Proceedings of the 21st International Conference on Modelling and Applied Simulation (MAS), 014
19th International Multidisciplinary Modeling & Simulation Multiconference

2724-0037 © 2022 The Authors.
doi: 10.46354/i3m.2022.mas.014

Design and analysis of alternatives for the supply of components within the production facilities of new customers of a company with a full-service provider model

Ariana Gazcón-Rivera[1], Jenaro Nosedal-Sánchez[2], Luis Armando Peña-González[3] and Javier García-Gutiérrez[4]*

[1, 3, 4]Universidad Autónoma del Estado de México, Cerro de Coatepec s/n, Ciudad Universitaria Toluca,50100, México
[2]Universidad Autonoma de Barcelona, Campus Sabadell, Carrer dels Emprius 2, Sabadell, 08202, Spain

*Corresponding author. Email address: jgarciag@uaemex.mx

Abstract

Service providers face daily problems while looking for opportunities to improve their activities and impacts on customers. Depending on how operations are carried out, it limits or enables supply chain operations at the echelon it belongs. The work focuses on addressing a current and specific problem that a company faces by incorporating a new client to provide fastening components under the full-service provider model, where it seeks to find the optimal assignment of the orders (pallets) to the operators in charge of receiving and delivering materials with different mixtures and quantities of products in each shift in facilities of the end customer to supply an assembly line. The application of modeling and optimization techniques with Solver in MS Excel is designed to build a minimization model that determines the proportional and equitable allocation of distances that operators must travel from the landing door to each utilization point or temporary storage, guaranteeing the delivery of all the pallets received. This framework modeling is implemented in a template that facilitates the decision-making process, later ensures the transfer of the tool to the company, and finally, is incorporated into its daily operation.

Keywords: MS Excel Solver; modelling techniques; optimization; assignment; internal shipping

1. Introduction

The case study refers to a company dedicated to fasteners materials supplying following the full-service provider model. As a part of a project proposed by the company, it is required to analyze and create substantiated value recommendations to generate opportunities and resolve current concerns since it is inside of the process of incorporating a new client to carry out its operations, where components for the supply of an assembly line are provided.

The problem addressed is related to the operators' allocation of internal shipping activities to supply component orders within the assembly line. The carrying components process starts at a specific point called origin, represented by a dock and a loading and unloading area, to another point called destination, represented by the different utilization or temporary storage areas. Under this operation context, a balanced and more equitable allocation among the operators is sought, an allocation that can be evaluated by comparing the number of pallets and the distances from the origin point to the destination point that each operator moves, assuming that in this way each operator will be more efficient in accomplishing the assigned shipping and picking activities.

Currently, the activities execution is planned to be made by the operators as follows: one lead operator assigns the activities to the remaining operators to perform the tasks within the line. Operators will move through the six areas of the assembly line to the different storage areas, which include the following areas: stairs, chassis, engines, piping, cabin trim, and final assembly.

In response to the company's needs, the application of modeling and optimization techniques is proposed to identify and propose solutions that allow improving the operations of the internal shipping process, benefiting the personnel (operators) in charge of carrying out the activities and making the operation process more efficient, this is, the reduction of the process completion time.

This article includes a review of the literature in section 2. In section 3, a detailed explanation of the problem to be solved and its respective modeling and computational implementation is provided. The models' results of solving an instance with actual shipment data are shown in section 4. Also, this section presents the optimization results and compares two other scenarios by applying empirical allocation rules using the operator in charge. In section 5, based on the results obtained, the use of the proposed tool is discussed to make effective decisions for the work assignment, benefiting the workers by balancing the workload. Finally, conclusions are listed about evaluating the tool's usefulness for making operational decisions that allow the company to improve the process performance and the service provided to the end customer.

2. State of the art

The industrial engineering market and operations management in general, during the last decades in the area of services, has met challenges where clients request services adapted to specific needs, is involved in a sum of services offered in a competitive and growing environment, so adequate methods and tools were needed to develop, structure and manage services (Klingner et al., 2011).

