Increasing Forklift Time Utilization in a Food Equipment Manufacturing Plant with a Kaizen Event

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Abstract. The COVID-19 pandemic impacted several services organizations such as hotels and restaurants. Some studies suggest that 50% of restaurants closed during quarantining days will not reopen in the future, producing a domino effect with their suppliers. Therefore, to survey in this crisis, organizations focused their efforts on reducing waste and/or repurposing their manufacturing operations by introducing new products. The purposes of this paper are (1) to mention an overall strategy followed by food equipment manufacturing plant to address the COVID-19 pandemic challenge; and (2) to describe one of the five Kaizen events conducted to address COVID-19 challenges. This Kaizen focused on increasing forklifts utilization rate from 44% to 80%. The authors followed three steps to achieve this aim: understanding company background, conducting a literature review, and elaborating on a Kaizen event. Practitioners in manufacturing and services organizations could extract several highlights to help them to sort operations problems during crisis time. However, future research still needs to understand the socio-economic impact that COVID-19 pandemic around the world.

Keywords: Optimization models · Material handling · Kaizen · Forklift · Continuous improvement · COVID-19

1 Introduction

In February 2020, after the World Health Organization declared the COVID-19 pandemic, the entire world faced an economic crisis; manufacturing losses, unemployment, poverty rate increase, and closed services organizations [1–3]. Therefore, companies and governments worked together to preserve life, health, and economic stability.

Some of the first publications related to the COVID-19 pandemic impact suggested that about 20% of companies had a contingency plan for events that disrupted the day-to-day operations [4]. Companies worldwide were unprepared for an emergency of this magnitude, forcing them to implement different drastic actions to survey, such as following quarantining regulations, repurposing their manufacturing operations (e.g., producing health equipment, mask, and air ventilators), and increasing process efficiency.

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Unfortunately, manufacturing and services organizations understood late the relevance of having long-term strategies and contingency plans [5, 6].

On the other hand, the COVID-19 pandemic changed society's consumption behaviors and needs, accelerating new business opportunities. Therefore, the purposes of this paper are (1) to mention an overall strategy followed by a food equipment manufacturing plant to address the COVID-19 pandemic challenge; and (2) to describe one of the five Kaizen events conducted. This Kaizen event was focused on increasing the utilization rate of forklifts in FEMP. The authors followed three steps to achieve these aims: conducting a literature review, understanding company background, and elaborating a Kaizen event. Lastly, the authors reflect on this research's theoretical and practitioners' implications in the conclusion section,

2 Literature Review

2.1 Kaizen Events

Kaizen, change for improvement or continuous improvement, is a Japanese concept that Imai [7] defined as improving every day, everyone, and everywhere. To achieve this, Kaize should be understood as a managerial philosophy, as an element of Total Quality Management (TQM), and as a set of improvement tools and methodologies [8]. To achieve this, organizations used different initiatives, methodologies, and frameworks as continuous improvement projects (e.g., Kaizen event, Lean Six Sigma, Six Sigma, and quality improvement projects).

Farris et al., [9 p. 10] defined a Kaizen event as "a focused and structured improvement project, using a dedicated cross-functional team to improve a target work area, with specific goals in a accelerated timeframe." Although a common timeframe for a Kaizen event is usually from one to seven days [10–12], there are days or weeks for planning and data collection activities before the Kaizen event [13, 14].

Several drivers move manufacturing organizations to conduct a Kaizen event, such as improving quality, reducing waste, and increasing productivity [15]. Some achievement in manufacturing organizations that used Kaizen events includes [16–18]: increase production, reduce change over, reduce material use, reduce floor space, reduce distance travel, and others.

Now, it is important to understand the relevant literature available about forklifts.

2.2 Forklifts

The material delivery optimization's interest can be regarded because of a need for a precise delivery schedule to avoid line stoppage and the high cost of transportation. The most used transport vehicles for material delivery at assembly lines are forklifts, two trains, and autonomous guided vehicles [19]. The number of forklifts is always heavily oversized due to transportation fluctuations. Forklift performance depends on traffic in plant and factory design, and finally, because it is still manual transport, the human factor is vulnerable to social disturbances [20]. Therefore, the flexibility offered by forklifts causes a significant loss of efficiency.

