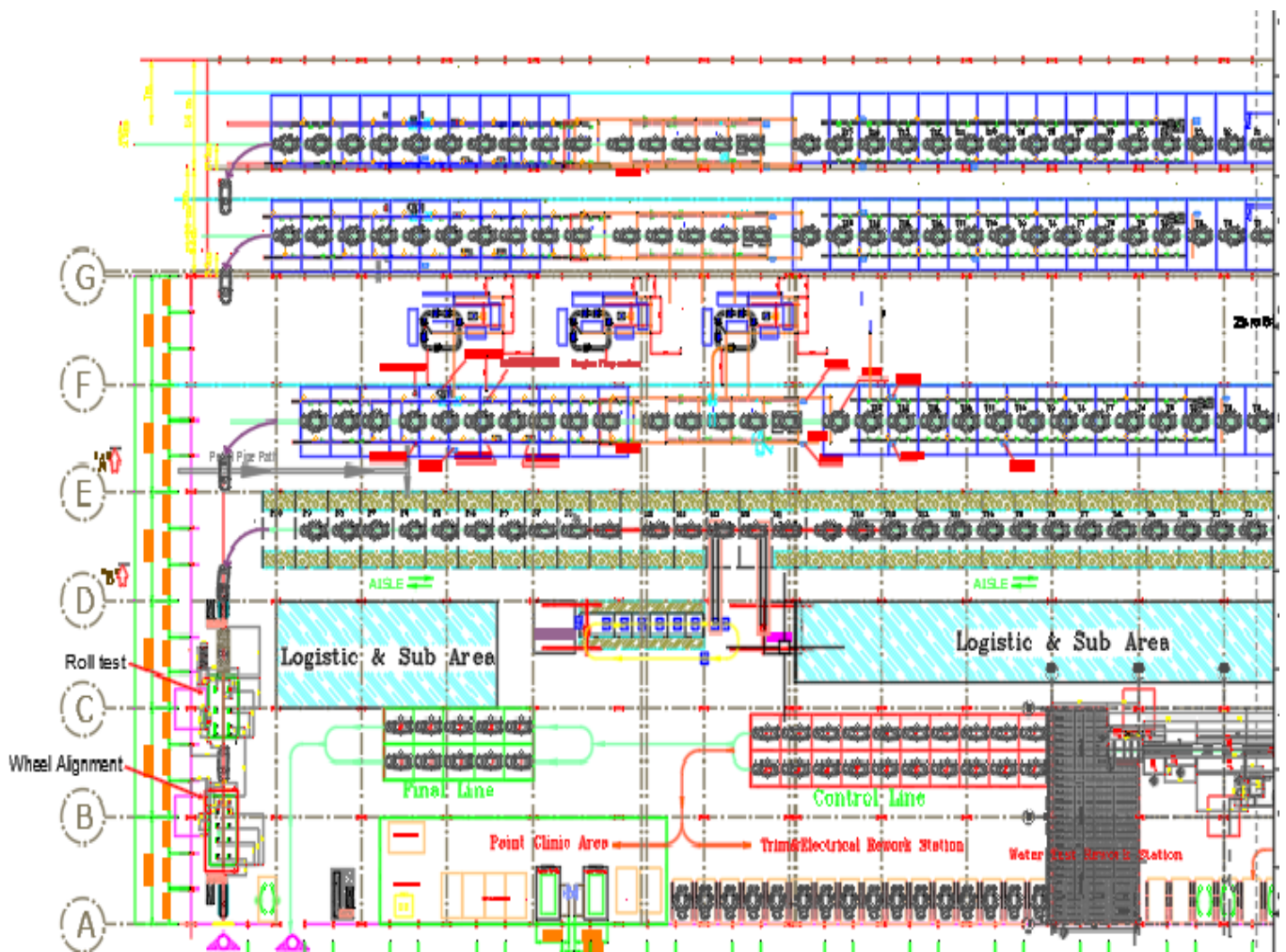
Figure 1. Suggested Methodology Steps

Figure 2. The layout of productions line

Table 1. Step by Step Line SAIPA Assembled		
Assembly operation stations	**Activities to be performed**	**Abbreviations of the operation**
1	-Washing the body and prepare to assemble - Connecting the fuel tank	T0
2	- Connecting the insulation under the dashboard - Connecting the door lock	T01
3	-Prepare the main and subsidiary wires -link the hand brake	T02
4	- Connecting the brake separator to the pipes - Connecting (wiper motor) with the arms	T03
5	- Connecting steering column - Connecting pedals(klieg, fuel, brakes)	T04
6	- Connecting the cooling radiator - Buckle the back seat belt	T05
7	- Connecting the front doors - Front door glass installation	T06
8	- Connect the back doors - Rear door glass installation	T07
9	- Bonding of ground insulation and floor covering - Connecting the four door locks	T08
10	- Connecting the rear bumper and taillights - Connecting the box lock	T09
11	- Connecting the cooling system with the fan - Dashboard placement and instrument cluster	T10
12	- Connecting the cooling tubes - Attaching the front strut	T11
13	- Front and rear linkage - Connecting parts of the structure	T12
14	- Attaching side mirrors - Connecting the steering wheel	T13
15	- Vehicle inspection point by quality control	T14
16	-Connecting the side brake to the brick tubes - Installing the double in (Shift Drive) - Installing the engine	M01