A full-service provider supplies broad coverage of products and services in a particular domain that consolidates and joins the supplies, provisions, and requirements of different suppliers in a single supplier. A company that represents a full-service provider can avoid revenue loss by extending its service and adding it to the product. In addition, close contact with the clients allows for knowing their needs and information that can be used to improve products and services (Kilani & Awad, 2019). Full-service provider companies have a Supply Chain (SC) where they integrate all the participants involved directly or indirectly to satisfy the customer. The manufacturer, suppliers, and its customers participate at the company's SC. The company under study represents a supplier of essential manufacturing components at the customer's facilities.

The primary motivation of this study was a recognized need for the company to find effective third-party logistics solutions for the supply of fastening materials, particularly the assignment of work to operators at customer sites (internal shipping).

According to the operating environment and the management decisions around the process under study, it was characterized as an activity allocation problem, which can be modeled as an optimization problem and, more specifically, as a particularization of the *Job Shop Scheduling* problem. The model is a combinatorial optimization problem in which resources are limited for the tasks' assignment over a horizon planning and the optimization of one or more objectives (Peña & Zumelzu, 2006).

A *Job Shop Scheduling Problem* consists of the plan development to assign the machines to each operation to optimize an indicator. According to some authors (Mencía et al., 2015; Peña & Zumelzu, 2006; Wang et al., 2017), a Job Shop Scheduling Problem can be defined as a set of N tasks (J_1, ..., J_n), a set of M resources (R_1, ..., R_m), and a set of p operators (O_1, ..., O_p). Given the previous identification of these variables, the general structure for modeling and solving this type of problem is presented in the following section.

For the realization of this project, literature about the techniques that can be used for this specific problem was reviewed, from the use of linear programming, simulation, and other optimization approaches such as evolutionary algorithms.

The importance of optimization problems in the industrial world has implied using new tools such as spreadsheets that make it easy to iterate with the user due to their simplified interface (Sánchez-Álvarez & López-Ares, 1998).

3. Methodology

Optimization is one of the disciplines of operations research, which aims to find the best solutions among possible alternatives based on a quantitative-based procedure. Optimization techniques are divided into two groups: first, exact approximations such as linear programming, mixed-integer linear programming, nonlinear programming, stochastic linear programming, and dynamic programming; and the second group, approximate approximations, which includes evolutionary algorithms, heuristic searches, and multi-agent systems; this second groups allow to find a practical solution to complex problems (Sánchez et al., 2010).

Mixed Integer Linear programming (MILP) is used for optimization problems in which these three components are included (Sánchez et al., 2010; Taha, 2012; Winston, 2004): the objective function is the quantitative measure for the management of a system that it is desired to optimize (maximize or minimize), the constraints represent the set of relations that the variables are forced to fulfill, and finally, the variables represent the decisions that can be made to affect the value of the objective function. This problem was formulated for flexible operations with operators and multiple modes per job by applying this problem to programming in Borreguero-Sanchidrián et al. (2018) as a Mixed Integer Linear Programming (MILP).

The construction of the optimization model entails a series of steps, among which it is required to identify each of the elements mentioned earlier and the existing features in the current system or process. The model logic is structured, validated, and later replicated with the tools or software.

It was chosen an MS Excel implementation to ensure ease of use by the company, so the model and its variables were managed in spreadsheets. Data handling involves the MS Excel template organization, the cells devoted to the decision variables, objective function, constraints and the model definition in the tool MS Excel Solver (Gutiérrez Villaverde; Sanchez et al., 2010).

3.1. Previous steps to the modeling and description of the databases

Next, the different databases for obtaining the information for the structure and development of the optimization model are described, in addition to the explanation of the process carried out.

3.1.1. Detection of destination points or storage areas

Information is obtained from a spreadsheet document that contains all items data required by the client company. This document includes all information in the following form: an alphanumeric identifier per item, the destination of the storage area, and the location to which it is directed (to stairs, chassis, engines, piping, cabin trim, and final assembly).

3.1.2. Location of the dock and destination points

From the analysis of the facilities' physical distribution, the distances between the point of origin / dock and the different storage areas of the production lines are identified. For the horizontal axis, they use numbers, and for the vertical axis, letters in such a way that it is possible to obtain quadrants to identify of the destinations of the requirements. A scale of 15 meters is used for each quadrant from the plans' information, as shown in Figure 1.

