Preparing Operations Scheduling Using Simulation: A Case Study in Ramadi Teaching Hospital

Samah Hassan Abdul Hamid and Shifa Balasim Hassan
Technical College of Management - Baghdad, Middle Technical University, 10047 Baghdad, Iraq
dcc2013@mtu.edu.iq, shifa-2017@mtu.edu.iq

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Abstract: This study aims to schedule surgeries for incoming patients at Ramadi Teaching Hospital by using simulation and evaluating it based on scheduling criteria, followed by selecting the best technique based on the evaluation results. Simulation was used as a suitable method to model the proposed surgery scheduling based on the scheduling methods. This study was targeted at the urology department because the department performs a large number of surgeries and has only one operating room. The case study approach was adopted to analyse the hospital's reality and build a simulation model, then apply operational scheduling techniques and evaluate its performance through scheduling criteria. The research sample was represented by the surgeries performed in January, which amounted to (217) surgeries in the morning meal. The simulation model is based on the fact that the number of surgeries is the same as in the real world, and surgery and due times are randomly different for each patient. The study concluded that the Shortest Processing Time (SPT) technique outperformed two key metrics for healthcare organizations: the number of surgeries completed in the room and the average number of hours it takes to complete these surgeries. The study ends with recommendations, the most important being the need to abandon the traditional way of fixing surgeries and practice the SPT technique.

1 INTRODUCTION

Quality management systems have become a fundamental requirement for industrial organizations operating in highly competitive and safety-critical sectors, particularly the automotive industry. Among the internationally recognized standards, IATF 16949:2016 represents a comprehensive framework that integrates ISO 9001:2015 requirements with additional automotive-specific quality and process control provisions developed by the International Automotive Task Force (IATF).

Unlike general quality standards, IATF 16949 emphasizes not only compliance with customer requirements but also the prevention of defects, reduction of variation, and continuous improvement across the entire automotive supply chain. This standard is designed to ensure consistent product quality, operational efficiency, and risk-based thinking throughout production and supporting processes.

Recent advancements in data analytics and artificial intelligence have further strengthened the role of quality management systems by enabling real-time monitoring, predictive analysis, and decision-support capabilities in manufacturing environments. These technologies facilitate improved resource allocation, reduction of operational inefficiencies, and enhanced process control, aligning industrial operations with Industry 4.0 paradigms.

In developing countries, however, many industrial organizations still face challenges in fully implementing international quality standards due to limited technical capacity, insufficient process digitalization, and weak compliance monitoring systems. This is particularly evident in legacy manufacturing facilities that continue to rely on traditional, experience-based operational practices.

The State Company for Automotive Industry and Equipment in Iraq represents one such context, where operational processes—especially in production-critical units such as battery manufacturing—require systematic evaluation against international standards. In this regard, the present study focuses on assessing operational compliance with Clause 8 (Operation) of IATF 16949:2016, using a structured analytical framework supported by quantitative measurement techniques and computational assessment tools.

Accordingly, the study aims to identify the gap between actual operational practices and standard requirements, and to quantify the level of compliance across key operational dimensions, including production planning, supplier control, service provision, and non-conformance management.

2 THEORETICAL FRAMEWORKS

Scheduling is allocating organizational resources to execute tasks within a defined period, as described in [8]-[10]. It is used for resource allocation, human resource planning, production process scheduling, and material procurement. As described in [11] and [12], this complex task requires precise planning, sequence of work, timing, and task distribution according to customer demands to minimize the total task completion time, increase productivity, and increase production efficiency [13].

Operations scheduling is necessary to reduce costs and optimize organizational resource utilization [14]. The benefits include a clear picture for management of internal activities and workflows, fair work distribution and job order arrangement, and employee satisfaction. The strategic importance of scheduling in two areas. Scheduling is especially critical in healthcare organizations, where it facilitates the distribution of duties among healthcare staff and work centers, allocates devices, equipment, and nursing staff to departments, and speeds up healthcare service delivery [15], [16].

The most common methods used today are scheduling techniques [17], [18], these techniques are heavily used by organizations to solve scheduling problems by arranging work orders by priority [19]. Operations scheduling techniques for single-machine tasks were divided into static and dynamic. In this study, we consider static techniques for operations scheduling [20], i.e., techniques that determine task sequences on a single machine or work center.

