Headcount optimization using discrete event simulation at Flower Shop, Inc.

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***Abstract*– Flower Shop, Inc is a luxury flower shop located in Puerto Rico. In the last two years it experienced a 603% increase in demand, due to a change in venue. A discrete event simulation model was created to determine appropriate headcount in regular dates, plus peak seasons. The results of this simulation were the optimized staffing quantities for weekends, weekdays, and peak dates that maximizes the use of resources and minimizes the service time.**

***Keywords*—process improvement, discrete event simulation, industrial engineering, senior design experience**

I. INTRODUCTION

As one of the top venues flower arrangements, plants, vases, and others, Flower Shop Inc. is always looking to maintain its high level of service and creative work. With a recent increase in demand of 600% due to a change in venue, several areas of opportunity to increase the value proposition of the business were identified. The top areas for improvement include management of headcount to minimize service time; both in creating arrangements and the checkout line. A simulation was developed to maximize the utilization of the resources (sales associates and florists) in the system while minimizing the average time of the entities (clients and tasks) in the system. A system can be defined as a collection of entities interacting with a similar purpose inside the same activities, assumptions, and rules [1].

Simulation can be useful in manufacturing and service settings, with several applications existing to model processes and perform experiments. In this paper, Simio was used as the modeling software for the simulation [2]. Simulation has been shown to be an important tool in process improvement activities. Previous successes of simulation and process improvement are shown in [3], with a simulation developed in the Analyze phase within DMAIC. This simulation run experiments on the quality of a die casting process, and modeled the improvements achieved in the project. Another application [4] of simulation, in this case of a service facilities shows the applicability of simulation to service processes and facilitates the modeling of stochastic arrivals for patients to a healthcare facility. In paper, we will also measure the arrival and service times of customers, which will then be fit to a probability distribution. The stochastic nature of this process makes feasible to model with discrete event simulation.

This research describes the success of the application of simulation process as part of a senior design experience to improve processes that are not related to transportation nor repetitive manufacturing scenarios. The simulation objectives established were*:*

1) Maximization of resource's utilization: at least 50% utilization.

2) Service time reduction: at least 5% reduction based off optimization of resources and decrease in waiting times.

The research methodology aims to design a process that can comply with demand by having an optimal staffing level. Developing a simulation requires determining the standard times of each task, the interarrival times and their variability, the client mix, among other aspects. The methodology required to model the process, obtain results, and make recommendations is inspired in [5] and applied to the development of this paper:

1) Define conceptual model: understand process, identify entities and resources, develop concept map.
2) Data analysis: fit distributions for arrival and service times.
3) Root cause / causality analysis + Decision analysis and alternatives selection: design scenarios considering season's demands plus validation and verification of simulation model.
4) Simulation Results: obtain staffing results from simulation.
5) Conclusions: verify is objectives were achieved.
6) Next Steps: provide recommendations

II. DEFINE CONCEPTUAL MODEL

The first step when developing a simulation was creating a concept map as the one presented in Fig. 1. This map completed after detailed observation of the process and helps organize the construction of the model. In the conceptual map, the grey boxes represent the sources or sinks of the entities, the arrows represent the flow of the entities, and the green circle represents the servers.

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Entities were defined within two groups – client and tasks. Clients include customers that visit the store but do not make any purchase (DoesntBuy), clients that buy ready-made products (ReadyMade), and clients that buy arrangements (Arrag). Tasks include administrative (Admin), preparation and management of merchandise (Merch), social media (Social), watering plants (Water), and cleaning (Clean).