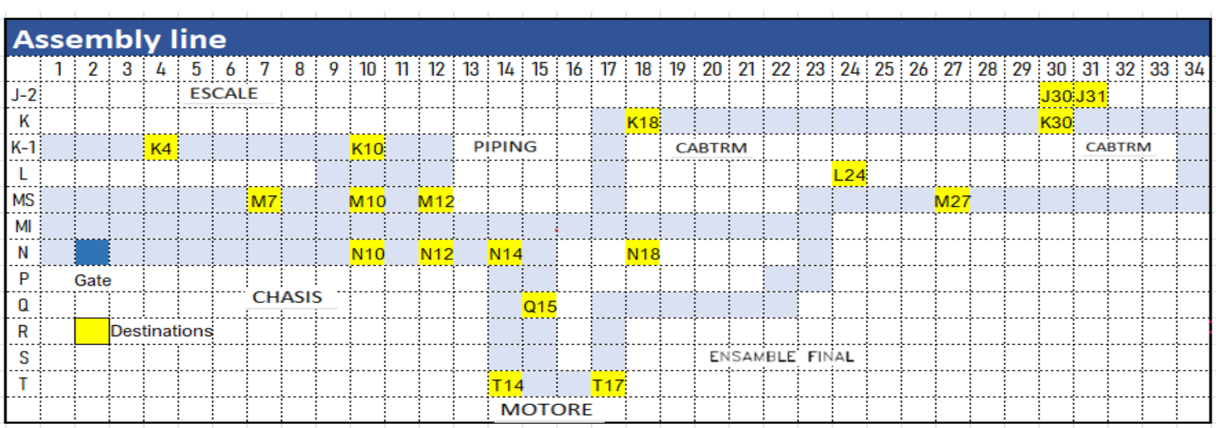


Figure 1. Representative drawing of the plan of a production line and its areas

3.1.3. Identification of the destinations of the requirements

The destinations identification is obtained from a spreadsheet file containing: each forecasted item description, the alphanumeric identifier, and the requirements estimated quantities by date. A new one is created from this file that serves to identify the destination of each item required on the specified date.

A list is used to schedule the day the company studied will start its operations with the client. It was found that the requirements would go to 15 destinations for that day, as shown in Table 1.

Table 1. Destinations of the requirements

Destinations	Storage area
1	J30
2	J31
3	K10
4	K30
5	K4
6	L24
7	M12
8	M27
9	M7
10	N10
11	N12
12	N18
13	Q15
14	T14

3.2. Optimization model development

The model resulted for the described problem is here shown.

3.2.1. *Model components*

k represents personnel called operator k (1,2,3,...,K).

n represents the number of pallets received n (1,2,3,...,N).

d_k total distance for each operator, where d is represented by 15 cartographic units of the drawing of the assembly lines of the client company and k (1,2,3,...,K).

d_T total distance travelled, where a 1 unit d is represented by 15 cartographic units of the drawing of the assembly lines.

$\bar{d}_T$ average total distance travelled, where a 1 unit d is represented by 15 cartographic units of the drawing of the assembly lines.

W objective function to be minimized.

n_k assignment of the n pallets to the k-th operator

3.2.2. *Objective function*

The objective function is to minimize the total distance traveled with a more equitable allocation of n_k; allocation of the n pallets to the operator k with the lowest percentage in the accumulated deviation with n (1,2,3,...,N) and k (1,2,3,...,K), which is obtained with the objective function (1).

$$\boldsymbol{Min\ W} = \sum_{k=1}^{K} \frac{(d_k - \bar{d}_T)}{\bar{d}_T} \qquad (1)$$

3.2.3. *Decision variables*

The decision variables considered are the following.

p_1 maximum percentage allowed in the differences of assignment to the k-th operator.

p_2 minimum percentage allowed in the differences of assignment to the k-th operator.