The most common scheduling techniques, often applied in process-oriented organizations such as hospitals, which include [21]:

1) First-Come, First-Served (FCFS) Technique means that tasks are processed in the order they arrive at the work center. FCFS prioritizes arrival sequences at the machine or work center, ignoring due dates and processing times [22].
2) Shortest Processing Time (SPT) Technique. This technique arranges tasks according to the least processing time at the work center and executes the task with the least processing time first, followed by the other tasks in ascending order of processing time.
3) Earliest Due Date (EDD) Technique. First, tasks are processed by their due dates; in this case, the earliest tasks are processed first, followed by the other tasks in ascending order of their due dates. This technique is the best choice for organizations oriented to priority in order fulfillment, to minimize average flow time and work-in-progress inventory, and to maximize the utilization rate of available resources.
4) Longest Processing Time (LPT) Technique. This technique prioritizes tasks with the longest processing time first and then the rest in descending order of their processing time.

The SPT technique decreases average flow time, number of delayed tasks, and work-in-progress inventory while increasing utilization [23]. However, it hurts tasks that take a long time to process since the difference between the completion and due dates is large [24]. The study in [25] reported that EDD is often applied when processing times of tasks are long and critical. It can, however, delay the completion of shorter processing time tasks beyond their due dates in favor of longer tasks.

The operations scheduling approach depends on different criteria that affect what operations managers want to achieve, like meeting due dates, minimizing completion time, or maximizing resource utilization by minimizing idle time [20]. In [26], it was stated that operations scheduling is evaluated based on several criteria, depending on the operational goal, such as reducing idle time and maximizing resource utilization. The most common criteria include:

The completion time was defined as the time a task spends in a service system or factory, including total operational (processing) times, setup and preparation times, transition times between tasks, and wait times caused by machine breakdowns or unavailability. This criterion aims to minimize each task's completion time [6]. The completion time rate is calculated by dividing the total flow time by the number of tasks, as shown in the following equation:

$$MS = \frac{\sum p_j}{J}. \quad (1)$$

Where:

- Pj = processing time of the job;
- J = number of jobs.

Utilization rate refers to the percentage of actual work time for a specific resource, calculated as the total active time of a machine or worker divided by the total available time multiplied by 100. The aim is to maximize resource utilization [27], as represented in the following equation:

$$U = \frac{\sum A_j}{\sum p_j} \times 100\%, \quad (2)$$

where:

- Pj = processing time of the job;
- A_j = Available time.

Number of Tasks in the System: Pinedo [6] defined this as the total tasks awaiting processing and held as work-in-progress inventory. The aim is to reduce the level of work-in-progress by calculating the current work rate for a set of tasks by dividing the total flow time by the total completion time, as shown in the following equation:

$$WIP = \frac{\sum F_j}{\sum p_j}, \quad (3)$$

where:

- WIP=Work in Process;
- F_j = Flow time of the job.

Delay time was defined as the time by which completion of a task outstrips its specified due date, a critical criterion since noncompliance with due dates can lead to loss of customers and competitive markets [28]. The aim is to minimize the number of delayed tasks relative to their due dates, represented by the difference between flow time and due date, as shown in the following equation [29]:

$$T = \frac{\sum t_j}{J}, \quad (4)$$

where:

- T=Average tardiness;
- t_j = Flow time of the job;
- J=total number of jobs.

3 IMPLEMENTATIONS

3.1 Simulation Model Inputs

A simulation model was designed to schedule surgical operations using operations scheduling techniques based on data collected and analyzed from the surgery unit's records for the research sample. Table 1 presents a sample of the data collected and analyzed for constructing the simulation model.

Table 1 illustrates the following details:

- Number of Surgeries. Is the number of Urology Surgery Unit surgical procedures performed in the morning shift of January, which was 217.
- Surgery Scheduling Date. Is the date when the physician decides the patient is ready for surgery and sets it.
- Surgery Date. Represents the date when the specialist performed the surgery. The hospital review form or prescription document from private clinics, which are filed in the patient's record in the archive room of the Statistics Department, contains this information.
- Surgery Time. It denotes the time it takes to do the surgery, from when the patient enters the operating room to when they leave.
- Due Times. The surgery scheduling date minus the surgery date, excluding public holidays and Fridays, was calculated for the due time for each surgery. When the scheduling date is subtracted from the surgery date, it is calculated and used to calculate the average delay times.
- Delay Times. It represents the number of hours the surgery was delayed from its scheduled date. The delay average is calculated by subtracting the flow time from the due time for each patient and adding the delay times to give the total delay time. Delay times less than zero were converted to zero, indicating that the surgery was not delayed. A positive delay time means the surgery was delayed and took longer than the due time.
- Available Time. It refers to the total working time in January. The month under study had six working days per week, so excluding public holidays and Fridays, when no work was done, there were 26 working days. The total working time in the hospital is the number of working days times daily working hours, so 182 working hours in the month. It is used to calculate the utilization rate.