Several studies have been conducted to solve transport vehicles utilization from different perspectives, such as capacitated vehicle routing problem with two-dimensional loading constraints [21]; an integrated supply model of manufacturing processes, which included facility location and assignment [22]: and scheduling the delivering of raw material at assembly lines while using the minimum number of vehicles [19].

To meet any efficiency goal is important to study and analyze production and the activities made by the material handling vehicles used in the shop floor, so the variables in the model make it more accurate and closer to the real scenario.

3 Food Equipment Manufacturing Plant Profile

The Food equipment manufacturing plant (FEMP) is a part of a multinational organization. Before the COVID-19 pandemic, FEMP had more than 500 employees, nine product families (mainly for exportation), and used more than one thousand SKUs. Its primary customers were hotels and restaurants.

FEMP's products demand was cycled (see Fig. 1). January and February 2020 showed a better year than 2019; however, with the COVID-19 pandemic, FEMS's products demand decreased 24%.

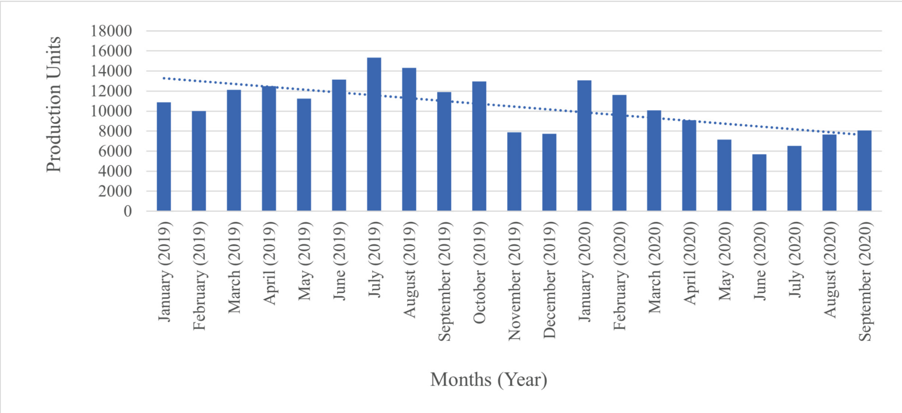

Fig. 1. 2019 and 2020 FEMP's production

To reduce the financial impact produced by the product demand decrease, FEMP conducted an organizational and operational excellence assessment. First, from the organizational excellence assessment, FEMP identifies a weakness in the lack of strategic planning process. Therefore, FEMP conducted a strategic planning process to repurpose new products in the food sector's manufacturing operations that respond to new customer needs, such as handless machines and small kitchens (ghost kitchens). This strategy is part of a working paper. Second, from the operational excellence assessment, FEMP identified several improvement opportunities. Therefore, FEMP conducted five Kaizen events to improve operations efficiency. This paper describes the Kaizen event worked to increase the forklift utilization rate.

4 Kaizen Event

This Kaizen event consisted of four phases in 14-weeks: preparation (four weeks), analysis (two weeks), implementation (six weeks), and closing (two weeks). During each of these weeks, the Kaizen event team spent two hours per day on Kaizen event activities and the remaining time in the day-to-day work. This is a total of 140 h.

4.1 Kaizen Event Preparation

This phase consisted of four main activities conducted in four weeks: Kaizen team selection, Kaizen event planning, Kaizen team preparation, and data collection. Each of these activities is described as follow:

a) *Kaizen team selection (3 h).* After analyzing the facility operations, an external facilitator recommends eight members: three production supervisors, three forklift operators, one warehouse supervisor, and one external leader. This team was created considering Farris et al., [23] critical success factors to achieve Kaizen event outcomes. The list of team members was shown to the production manager for approval; and his only condition was did not remove employees from the day-to-day operation.
b) *Kaizen event planning (5 h).* Considering the production manager's request, the external facilitator proposes to work in the Kaizen event for the last two hours of the shift every day. This idea was accepted and communicated by the production manager to his employees. Other Kaizen event planning activities include defining a working area, defining stakeholder meetings, defining team member roles, defining team member integration meetings, and identifying other resources needs. These activities were conducted by the external facilitators and the external leader.
c) *Kaizen team preparation (20 h).* Considering the lack of Kaizen team members knowledge in lean and quality analysis tools (e.g., Pareto diagram and cause-effect diagram, etc.), the external leader creates a small lean and quality analysis tools training course. This course was created using information and examples from FEMP day-to-day operations and was taught to other FEMP associates and leaders to develop the same language in the organization and facilitate communication during the meetings.
d) *Data collection (12 h).* Kaizen event leader was responsible for collecting historical data related to warehouse facility, forklift utilization, production planning, product demand, and others. Data that FEMP was not measuring that could impact the progress of this project negatively are inventory, replenishment times, and the consumption rate of raw material in each production line.