3.2.4. *Parameters*

Parameters d_T and $\bar{d}_T$ are obtained with (2) and (3):

$$d_T = \sum_{k=1}^{K} d_k \qquad (2)$$

$$\bar{d}_T = \sum_{k=1}^{K} \frac{d_T}{K} \qquad (3)$$

3.2.5. *Constraints*

$n_k \leq K$ where n = (1,2,3,...,N) and k = (1,2,3,...,K)

$n_k = Z$ where Z (integer value), n = (1,2,3,...,N) and k = (1,2,3,...,K)

$n_k \geq 1$ where n = (1,2,3,...,N) and k = (1,2,3,...,K)

$\frac{(d_k - \bar{d}_T)}{\bar{d}_T} \leq p_1$ where k = (1,2,3,...,K)

$\frac{(d_k - \bar{d}_T)}{\bar{d}_T} \geq p_2$ where k = (1,2,3,...,K)

3.3. IMPLEMENTING THE MODEL IN MS EXCEL SHEETS

Later, the model is implemented in MS Excel. This procedure consisted of the following steps:

1. Organization of the model data electronically in the MS Excel sheet.
2. Indication of the cells representing the target function.
3. Indication of the cells representing the decision variables (changing cells).
4. Indication of the cells related to the constraints.
5. Solution of the model and its interpretation.

Figure 2 represents the database of routes and distances that feeds the template of the assignment of the n pallet to the k operator, where the distance column of Figure 3 calls the desired data.

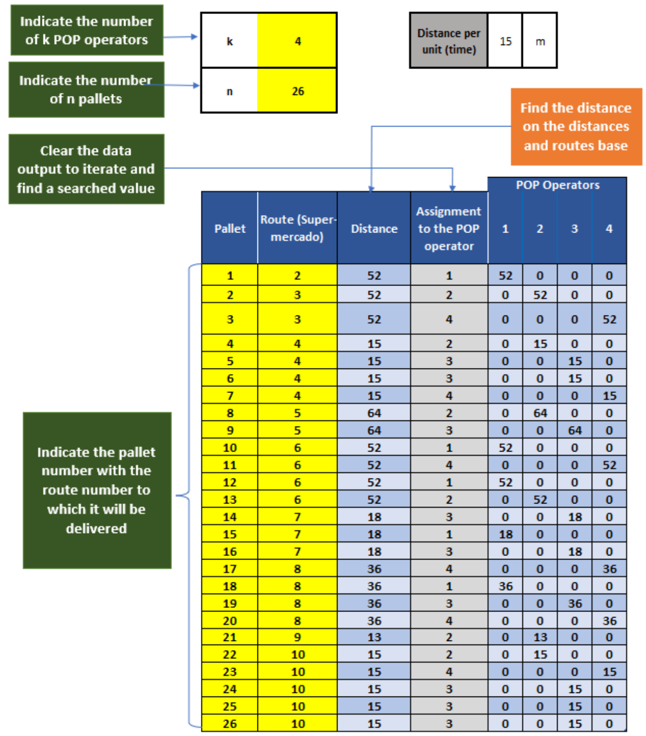
	A	B	C	D
1	Route	Distance(units)	Supermarket	Bin Location
2	1	_	760 Piso	VC0 - ESCALE
3	2	52	J30	VU0 - CABTRM
4	3	52	J31	VU0 - CABTRM
5	4	15	K10	VC0 - ESCALE
6	5	64	K18	VU0 - CABTRM
7	6	52	K30	VU0 - CABTRM
8	7	18	K4	VD0 - ESCALE
9	8	36	L24	VU0 - CABTRM
10	9	13	M10	VI0 - PIPING
11	10	15	M12	VI0 - PIPING
12	11	38	M27	VU0 - CABTRM
13	12	13	M7	VE0 - CHASIS
14	13	9	N10	VC0 - ESCALE
15	14	11	N12	VI0 - PIPING
16	15	13	N14	VP0 - EFINAL
17	16	23	N15	VK0 - MOTORE
18	17	27	N18	VP0 - EFINAL
19	18	22	Q15	VK0 - MOTORE
20	19	18	T14	VL0 - MOTORE
21	20	21	T17	VK0 - MOTORE

Figure 2. Spreadsheet with distances and destinations

Figure 3 represents the template in which the input data is entered to feed the model and proceed to optimization. In k, the number of operators preparing to move the pallets to the supermarkets is given. In n, the number of pallets received is specified. The data of the requirements received are stated in the Pallet column and the Destination column.

The Distance column provides the estimated distance corresponding to the pallet and the supermarket it is directed to. The Assignment to the Operator column is where the optimization results will be shown. Finally, the Operators columns will reflect the values corresponding to the distance that each operator will travel if the workload is assigned.