3.2 Simulation Dataset Description

Table 2 provides a simplified segment of the simulation table, consisting of 217 surgeries. It includes the essential data for applying scheduling techniques and evaluating them according to operations scheduling criteria, as follows:

- The total number of surgeries is represented by the last number in the sequence column and is used to determine the average completion time, utilization rate, and delay rate.

- The sum of surgery times is used to calculate the average completion time, and it is also used in applying scheduling techniques (SPT, LPT).
- Flow time is used to calculate the average number of jobs in the system.
- The delay time is used to determine the average delay time.
- The surgery date is used in applying the (EDD) technique.
- The surgery scheduling date is used in applying the (FCFS) technique.

3.3 Simulation Model Development

MATLAB were used to create simulation models for this research because it can generate random data, perform mathematical and engineering operations, analyze data, and present the results in tables and graphs. The logical steps for the simulation model are represented in a flowchart, as shown in Figure 1. The steps are as follows:

- Identify Key Simulation Variables. These include the surgery duration and due time used when applying scheduling techniques.
- Calculate the Mean and Standard Deviation. These are computed for the surgery duration and the due time.
- Generate Random Data. Data similar to the actual data are generated within the same range of the mean and standard deviation of the real data using MATLAB, with 1,000 iterations to achieve data stability.
- Apply Operations Scheduling Techniques. FCFS, SPT, EDD, and LPT are applied to the generated random data.
- Calculate Scheduling Criteria. Each iteration's scheduling criteria are calculated for the random data.
- Compute the Average for Each Criterion. The mean for each scheduling criterion is obtained by dividing by the total iterations, which is 1,000 cycles.

Table 1: Data collected and analyzed for building the simulation model.

No	Surg. Schedul.	Surg. Date	Surg. (hours)	Flow (hours)	Due (hours)	Delay (hours)
1	28-Dec	2-Jan	0.5	0.5	21	0
2	28-Dec	2-Jan	0.25	0.75	21	0
3	30-Dec	2-Jan	0.33	1.08	14	0
4	25-Dec	2-Jan	0.58	1.66	42	0
5	30-Dec	2-Jan	0.33	1.99	14	0
6	26-Dec	2-Jan	1.25	3.24	35	0
7	27-Dec	2-Jan	0.33	3.57	28	0
8	30-Dec	2-Jan	0.42	3.99	14	0
9	30-Dec	2-Jan	0.25	4.24	14	0
10	31-Dec	2-Jan	0.33	4.57	7	0
11	28-Dec	2-Jan	0.25	4.82	21	0
12	26-Dec	2-Jan	0.33	5.15	35	0
13	27-Dec	2-Jan	0.42	5.57	28	0
14	27-Dec	2-Jan	0.5	6.07	28	0
15	31-Dec	2-Jan	0.33	6.4	7	0
16	30-Dec	3-Jan	1.33	7.73	21	0
17	30-Dec	3-Jan	0.58	8.31	21	0
18	31-Dec	3-Jan	0.42	8.73	14	0
19	31-Dec	3-Jan	0.5	9.23	14	0
20	28-Dec	3-Jan	2	11.23	28	0
21	31-Dec	3-Jan	0.5	11.73	14	0
22	27-Dec	3-Jan	0.58	12.31	35	0
23	27-Dec	4-Jan	1.5	13.81	42	0
24	31-Dec	4-Jan	0.33	14.14	21	0
25	30-Dec	4-Jan	0.25	14.39	28	0
26	30-Dec	4-Jan	1	15.39	28	0
27	31-Dec	4-Jan	0.5	15.89	21	0
28	30-Dec	4-Jan	0.42	16.31	28	0
29	2-Jan	4-Jan	0.42	16.73	14	2.73
30	2-Jan	4-Jan	0.5	17.23	14	3.23

Table 2: Simulation data sample.