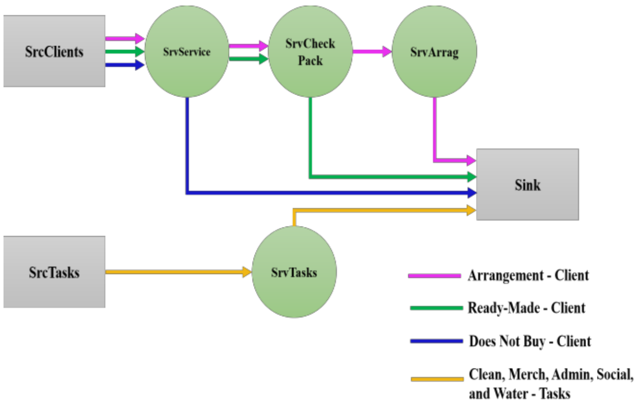


Fig. 1 Sequence of entities through servers.

II. DATA ANALYSIS

Once the entities were defined, we proceeded to the determination of the processing times for each service. The processing times are listed in Table I. A stopwatch time study 575 samples based on 0.05 confidence level (α) was performed to acquire the cycle times. Using StatFit3 software, the processing time for each server was defined. Notice that some entities travel through different servers, and this affects the total time in system.

Table I. Entities Identified

Entity	Description	Processing Time
DoesntBuy	Client who does not buy.	Processing time of SrvService (expanded in Table III).
ReadyMade	Client who buys ready-made products.	Processing time of SrvService and SrvCheckPack (expanded in Table III).
Arrag	Client who orders and buys arrangements.	Processing time of SrvService, SrvCheckPack, and SrvArrag (expanded in Table III).
Admin	Administrative tasks.	1+Random.Lognormal(1.31,0.902) minutes
Merch	Tasks related to receiving and handling merchandise.	12+Random.Lognormal(0.936,0.747) minutes
Social	Tasks related to social media and customer reach.	Random.Uniform(1,8.59) minutes
Water	Watering of plants and flowers.	Random.Uniform(5,18.7) minutes
Clean	Cleaning activities.	1+Random.Lognormal(1.39, 1.26) minutes

When analyzing the StatFit results and selecting the distribution that best resembles the processing or interarrival time, the rank, acceptance and Akaike probability were taken into consideration, as seen in Table II. Other criteria taken into consideration was the fit of the graphs. Fig. 2 displays the Fitted Distribution Model for Admin and Fig. 3 demonstrates Fitted Distribution Model for Merch and Cleaning. A fitted distribution model was created for every task.

Table II. Autofit of Distributions for Tasks by StatFit

Task	Distribution	Rank	Acceptance	Akaike Probability
Admin	Lognormal (1,1.31,0.902)	100	Do not reject	0.387
	Exponential(1,4.86)	18.6	Do not reject	0.161
	Uniform(1,12.5)	14.7	Do not reject	1
Merch	Lognormal (12,0.936,0.747)	100	Do not reject	1
	Uniform(12,18.9)	9.57	Do not reject	0.927
	Exponential(12,3.14)	6.29	Do not reject	0.0432
Social	Uniform(1,8.59)	100	Do not reject	1
	Lognormal (1,1.05,1.29)	1.55	Do not reject	0
Water	Uniform(5,18.7)	100	Do not reject	1
	Lognormal (5,1.74,0.836)	10.6	Do not reject	0.00416
Clean	Lognormal (1,1.39,1.26)	100	Do not reject	0.486
	Exponential(1,7.55)	20.1	Do not reject	1
	Uniform(1,21.2)	0.0004 37	Reject	0.656