Figure 4 represents the analysis of Figure 3, where the Permissible range refers to the data entry of the minimum and maximum percentage value allowed in the differences of assignment to the k operator, assuming the total distance traveled, the average distance, the distance traveled by an operator, the number of pallets per operator, the estimated time and some statistical data. Such statistical information could be the difference in the distance traveled by the operated k concerning the average distance for a perfectly equal allocation, the percentage difference of the distances between the operator k and the average distance if the assignment is at a lower level and higher level between the k operators. Finally, in cell 23S Cumulative deviation is the percentage of the cumulative deviation of the allocation distances that will serve as the target function.



Pallet	Route (Super-mercado)	Distance	Assignment to the POP operator	1	2	3	4
1	2	52	1	52	0	0	0
2	3	52	2	0	52	0	0
3	3	52	4	0	0	0	52
4	4	15	2	0	15	0	0
5	4	15	3	0	0	15	0
6	4	15	3	0	0	15	0
7	4	15	4	0	0	0	15
8	5	64	2	0	64	0	0
9	5	64	3	0	0	64	0
10	6	52	1	52	0	0	0
11	6	52	4	0	0	0	52
12	6	52	1	52	0	0	0
13	6	52	2	0	52	0	0
14	7	18	3	0	0	18	0
15	7	18	1	18	0	0	0
16	7	18	3	0	0	18	0
17	8	36	4	0	0	0	36
18	8	36	1	36	0	0	0
19	8	36	3	0	0	36	0
20	8	36	4	0	0	0	36
21	9	13	2	0	13	0	0
22	10	15	2	0	15	0	0
23	10	15	4	0	0	0	15
24	10	15	3	0	0	15	0
25	10	15	3	0	0	15	0
26	10	15	3	0	0	15	0

Figure 3. Work assignment template

3.4. Use of MS Excel Solver

MS Excel Solver is an optimization tool built into a spreadsheet environment. To most MS Excel users, it looks like another function of Excel because of the user interface. Even though its algorithm underneath is not as efficient as any other optimization software developed for consulting and research purposes, the ease of use and the complexity of the current problem makes it a good choice.

The use of MS Excel Solver will need a previous installation procedure (e.g. Gutiérrez Villaverde, 2018). Once the distances and destinations data have been entered and the number of k operators, the number of pallets, and their destination, the model is optimized using the Solver command located in the Data menu. It is essential to know the cells for the target function, decision variables, and parameters.

Figure 5 represents the parameters that will serve as inputs to the model for the problem to be optimized, illustrated in Figure 3 and Figure 4.

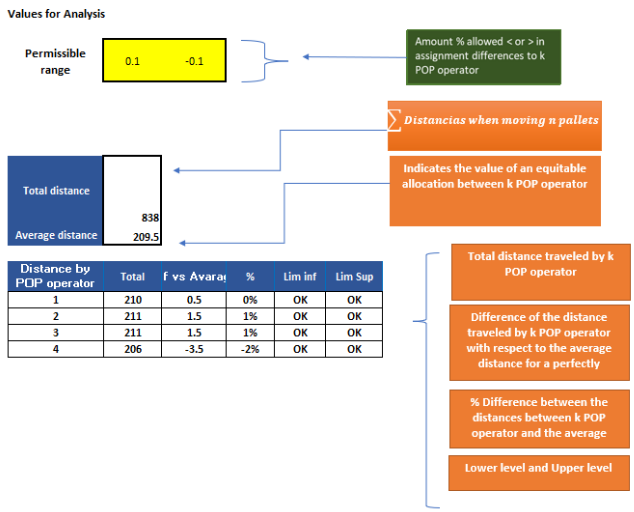


Figure 4. Data analysis

The objective function (cell S23) is located as a target cell, indicating the Min option that specifies that this is a minimization model. The decision variables are marked by collecting the range of cells they occupy (E7:E32), which are the changing cells.

The button Add is selected to enter the constraints, and the constraints cells are entered on the left. The right part assigns the numeric value of the independent term of the constraint, and in the central body, it is selected its relational sign.

The resolution method is selected, in this case by using an evolutionary algorithm, and continues to solve.