17	-Connecting the fuel hose -Attaching the exhaust insulator	M02
18	- Installing the four wheels -Connecting the front brakes	M03
19	-Connecting air ducts and air filter and power tubes - Connecting the radiator	F01
20	-Connecting headlights -Connecting the fuse box -Installing water sprinklers for the windshield	F02
21	- Connecting the front and back seats - Preparing the battery - Installing the front and back windows	F03
22	- Filling the radiator with water - Filling the car engine with oils - Filling refrigerant gas into the cooling system - Filling the tank with fuel - Filling the steering wheel oil	F04
23	- Definition and programming of the control panel - Vehicle inspection point by quality control	F05

Table 2. Average times and number of worker in stations		
Abbreviations of the operation	**Mean processing time for each station**	**No worker each station**
T0	10	4
T01	15	4
T02	15	4
T03	15	7
T04	15	7
T05	15	6
T06	15	5
T07	15	6
T08	15	7
T09	15	6
T10	15	5
T11	15	5
T12	15	5
T13	15	5
T14	15	5
M01	15	6
M02	15	6
M03	15	6
F01	15	4
F02	15	3
F03	15	2
F04	15	4
F05	15	4

Building of Model & Simulation by ARENA

A comprehensive simulation model has been developed using ARENA simulation software version 14, which is a powerful tool for modeling and analyzing systems. This model represents the assembly line for SAIPA saloon cars. The production operates on a single shift per day, with a total available time of 7,5 hours per shift. This includes a 30-minute lunch break.
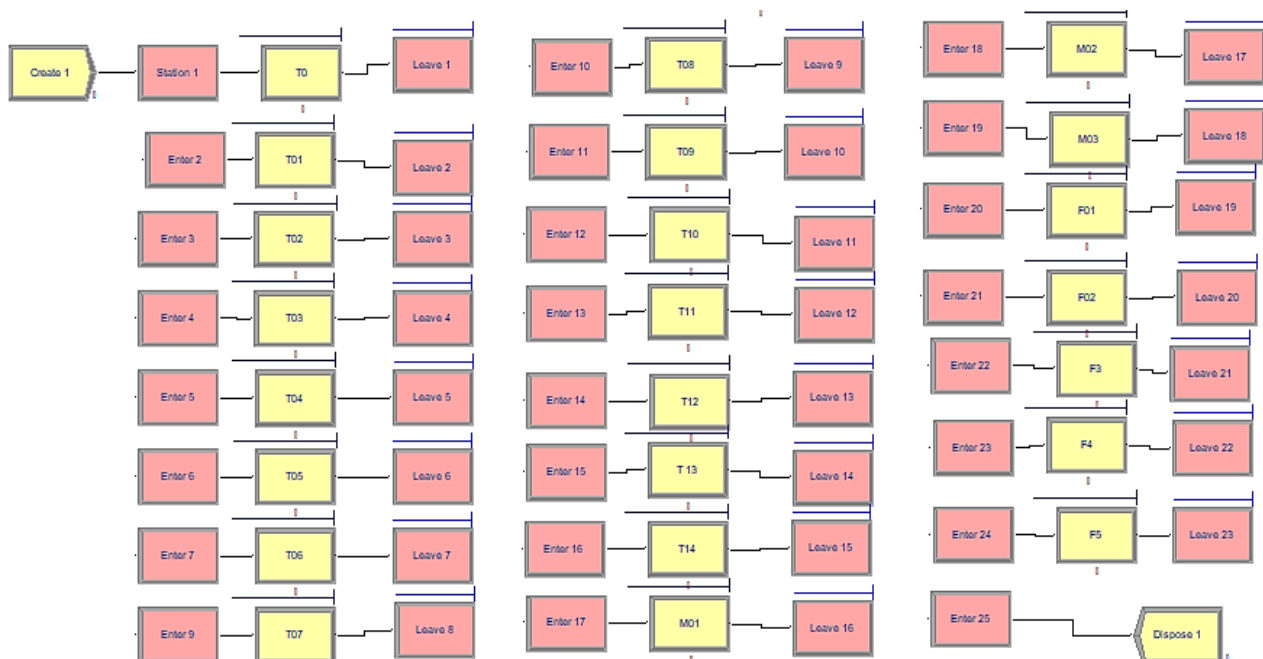