Overall, these Kaizen event preparation activities took 40 h (four weeks). Now, the team was ready for a kickoff meeting.

4.2 Kaizen Event Analysis

The Kaizen event analysis phase consisted of two weeks (15 h). During these weeks, the Kaizen team conducted progress meetings with customers and stakeholders to show continuous improvement project progress and solve any time barriers. The main activities conducted by the Kaizen team are summarized as follow:

a) *Kickoff meeting (1 h).* During a kickoff meeting, with the attendance of the plant manager, several stakeholders, and the Kaizen team, the plant manager spoke about the relevance of this continuous improvement project during the lack of production that the FEMP was having in the COVID-19 pandemic days. It was clear the all the attendees the support from the plant manager to this Kaizen.
b) *Understanding FEMP operations (4 h).* The company has eight assembly lines supplied from a central warehouse. Therefore, the company needs a good delivery schedule that enables them to deliver on time, ensuring each line has enough materials to satisfy the demand. To better illustrate the shop floor and the location of each assembly line, the Kaizen team obtained a FEMP layout copy, which was shown in the Kaizen team meeting room.
c) *Demand studies (5 h).* Two demand studies were conducted using data from 2019 and the five months of 2020. First, regarding production volume, it is observed that three out of the eight production lines captured 84% of the production volume. Also, it is observed that the FEMP assembly line L1 represents 48% of the total annual production of the manufacturing company. Second, analyzing demand trends from January 2019 against January 2020, there's a growth in demand of 18%; however, the behavior due to the COVID-19 effect is not repeated along the following months. After March 2020, production decreased 62%. This decrease is related to the temporary closure of main customers, such as restaurants and hotels. Another finding to highlight is the observed seasonality pattern: two straight months' demand rises then falls. The Kaizen team concluded that this seasonality is highly related to customers' needs during summer times.
d) *Forklift's activities studies (5 h).* There are two types of forklifts: standing and seated man or reach trucks and counterbalance forklifts. Forklift's activities study was conducted using a database of 1,361 records of forklift movements. FEMP has nine forklifts of reach trucks and eight counterbalance forklifts. Counterbalance forklifts have 70% of idle time while reach trucks, 58%. Overall, it was detected that they were idle almost 66% of the time. The rent of 17 forklifts represent to FEMP an annual cost of $306,000 USD.

Clearly, there's an opportunity to make better decisions in the forklift management area. Decide how many forklifts are needed in the production site while satisfying the operation.

4.3 Kaizen Event Implementation

This section presents an optimization program based on the real assumptions and conditions observed in the Kaizen event analysis phase. As mentioned earlier, the company is not measuring inventory, replenishment times, or the consumption rate of raw material in each production line; however, the Kaizen team recovered some data through records taken in site production. This information is presented in Table 1.

Table 1. Variables considered

	Type	Demand	Capacity of forklifts	Total time of travel	Idle time	Loading time	Unloading time
Route 1	Raw material	51	1	125.7	281.1	152.9	40.0
Route 2	Raw material	62	1	122.9	157.4	154.8	40.0
Route 3	Raw material	51	1	100.8	312.4	123.5	40.0
Route 4	Raw material	48	1	46.0	476.0	75.0	52.5
Route 5	Raw material	7	1	130.9	0.0	342.9	137.1
Route 6	Finished goods	72	3	82.2	222.5	63.5	90.0
Route 7	Finished goods	91	1	38.8	11.8	73.8	90.0

Note: demand in pallets, capacity in pallets, and time in Seconds.

We also know that the shift lasts 9.5 h, the fork lifters have 30 min to take a break. With this information, the Kaizen team coded a model in python. Object-oriented programming (OOP) was the most suitable way to address the case study. OOP uses objects and classes. A class can be thought of as a blueprint for objects. These can have their attributes (characteristics they possess) and methods (actions they perform). With these classes, functions, and objects, the model would be assigning forklifts to the different routes the company had already established and supplied the demand with the minimum number of vehicles possible.

The main assumptions that were observed, discussed, and established in the company's case were considered while developing the model (see Table 2).