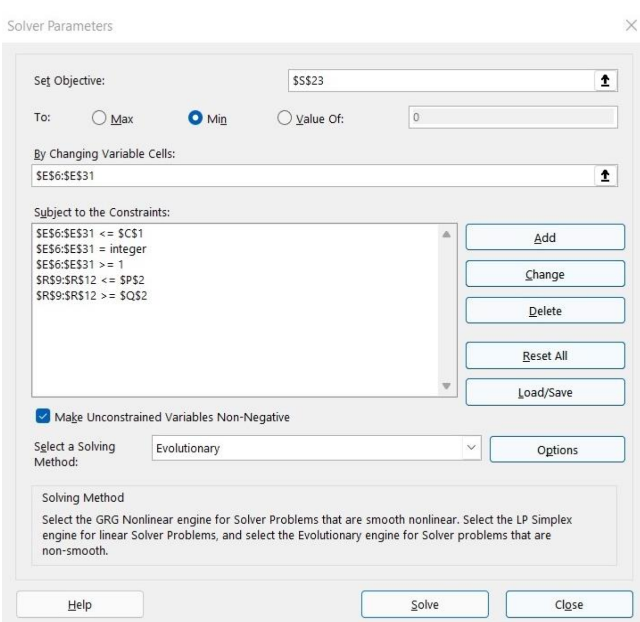


Figure 5. Solver parameters

At the end of the process, it is indicated if initial values have to be maintained or an optimal solution. Also, there is an option to save a given scenario, as shown in Figure 6.

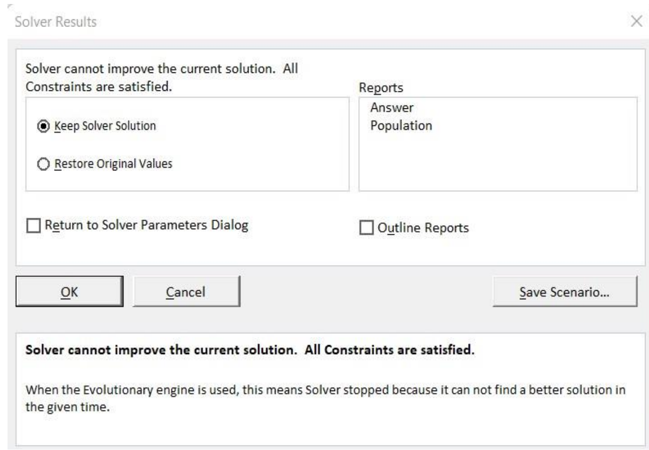


Figure 6. Solver results

3.5. Application of the model and analysis of scenarios

For the assignment process, two allocation scenarios obtained from applying rules that decision-makers could use empirically are analyzed and compared without using the optimization model. In the first scenario, the k operators carry the following order; pallet 1 with operator 1, pallet 2 with operator 2, and pallet 3 with operator 3; and repeat the order of the sequence.

The second scenario is by equal blocks, i.e., the first group of pallets is assigned to the first operator, the second group of pallets to the second operator, and successively. Finally, a third scenario is obtained to establish a comparison, which is the result when using and solving the optimization model through Solver.

Table 2 shows a summary table of the locations to which the requirements are destined, corresponding to the day the company will start operations at the client's facilities.

Table 2. Target locations of the requirements.

Base	Destination/Storage Area	N_o
June 28	J30	2
	J31	3
	K10	4
	K30	6
	K4	7
	L24	8
	M12	10
	M27	11
	M7	12
	N10	13
	N12	14
	N18	17
	Q15	18
	T14	19
	T17	20

4. Results and Discussions

It can be observed that in the first scenario, based on a consecutive succession in the assignment of work to operators; Table 3 shows an assignment with a percentage of accumulated deviation of 36%, a value that indicates how different or disproportionate is the allocation between operators with a minimum distance traveled of 188 units at a maximum one of 247 units, which means that this allocation is not the most appropriate. While one operator travels less than 3 km, the other travels almost 4 km in the same shift.