Figure 3. Simulation Model of Production Line

Verification and Validation of Model

Simulation models are used to represent real-world systems, but they can never be exact duplicates of those systems. These models provide a simplified version of the system that can be used to analyze and predict its behavior under different conditions. It is important to keep in mind that the accuracy of the model depends on the quality and completeness of the data used to create it. It is essential to thoroughly verify and validate a model for its intended use. Verification ensures correct implementation of a model's design. Validation involves evaluating how closely a simulation model and its associated data resemble the actual real-world system. This comparison involves analyzing and comparing the simulation model outputs with the performance of the existing system. According to the simulation model, the daily production output for five replications averaged 28 cars which aligns with the system's actual daily production of 28 vehicles. This indicates that the simulation accurately reflects the production line.

RESULTS AND DISCUSSION

In this section, we will present and discuss the results of this study, providing a detailed analysis of the findings and their implications.

Designing an effective system requires understanding, data collection, and rigorous verification.

1. The downtime of all machines could be higher on average.
2. After analyzing the time data, it is clear that jobs should be distributed evenly.
3. The labor costs associated with the production line exceed the planned budget.

There are three main effected parameters on production assembly line:

- Workers utilization: The number of workers is more than the planned number. At the same time, most of the individuals in the organization work with little efficiency.

Table 3. The relation between number in and out of cars in line

Number Out	28
Number In	59
Average WIP	32

Table 4. The calculation of salary costs

Total no of worker	116
Each worker has salary	400,000 IQD
Total salary in month	46,400,000 IQD
Total salary for 6 month	278,400,000 IQD

Table 5. Number of workers with their efficiency percentage

Worker symbol with number of station	No Worker	Value Utilization
W M1	6	7,9 %
W0	4	13,6 %
W01	4	18 %
W02	4	16,8 %
W03	7	10 %
W04	7	9,9 %
W05	6	9,9 %
W06	5	12,4 %
W07	6	10,4 %
W08	7	8,5 %
W09	6	9,6 %
W10	5	11,7 %
W11	5	11,6 %
W12	5	10,9 %
W13	5	8,9 %