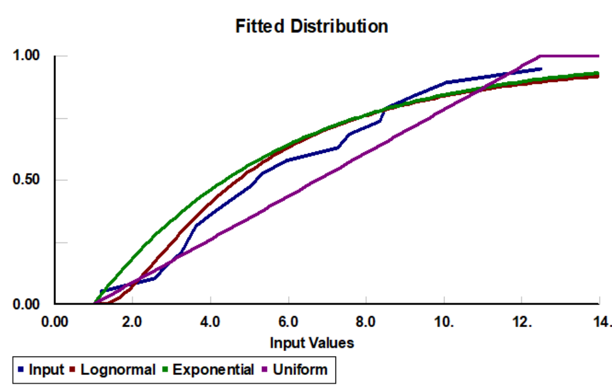
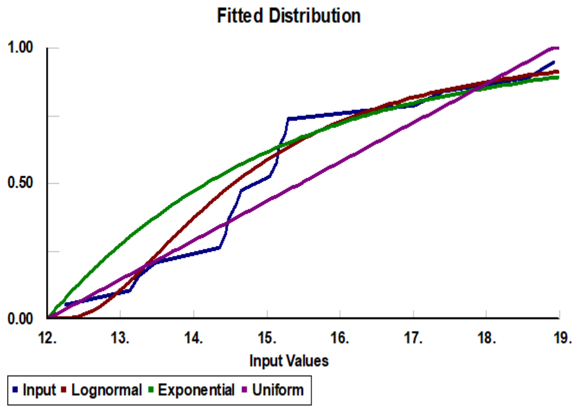


Fig. 2 Fitted Distribution Model for Admin.



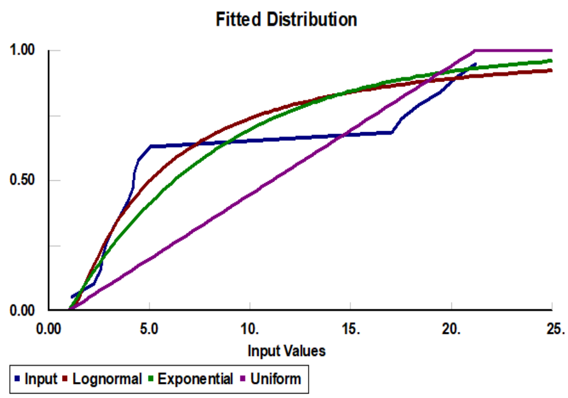


Fig. 3 Fitted Distribution Model for Merch and Cleaning.

Similarly, the information gathered was analyzed using StatFit to determine the processing time of the servers' stations as presented in Table III. In this instance, the focus was the stations related to the service provided to clients. Depending on what and if the client purchases, they will stop in different service stations to receive the provision they require.

Table III. Servers Defined

Server	Function	Processing Time
SrvService	Provide service and orientation about the products.	9+random.exponential(117) seconds
SrvCheckPack	Process checkout for every sale and packaging for ready made products.	34+random.lognormal (4.6,0.637) seconds
SrvArrag	Creation and packaging of arrangements.	1.47e+003+random.lognormal (6.39,0.852) seconds
SrvTasks	Process watering, administrative, social media, merchandise, and cleaning tasks.	Varies for each task (Table 1)

Parallel to the tasks entities, when analyzing the StatFit results and selecting the distribution that best resembles the processing time or interarrival time different criteria was taken into consideration to statistically select the most representative distribution. The criteria were the rank, acceptance, fitted distribution model, and Akaike probability. The options analyzed are presented in Table IV.

Table IV. Autofit of Distributions for Servers by StatFit

Server	Distribution	Rank	Acceptance	Akaike Prob
SrvService	Exponential (9,11)	95.6	Do not reject	1
	Lognormal (9,4.32,1.1)	70.9	Do not reject	0.023
	Uniform (9,460)	0	Reject	0
Srv CheckPack	Lognormal (34,4.6,0.637)	100	Do not reject	1
	Uniform (34,308)	0.0599	Reject	0.068
	Exponential (34,116)	0.00079	Reject	0
SrvTasks	Lognormal (1.47e+003,6.39,0.852)	100	Do not reject	1
	Exponential (1.47e+003,785)	2.14	Reject	0.43
	Uniform (1.47e+003,3.93e+003)	0	Reject	0

III. Root Cause / Causality Analysis

Clients and tasks have an independent interarrival, and therefore, and independent mix ratio. The mix ration refers to the quantity that a type of entity that entries to the system in comparison to the other types of entities. The client mixes changes depending on the observed scenario – weekdays (Table V), weekends (Table VI), or peak weeks (Table VII). Examples of peak weeks includes Valentine's Day week and Mother' Day week.