The block assignment is chosen when generating the analysis results with scenario 2 in Table 4. It is observed that the distances assigned to the operators are not appropriate since the difference in the total distance traveled is 266 units between the allocation of the operators, in addition to the fact that the percentage of the accumulated deviation in the assignment is very high and does not reflect the results of the proposed objective. In this case, the allocation is notoriously inequitable, so the effect of such assignment introduces an unnecessary extension of time to complete the internal shipping since the available capacity is underutilized (one operator will travel less than half of the rest).

Table 3. Results were obtained in scenario 1

	Units of distance traveled	Number of pallets	Percentage difference between operator distances and mean	Estimated distance traveled d=15 m
Operator 1	247	7	18%	3705
Operator 2	203	7	-3%	3045
Operator 3	188	6	-10%	2820
Operator 4	200	6	-5%	3000
Total distance traveled	838	26		12570
Average distance traveled				3142.5
Percentage of cumulative deviation of distances for allocation				36%

Table 4. Results obtained in scenario 2

	Units of distance traveled	Number of pallets	Percentage difference between operator distances and mean	Estimated distance traveled d=15 m
Operator 1	216	7	3%	3240
Operator 2	354	7	69%	5310
Operator 3	180	6	-14%	2700
Operator 4	88	6	-58%	1320
Total distance traveled	838	26		12570
Average distance traveled				3142.5
Percentage of cumulative deviation of distances for allocation				144%

When analyzing scenario 3, Table 5 shows the results obtained from the model optimization in the spreadsheet, indicating an improvement in the proportional allocation to each operator in which the percentage difference between the distances is a maximum of 2 units between operators, even though the allocation of the number of pallets shows variations. Finally, the value to minimize through optimization is reduced to only 3%, a significantly lower than the other two scenarios. In Figure 7, this comparison is illustrated. It can be seen that the proposed workload allocation, through the results of the use of optimization, allows more significant equity in the distribution of work to less accumulated deviation.

Table 5. Results obtained in scenario 3

	Units of distance traveled	Number of pallets	Percentage difference between operator distances and mean	Estimated distance traveled d=15 m
Operator 1	210	5	0%	3150
Operator 2	211	6	1%	3165
Operator 3	211	9	1%	3165
Operator 4	206	6	-2%	3090
Total distance traveled	838	26		12570
Average distance traveled				3142.5
Percentage of cumulative deviation of distances for allocation				3%

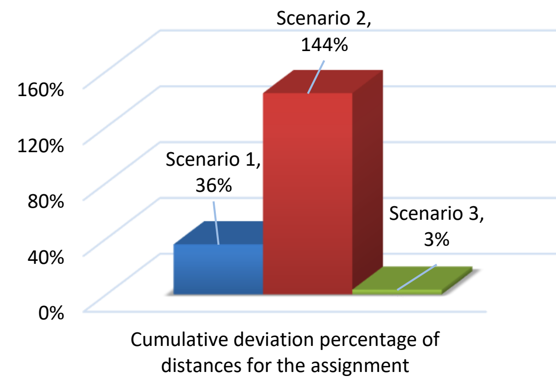


Figure 7. Results of the target function

Using the optimization technique and tool implemented in this study case helped reach better decisions for fulfilling the objectives set, as shown in Figure 8.

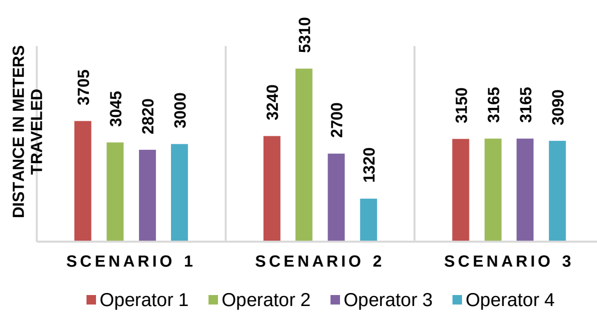


Figure 8. Assignment results in each scenario

As explained in the previous sections, this optimization model allocates the most balanced workload for the operators that perform the internal shipping, and its application can be made for any production lines served. The proposed model is based on distances; however, future work is expected to complement the model by explicitly considering the execution times associated with this process.