Table 5. Number of workers with their efficiency percentage		
Worker symbol with number of station	No Worker	Value Utilization
W14	5	17,7 %
WF1	4	10,3 %
WF2	3	13,7 %
WF3	2	19,7 %
WF4	4	9,5 %
WF5	4	9,4 %
WM2	6	15,6 %
WM3	6	15,6 %
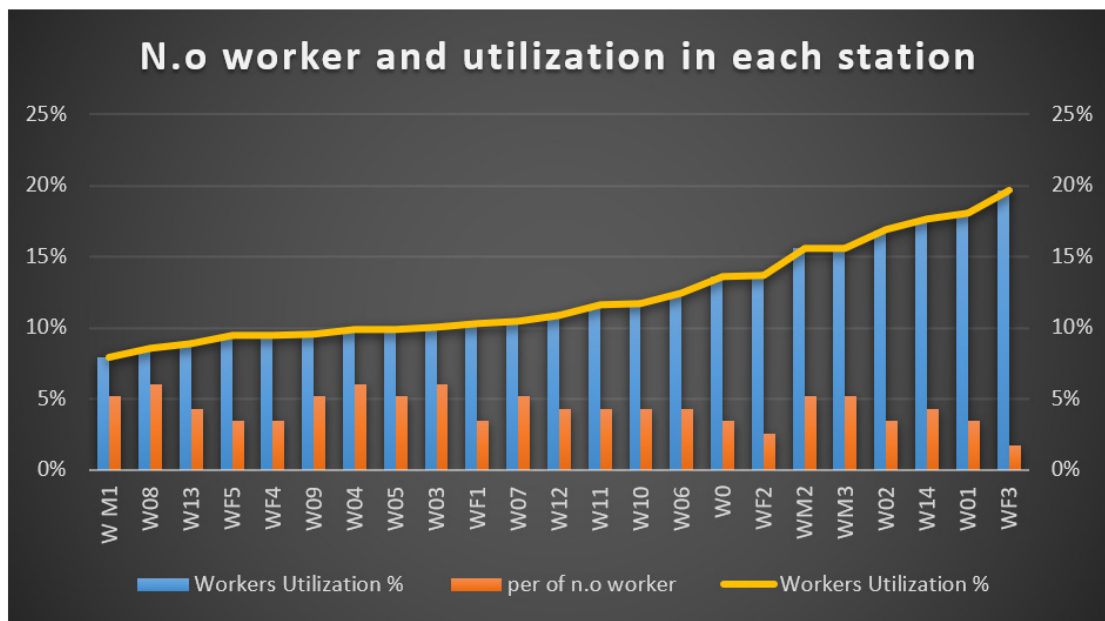
Figure 4. The output of existing production lines for worker

• Work-In-Process (WIP): The current quantity of work in process exceeds the planned amount. Simultaneously, aligning work-in-process (WIP) with an enhanced throughput can be realized through efficient inventory management and process optimization.

No.	Station name queue	Average waiting time
	Table 6. The Station name queue and average waiting time	
1	F01.Queue	0,00
2	F02.Queue	0,00
3	F4.Queue	6,4296
4	F5.Queue	0,00
5	M01.Queue	0,00
6	M02.Queue	17,0946
7	M03.Queue	18,7270
8	T 13.Queue	19,4500
9	T0.Queue	18,9320
10	T01.Queue	19,0098
11	T02.Queue	19,2417
12	T03.Queue	18,5868
13	T04.Queue	18,7662

Table 6. The Station name queue and average waiting time		
No.	**Station name queue**	**Average waiting time**
14	T05.Queue	19,0097
15	T06.Queue	19,6863
16	T07.Queue	18,7174
17	T08.Queue	18,7591
18	T09.Queue	18,9236
19	T10.Queue	19,9721
20	T11.Queue	19,3084
21	T12.Queue	19,0719
22	F3.Queue	19,3494
23	T14.Queue	19,4610

CONCLUSIONS

The existing assembly production line was analyzed, and existing setup bottlenecks were identified in the process. A simulation-based model was developed using the Arena 16 simulation package, and generated results were tested with production line manufacturing mentioned in the case study. All the values used in the comparison were generated by simulation in Arena 16 at five replication lengths for six-month run periods. A discrete-event system simulation is a powerful tool for modeling and analyzing manufacturing systems. It has a good record of applications in the industrial sector. This study illustrates the benefits of the time/cost tradeoff, including the potential advantage of achieving good service levels and helping companies avoid unnecessary investments. The presented work scope can be to improve the cost associated with labor and maintenance costs.

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None.

CONFLICT OF INTEREST

None.

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