Table V Weekdays Rate Table

Hour	Monday	Tuesday	Wednesday	Thursday
10:00 am	4	3	3	4
11:00 am	4	4	4	5
12:00 pm	4	4	5	5
1:00 pm	4	5	5	5
2:00 pm	5	5	6	6
3:00 pm	5	6	6	6
4:00 pm	7	6	7	7
5:00 pm	6	7	5	7
6:00 pm	6	5	4	5

Table VI Weekends Rate Table

Hour	Friday	Saturday	Sunday
10:00 am	9	10	Store is closed
11:00 am	10	10	10
12:00 pm	10	10	10
1:00 pm	11	11	11
2:00 pm	11	11	11
3:00 pm	12	11	12
4:00 pm	12	12	12
5:00 pm	12	11	12
6:00 pm	12	11	Store is closed
7:00 pm	11	10	Store is closed

Table VIII Peak Season (Week) Rate Table

Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
10:00 am	NA[a]	2	3	2	7	9	19	NA
11:00 am	5	2	3	3	7	9	19	11
12:00 pm	7	2	4	7	8	10	21	11
1:00 pm	9	5	5	5	8	11	19	11
2:00 pm	9	4	6	5	11	11	21	15
3:00 pm	12	2	7	8	10	14	22	15
4:00 pm	10	3	8	7	13	16	20	15
5:00 pm	11	4	7	4	15	14	24	14
6:00 pm	7	2	9	3	9	15	19	10
7:00 pm	NA	NA	NA	NA	NA	14	19	NA

[a] Store is closed.

Resources were added to provide services in each server. Two types of resources were created: florist and sales. Both resources can work in every server to complete any tasks, but a priority is set to determine the seizing (allocation) of resources. The prioritization is expanded on Table VIII.

Table VIII Resource Allocation Order of Preference

Server	First choice	Second choice
SrvService	Sales	Florist
SrvCheckPack	Sales	Florist
SrvArrag	Florist	Sales
SrvTasks	Sales, Florist (no specific order)	Sales, Florist (no specific order)

After the processing of an entity is completed on a server, the resource is released to complete other processes. This was done by setting AddOn Process Triggers with lists on each server before and after processing. See Fig. 4 for SrvArrg process trigger.

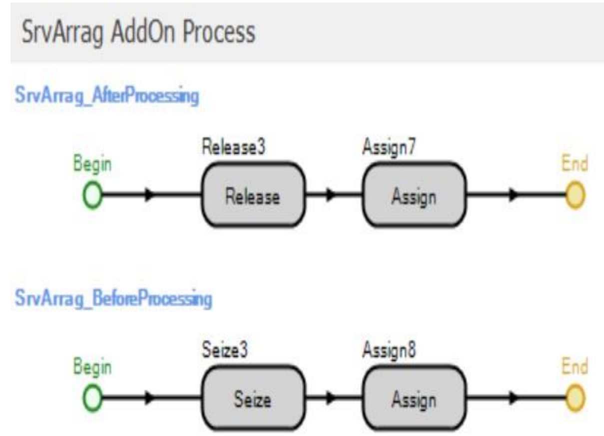


Fig. 4 SrvArrag AddOn Process Trigger

Furthermore, entity priority had to be established to prioritize clients over completing tasks. For example, if a resource is busy cleaning the store, they would pause that task to provide service to the client and then carry on with their additional tasks. Client mix was also extablished for the entities. During the data gathering process, the activity of the client was also recorded in terms of their purchases. In Table IX, it can be understood that most arrangements are bought during weekends and peak weeks, while the weekdays are mainly composed of selling ready-made products. This has a direct correlation with the resources required each day.