5. Conclusions

By applying the proposed methodology, it was possible to build an optimization model with Solver in MS Excel, which allows solving the problem of assigning the workload of the k operators, fulfilling the declared objective. This objective consisted in improving the execution of the internal shipping process from the optimized workload allocation in a balanced and equitable way). The developed model allows assigning the workload to the operators along with the different destinations of one of the production lines. The routes' distances are estimated according to the requirements and the destinations/storage areas at the customer's facilities, where, from the distance information, the travel time between origins and destinations is estimated. On the other hand, the results of the workload assignment allow each operator to benefit individually from the performance of internal shipping operations, where there will be no worker who performs activities in excess or there is an underutilization of the required capacity. Also, due to the implementation using the template in MS Excel, the data input allows the generation of an adaptable model and potential assimilation by the decision-makers. The model is helpful for the company since it is possible to adapt it and update it directly to different scenarios: the values of the inputs can change the number of the k operators, the number of pallets, and the percentage allowed in the allocation differences to the k operator.

The practical use and achievement of the results shown for the proposed approach relies heavily in the current operational rules, the most relevant are the following: first, each pallet contains items that belong to a specific supermarket; second, current locations of the supermarkets and the distances were obtained for the actual movement directions allowed in the plant premises. If the operational rules are changed or locations modified due to a different layout, the model and tool implemented must be adapted and updated accordingly.

Finally, it can be used daily and generate results for the activities involving the suppliers' and the clients' company.

Acknowledgements

This work was carried out with the support of CONACYT-Mexico, which supported Ariana Gazcón-Rivera as a national postgraduate fellow of the CONACYT-PNPC program. During the development of this work, Jenaro Nosedal-Sánchez was collaborating with the Serra Hunter Fellow from Universidad Autónoma de Barcelona and as a member of the National System of Researchers (SNI) of CONACYT-Mexico. Finally, Javier García-Gutiérrez also acknowledges the SNI of CONACYT program.

References

Borreguero-Sanchidrián, T., Pulido, R., García-Sánchez, Á., & Ortega-Mier, M. (2018). Flexible Job Shop Scheduling With Operators in Aeronautical Manufacturing: A Case Study. *IEEE Access*, 6:224–233. https://doi.org/10.1109/ACCESS.2017.2761994

Gutiérrez Villaverde, H. (2018). *Nota técnica sobre el uso del Solver Excel: versión 2.0*. Universidad de Lima, Facultad de Ciencias Empresariales y Económicas.

Kilani, Y.M.M. & Awad, H.A.H. (2019). Advantages of cloud supply chain management systems from the point of view of the service provider: an empirical study of advantages of cloud supply chain management systems from the point of view of the service provider. *Asian Journal of Management Sciences & Education*, 8(2):27–36. http://www.ajmse.leena-luna.co.jp/AJMSEPDFs/Vol.8(2)/AJMSE2019(8.2-03).pdf

Klingner, S., Böttcher, M., Becker, M., Arndt, D. & Schumacher, F. (2011). Managing complex service portfolios: A business case from a full service provider. *Reser.Net*, 1–13. http://www.reser.net/materiali/priloge/slo/klingner_et_al.pdf

Mencía, R., Sierra, M. R., Mencía, C. & Varela, R. (2015). Memetic algorithms for the job shop scheduling problem with operators. *Applied Soft Computing Journal*, 34:94–105. https://doi.org/10.1016/j.asoc.2015.05.004

Peña, V. & Zumelzu, L. (2006). *Estado del Arte del Job Shop Scheduling Problem*. Universidad Nacional de Colombia, 1–8.

Ramos, A., Sánchez, P., Ferrer, J., Barquín, J. & Linares, P. (2010). *Modelos matemáticos de optimización*. Universidad Pontificia Comillas.

Sánchez-Álvarez, I. & López-Ares, S. (1998). Optimización con Solver. *VI Jornadas Santiago - ASEPUMA*, 1–10. Santiago de Compostela.

Taha, H.A. (2012). *Operations Research. An Introduction*. 10th Edition. Pearson.

Wang, L., Cai, J., Li, M., & Liu, Z. (2017). Flexible Job Shop Scheduling Problem Using an Improved Ant Colony Optimization. *Scientific Programming*, 2017: https://doi.org/10.1155/2017/9016303

Winston, W.L. (2004). *Operations Research: Applications and Algorithms*, 4th Edition, Thomson Brooks/Cole, Belmont, 2004.