- The capacity of each forklift is limited and known
- Only one pallet could be delivered by cycle in raw material routes, in finished goods routes from one to three pallets
- The demand is known and deterministic
- The shortage is not allowed
- Only one warehouse is available to serve the assembly lines.

Objective function:

$$Minimize z = \sum_{i=1}^{n}\sum_{j=1}^{m} W_{ij} \cdot G_i \tag{1}$$

Table 2. Equations nomenclature

Type	Code	Name
Index	i	For the forklift ($i = 1, \ldots, n$)
Index	j	For the routes of delivery and pickup ($j = 1, \ldots, m$)
Data	n	Forklift index
Data	m	Route index
Data	t	Cycle
Data	s	Time of shift
Data	C	Forklift capacity in pallets
Data	C_{ij}	Forklift capacity in pallets to deliver to route j
Data	d_j	Demand of route j
Data	G_i	Cost for leasing forklift
Variables	X_{ij}	Total time for forklift i delivers for route j
Variables	Y_j	Number of pallets delivered in route j
Variables	W_{ij}	Number of forklifts in used for route j

Restrictions:

$$\sum_{i=1}^{n} Y_j \cdot W_{ij} \geq d_j \qquad \forall j = 1, \ldots, m \tag{2}$$

$$Y_j \cdot W_{ij} \leq C_{ij} \qquad \forall j = 1, \ldots, m,\ \forall i = 1, \ldots, n \tag{3}$$

$$\sum_{j=1}^{m} X_{ij} \cdot W_{ij} \leq s \qquad \forall i = 1, \ldots, n \tag{4}$$

$$X_{ij} \geq 0 \tag{5}$$

$$Y_j \geq 0\, and\ integer\, \forall j = 1, \ldots, m \tag{6}$$

$$W_{ij} \geq 0\, and\ integer \tag{7}$$

$$\forall i = 1, \ldots, n\, \forall j = 1, \ldots, m$$

The objective function, given by Eq. (1), minimizes the number of delivery forklifts used in a shift and its cost. Equation (2) ensures that the number of delivered pallets at each route will satisfy the demand. Equation (3) ensures that the total number of pallets delivered in each cycle does not exceed the forklift capacity. Equation (4) guarantees that the total time of delivery of the demand to each route does not exceed the shift time. Finally, Eqs. (5) to (7) state the nonnegative nature of the decision variables.

To validate the model's efficiency and performance, first, a pilot test was carried out to prove that the model works. Data from one week of operation was recovered and then compared with what could have been with the forklift assignment of the model. Due to COVID-19 measures, security and hygiene, they only operate six forklifts. One forklift was assigned to each route except routes five and six (they shared a forklift). It was not possible to complete the demand, so they added three more hours to the shift to satisfy the demand. Operating this way, a 68% of utilization rate was obtained. However, the model made a different forklift assignment, five forklifts, every route has its own forklift except five, six, and seven, with one forklift. The Kaizen team obtained a 91% of utilization rate.

A second pilot test was carried out with one day of operation; the data was entered into the model. With the demand of that specific date, the model assigned six forklifts. Each route has its forklift delivering, except five and six sharing a forklift. This assignment guarantees a 78% of utilization of the forklifts.

A sensitivity analysis was also made with the median with quartiles taken from the real historical data of demand to prove how the model reacts to changes in demand (see Table 3). March 2020 was considered as the sample to obtain the median with quartiles. The analysis was made with the median with quartiles to measure data dispersion to measure variability around the mean. The quartile breaks the data into quarters so that 25% of the measurement is less than the lower quartile, 50% is less than the mean, and 75% is less than the upper quartile.

Table 3. Sensitivity analysis results

Route	Sample		Median		Upper quartile		Lower quartile	
	# Forklifts	Utilization rate (%)	# Forklifts	Utilization rate (%)	# Forklifts	Utilization rate (%)	# Forklifts	Utilization rate (%)
1	1	94	1	91	1	98	1	76
2	1	91	1	87	1	93	1	73
3	1	91	1	87	1	93	1	73
4	1	96	1	92	2	50	1	78
5	0.5	47	0.5	46	0.5	50	0.3	89
6	0.5		0.5		0.5		0.3	
7	1	60	1	58	1	62	0.3	
Average		80		77		75		78

Data recovered from the original records were introduced into the program and the forklift assignation determined that six forklifts were needed to satisfy the demand with an 80% of utilization. With the demand median, the assignment of forklifts to each route stays the same. Six forklifts are considered to supply the demand on time with a utilization rate of 77%. In the assignment for the upper quartile of demand, there are changes to the number of considered forklifts to satisfy the demand, seven forklifts with a 75% utilization. Finally, even fewer forklifts are assigned to each route for the lower quartile. There are considered five forklifts (routes five, six, and seven) share one forklift the rest of the routes are being assigned with one forklift, with a 78% of utilization.