Table IX Entities Prioritization and Mix

Entity	Entity Priority	Weekdays Mix	Weekends Mix	Peak Weeks Mix
DoesntBuy	1	50	50	39.4
ReadyMade	1	47.85	45.85	46.6
Arrag	1	2.15	4.15	14
Admin	3	30		
Merch	3	30		
Social	3	10		
Water	3	20		
Clean	2	10		

As the logistic components of the model were set, the physical appearance of the model was also refined. It included a detailed layout with animated and static symbols, labels, and correct proportion from two- and three-dimensional congruence, see in Fig. 5.

Fig. 5 Two-Dimensional Model

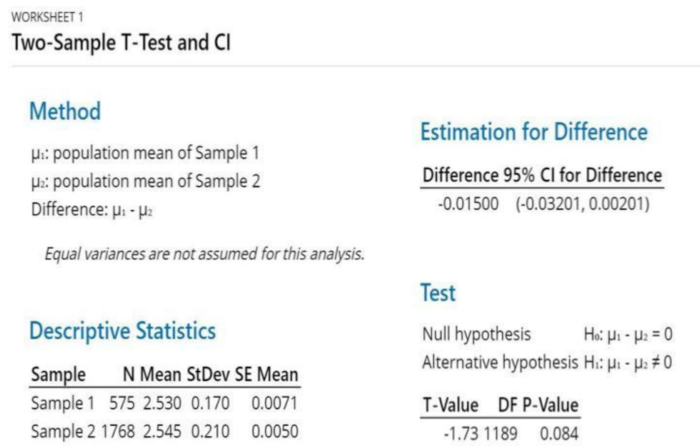
The layout and routes considered in the design of the model were based off the implementation alternatives. This means that the layout is based on the implementation suggestion, not the current scenario. See Fig. 6 and Fig. 7 to see three-dimensional representation.

Fig. 6 Three-Dimensional Model Entrance

Fig. 7 Three-Dimensional Model Checkout Station

To validate the simulation model, before modeling the improvements, the historic data was compared to the simulation results to verify accuracy. For this, two-sample T-tests were performed since the objective was to determine if two population means were equal or not. Minitab software was used to complete the testing as shown in Fig. 10. In this case the mean of the historic and simulation means for service time in minutes for clients that do not buy were compared. A 95% confidence interval for difference was considered and equal variances was not assumed for the test.

The null hypothesis, H_0, suggested that the service time means are statistically equal. On the contrary, the alternative hypothesis, H_1, states that the service time means are statistically different. Since the P-value was greater than 0.05 (five percent), the null hypothesis is not rejected [6]. This indicates that the mean is equal in both scenarios.



WORKSHEET 1

Two-Sample T-Test and CI

Method

μ_1: population mean of Sample 1
μ_2: population mean of Sample 2
Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Sample 1	575	2.530	0.170	0.0071
Sample 2	1768	2.545	0.210	0.0050

Estimation for Difference

Difference	95% CI for Difference
-0.01500	(-0.03201, 0.00201)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-1.73	1189	0.084

Fig. 10 Two sample T-Test.

The same hypothesis testing methodology was replicated for other entities to validate their results as well. The results were the failure to reject H_0 as shown in Table X. We conclude the simulation was representative of the current process in FSI.

Table X. Hypothesis Testing Results

Test	Two-Sample T-Test	Two-Sample T-Test	Two-Sample T-Test
Entity	DoesntBuy	ReadyMade	Arrangement
Historical service time (minutes)	2.53	5.491	45.379
Simulation service time (minutes)	2.545	5.509	45.132
P-Value	0.084	0.118	0.327
Conclusion	Do not reject H_0 ($\mu_1 = \mu_2$)	Do not reject H_0 ($\mu_1 = \mu_2$)	Do not reject H_0 ($\mu_1 = \mu_2$)

IV. SIMULATION RESULTS

Once the construction of the model was finished, the next step was to maximize the use of resources. The utilization of the resources was measured using state and output statistics to optimize it. In the optimization, the capacity of the florist and sales associates were the controls, or independent variables. Equations 1 through 4 are the designed constraints considered to optimize the model results.

$$0 \leq \text{FloristCapacity} \leq 8 \qquad (1)$$

$$1 \leq \text{SalesCapacity} \leq 12 \qquad (2)$$

$$\text{FloristCapacity} + \text{SalesCapacity} \geq 1 \qquad (3)$$

$$\text{Utilization} \leq 1 \qquad (4)$$

As responses, the total amount of resources (FloristCapacity + SalesCapacity) must be minimized, while the utilization is maximized. The utilization is the main response and must not be greater than one. Ten replications were executed for each scenario as presented in Fig. 9.