No.	Surg. Schedul.	Surg. Date	Surg. (hours)	Flow (hours)	Due (hours)	Delay (hours)
1	28-Dec	2-Jan	0.29284	0.29284	36	0
2	28-Dec	2-Jan	1.21867	1.51151	51	0
3	30-Dec	2-Jan	0.95128	2.46280	31	0
4	25-Dec	2-Jan	0.78709	3.24989	23	0
5	30-Dec	2-Jan	0.78602	4.03592	33	0
6	26-Dec	2-Jan	0.28689	4.32281	30	0
7	27-Dec	2-Jan	1.13976	5.46257	48	0
8	30-Dec	2-Jan	0.83580	6.29838	32	0
9	30-Dec	2-Jan	0.55026	6.84865	19	0
10	31-Dec	2-Jan	0.58618	7.43483	31	0
11	28-Dec	2-Jan	0.62518	8.06002	53	0
12	26-Dec	2-Jan	0.25609	8.31611	27	0
13	27-Dec	2-Jan	1.02144	9.33755	22	0
14	27-Dec	2-Jan	1.32733	10.6648	50	0
15	31-Dec	2-Jan	1.83573	12.5006	35	0
16	30-Dec	3-Jan	0.90984	13.4104	27	0
17	30-Dec	3-Jan	0.28643	13.6969	21	0
18	31-Dec	3-Jan	0.76746	14.4643	9	5.46436
19	31-Dec	3-Jan	0.19968	14.6640	36	0
20	28-Dec	3-Jan	0.38480	15.0488	28	0
21	31-Dec	3-Jan	0.36328	15.4121	39	0
22	27-Dec	3-Jan	0.28138	15.6935	9	6.69352
23	27-Dec	4-Jan	0.85074	16.5442	55	0
24	31-Dec	4-Jan	0.14878	16.6930	42	0
25	30-Dec	4-Jan	0.98660	17.6796	7	10.6796
26	30-Dec	4-Jan	1.04680	18.7264	51	0
27	31-Dec	4-Jan	1.16062	19.8870	24	0
28	30-Dec	4-Jan	0.66339	20.5504	38	0
29	2-Jan	4-Jan	0.96390	21.5144	37	0
30	2-Jan	4-Jan	1.52044	23.0348	19	4.03483

3.4 Simulation Results and Performance Evaluation

Table 3 presents a comparative analysis of four scheduling rules applied to the surgical operations simulation: First-Come, First-Served (FCFS), Earliest Due Date (EDD), Shortest Processing Time (SPT), and Longest Processing Time (LPT). The evaluation is conducted using four key performance indicators, namely average completion time, utilization rate, number of completed surgeries, and average tardiness. The results indicate that all scheduling techniques achieved a constant utilization rate of 82%, reflecting the fixed capacity of the single operating room and confirming that resource utilization is independent of the sequencing rule in this setting.

In terms of time-related performance, SPT demonstrates the best results, achieving the lowest average completion time (50 hours) and the lowest average delay (26 hours), which indicates superior efficiency in reducing both waiting and processing times. FCFS and EDD exhibit intermediate performance levels; however, EDD more closely reflects the actual hospital scheduling practice, which is associated with a baseline system performance of 76 hours for completion time and 46 hours for average delay. In contrast, LPT performs poorly across all time-based indicators, recording the highest average completion time (100 hours) and the highest delay (68 hours), thereby confirming its inefficiency in time-sensitive healthcare environments.

With respect to system throughput, FCFS completes 14 surgeries, SPT 23, and EDD 45, whereas LPT achieves the highest throughput with 100 completed surgeries. However, this increased throughput is accompanied by significantly degraded time performance, indicating that maximizing output does not necessarily translate into improved scheduling efficiency in surgical systems.