During the last Kaizen implementation meeting, the team presented its findings to the plant manager, customers, and stakeholders. Although the optimization model showed seven forklifts in an upper quartile, the plant manager decided to stay with three more forklifts as a buffer preventing potential problems of maintenance and peak demands. Therefore, this Kaizen event helps FEMP to reduce their annual operation cost by $126,000 USD.

Overall, Kaizen team spent 60 h during the six-week Kaizen implementation phase.

4.4 Kaizen Event Closing

Lastly, during the following two weeks (19 h), the Kaizen work in the Kaizen event documentation, which includes the following deliverables:

a) *Kaizen event file (2 h).* Every analysis, presentation, meeting results, and to-do list were collected file in a physical binder for future reference.
b) *Software application (10 h).* The Python program was converted into a software application to facilitate FEMP personal future forklift analysis
c) *Working instruction (5 h).* A step-by-step working instruction was developed to use the software application.
d) *KPI Follow up (2 h).* Forklift utilization percentage was included in the plant manager monthly meeting review.

Once the plant manager closed the Kaizen event, the Kaizen team was dissolve and each team member continued with their initial roles and responsibilities in FEMP.

5 Discussion

The purposes of this paper were (1) to mention an overall strategy followed by a food equipment manufacturing plant to address the COVID-19 pandemic challenge; and (2) to describe one of the five Kaizen events conducted. First, the authors briefly mentioned the initiatives that FEMP followed up to address the COVID-19 pandemic impact. The FEMP business initiative will be published in the *Operations Management Research* journal special issue in 2022. Second, out of the five Kaizen events conducted to FEMP, the authors considered that this paper presents an unusual application of the Kaizen event, contributing with two insights for continuous improvement practitioners: Kaizen event to mitigate the COVID-19 pandemic impact and Kaizen event with optimization. Ohno [24] suggested the importance of conducting Kaizen during good times; however, because of a lack of contingency plans in FEMP, the organization decided to use Kaizen events as an approach to mitigate the initial impact of the COVID-19 pandemic. On the other hand, instead of conducting several interactions to identify the best solutions, the Kaizen event team decided to apply optimization models to simulate and validate their decisions regarding the reduction of forklifts.

It is important to control the number of forklifts used at assembly lines since material handling costs represent 15% to 70% of a manufactured product [25]. Although this Kaizen event shows significant results, these results should not be generalized, and readers need to consider the following limitations. First, although a traditional Kaizen event takes from one to seven days (one week), the organization could not remove all Kaizen team members from their day-to-day operations during a complete week. Therefore, FEMP leaders found a different Kaizen event structure that adjusted to their needs (14-weeks and 2 h per day). However, this new approach represents a total time of 17.5 days ([14 weeks * five days * two hours]/[8 h per day]); more than twice of the standard Kaizen event structure, impacting negatively on Kaizen event team members interest in this project. Second, FEMP is a young organization with many opportunity areas and several improvement projects are required. During this Kaizen event, the organization also implemented 5S's. Therefore, results are not insolated to the Kaizen event implementation actions; 5S's implementation could impact this Kaizen event results. Third, as the authors mentioned earlier, FEMP does not measure many variables that could make the model even better and more accurate. Many assumptions were made by the company where the available variables used for the model to work (e.g., gasoline consumption per operator). However, the model proposed was successful as the first effort regarding decision-making on forklift management.

Over time, the operational result will become more like the program's results, depending on the adoption of the process by forklift operators. The model can be expanded regarding future work considering other objectives such as inventory on production lines, online raw material replacement times or frequencies, etc. Also, there are techniques utilized to efficiently schedule forklift motion are: dynamic loading, differential evolution heuristic approach, Adaptive Genetic Algorithms (AGA) method, and Evolutionary Algorithm (EA). Dynamic loading involves the AGV handling multiple loads. This will add value to the facility by minimizing the travel time and the number of laps the vehicle travels between jobs [26].

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