Scenario		Replications		Controls		Responses		Constra
Name	Status	Required	Completed	FloristCapacity	SalesCapacity	Utilization	Resource	Constra
001	Idle	11	11 of 11	2	3	0.370343	5	5
002	Idle	10	10 of 10	0	1	0.554231	1	1
003	Idle	11	11 of 11	3	5	0.370343	8	8
004	Idle	10	10 of 10	1	2	0.344987	3	3
005	Idle	11	11 of 11	2	4	0.370343	6	6
006	Idle	12	12 of 12	0	5	0.370392	5	5
007	Idle	10	10 of 10	3	1	0.356028	4	4
008	Idle	10	10 of 10	1	4	0.35253	5	5
009	Idle	10	10 of 10	0	3	0.372466	3	3
010	Idle	10	10 of 10	2	1	0.353034	3	3
011	Idle	12	12 of 12	0	4	0.370392	4	4
012	Idle	10	10 of 10	0	2	0.364131	2	2
013	Idle	10	10 of 10	1	3	0.35253	4	4
014	Idle	11	11 of 11	3	4	0.370343	7	7
015	Idle	11	11 of 11	2	5	0.370343	7	7
016	Idle	11	11 of 11	3	3	0.370343	6	6
017	Idle	11	11 of 11	2	2	0.371166	4	4
018	Idle	10	10 of 10	1	1	0.342063	2	2
019	Idle	11	11 of 11	3	2	0.371166	5	5
020	Idle	10	10 of 10	1	5	0.35253	6	6

Fig. 9 Scenarios and replicaions for optimization.

After executing the model, the simulation results were obtained as shown in Table XI. It includes the required staff for weekends, weekdays, and peak dates, considering the previous design recommendations.

Table XI Optimization Results

Simulation	Florists Required	Sales Staff Required	Utilization %
Weekdays	0	1	55.4 %
Weekends	1	1	92.8 %
Peak Week	5	4	94.9 %

On weekends, at least one florist is always required. On weekdays, the florist can either be on-call or some hours during the week to pre-made arrangements. On peak seasons, staffing increases significantly to manage demand.

V. CONCLUSIONS

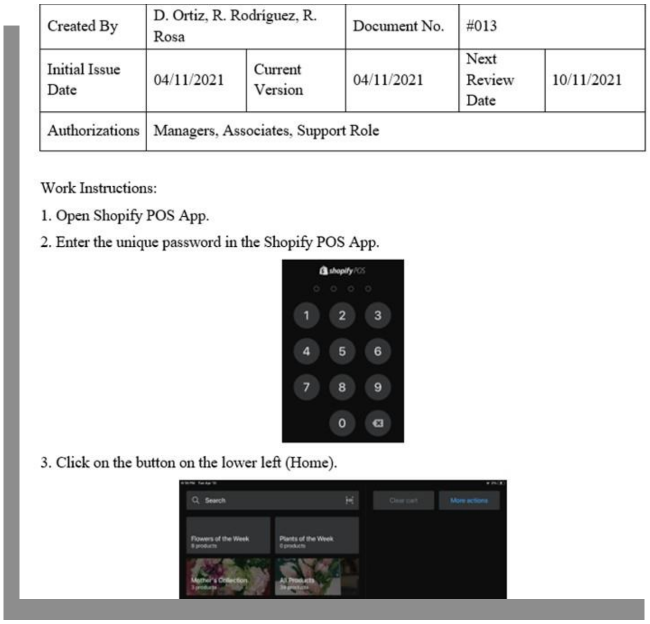
Process improvement can be used in manufacturing and service settings. Most process improvement strategies are associated to DMAIC [7]. As part of the deliverables of this paper, a simulation was developed with SIMIO software to maximize the utilization of the resources in the system. Simulation works with discrete events and has a wide use application for productive process in manufacturing and service industries [8]. A model was necessary for estimating the correct staffing levels considering scenarios based off the work required or demand. For this, the standard times of each task, the interarrival times and their variability, the client mix, among other aspects were be determined. Rate tables for the interarrival of the clients were designed for weekdays, weekends, and peak seasons. As the logistic components of the model were set, the physical appearance of the model was also refined.