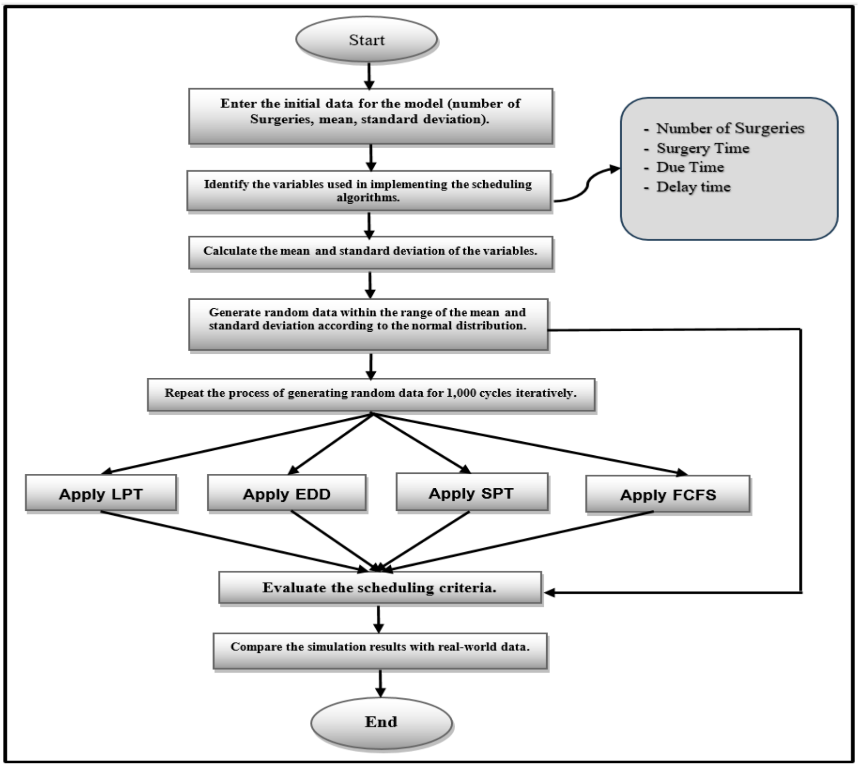

Figure 1: Logical diagram of the simulation model.

Table 3: Summary of surgical simulation results according to operations scheduling techniques.

Priority Dispatching techniques	Scheduling Criteria Applied			
	Average Completion Time (hours)	Average utilization (%)	Number of Surgeries	Average delay (hours)
'real'/ EDD	76	82	45	46
'FCFS'	73	82	14	39
'SPT'	50	82	23	26
'LPT'	100	82	100	68

Overall, the findings confirm that SPT is the most effective scheduling rule for minimizing completion time and delay while enhancing operational responsiveness in surgical scheduling environments.

4 CONCLUSIONS

This study presented a structured analytical assessment of operational compliance with Clause 8 (Operation) of IATF 16949:2016 within the State Company for Automotive Industry and Equipment in Iraq, focusing on the car battery manufacturing unit. A checklist-based evaluation combined with weighted scoring methods was used to quantify the degree of conformity across key operational domains.

The empirical findings reveal that the overall compliance level of the studied facility is 55%, indicating a substantial operational gap of 45% between current practices and the requirements of the IATF 16949:2016 standard. Among the assessed components, Release of Products demonstrated the highest compliance level, while Operational Planning and Control recorded the lowest performance, reflecting weaknesses in structured planning, risk identification, and process optimization.

The results further indicate that although certain operational areas such as supplier control and non-conformance management demonstrate moderate adherence to standard requirements, these practices remain largely procedural rather than systematically integrated into a fully functional quality management system.

From a theoretical perspective, the study contributes to the literature by demonstrating how structured compliance measurement can be used as a diagnostic tool for evaluating operational readiness in manufacturing environments under international quality standards. From a practical standpoint, the findings highlight the necessity of strengthening process integration, digital monitoring, and risk-based operational planning.

To enhance compliance and operational performance, the study recommends the following strategic actions:

1) Adoption of structured risk-based operational planning mechanisms aligned with IATF 16949 requirements to improve process stability and reduce variability.
2) Development of an integrated supplier quality management system, including supplier evaluation, auditing, and performance monitoring frameworks.
3) Implementation of standardized production control plans supported by digital tracking systems to ensure consistency across production stages.
4) Enhancement of training programs for operational staff, focusing on non-conformance handling, quality tools, and process improvement methodologies.
5) Strengthening of inspection and testing capabilities through upgraded measurement systems and potential integration of accredited external laboratory services.

Overall, the study confirms that bridging the identified compliance gap requires not only procedural improvements but also a shift toward a more data-driven, system-oriented quality management culture. Such transformation is essential for aligning the organization with international automotive quality standards and improving its long-term competitiveness.

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