The layout and routes in the design of the model were based of the implementation alternatives. As responses, the total resources (FloristCapacity + SalesCapacity) were minimized, making sure that the utilization of these resources was maximized, but not exceeding 100%. Moreover, the improvements complied represent a 9.9% reduction of service time, mostly driven by the reduction of clients waiting for resources. Results can be seen at Table XII and confirm all objectives were achieved.

Table XII Objective comparisons

Objective	Description	Schedule	Achieved
1	*Maximization of resource's utilization:* at least 50% utilization.	Weekday	55.40%
		Weekend	92.80%
		Peak	94.90%
2	*Service time reduction:* at least 5% reduction based off optimization of resources and decrease in waiting times.	N/A	9.90%

To maintain the sustainability of an implementation, work instructions defining the tasks that were frequently performed were created. These include good safety practices to help prevent accidents in the future. The work instructions include visual aids to enhance learning and standardization, as the example in Fig. 10.



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Authorizations	Managers, Associates, Support Role				

Work Instructions:

1. Open Shopify POS App.
2. Enter the unique password in the Shopify POS App.
3. Click on the button on the lower left (Home).

Fig. 10 Cash drawer tracking session closure work istruction.

VI Next Steps

This paper was part of a process improvement project reducing cycle times to improve production capacity and reduce nonvalue added activities. The FCI has future franchising plants, and as part as these efforts, future simulation experiments might be required.

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References

[1] L. W. Schruben, Graphical simulation modeling and analysis: Using sigma for windows, 1st ed. Boston: Boyd & Fraser, 1995.

[2] J. S. Smith, D. T. Sturrock, and W. D. Kelton, Simio and simulation: Modeling, analysis, applications. CreateSpace Independent Publishing Platform, 2018.

[3] N. Mishra and S. B. Rane, "Prediction and improvement of iron casting quality through analytics and Six Sigma approach," International Journal of Lean Six Sigma, vol. 10, (1), pp. 189-210, 2019.

[4] M. Arafeh et al, "Using Six Sigma DMAIC Methodology and Discrete Event Simulation to Reduce Patient Discharge Time in King Hussein Cancer Center," Journal of Healthcare Engineering, vol. 2018, pp. 3832151-18, 2018.

[5] G. S. Jamil et al, "Framework for the implementation of lean construction strategies using the interpretive structural modelling (ISM) technique," Engineering, Construction and Architectural Management, vol. 26, (1), pp. 1-23, 2019. DOI: http://dx.doi.org/10.1108/ECAM-03-2018-0136.

[6] D. C. Montgomery, Applied Statistics and probability for engineers. / Douglas C. Montgomery and George C. Runger, 5th ed. Chichester: John Wiley & Sons Inc, 2010.

[7] J. Pérez-Barbosa et al, "Optimization of Parachute Flying Time and Selection of Best Model," IIE Annual Conference Proceedings, pp. 453-458, 2021.

[8] L. Torres, "Floods Forecast in the Caribbean", in Flood Risk Management. London, United Kingdom: IntechOpen, 2017 [Online]. Available: https://www.intechopen.com/chapters/55906 doi: 10.5772/intechopen.68783