Improvement of material supply system through kitting concept and IT solutions

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Abstract

The performance of every assembly line depends on the availability of a large number of components which have to be supplied in a coordinated and precise manner, if a company doesn't have a well-constructed material feeding system it will not achieve good operative results. This paper is the result of a project developed at Daimler Buses Mexico where chassis are being assembled for Mercedes-Benz Buses with an existing high cost due to rework process on units with missing parts. Through Lean Logistics and PDCA Cycle Methodology the kitting concept was redefined and different proposals involving the kitting method were established; several IT solutions in the material supply process and in the material control system were also an important contribution. In addition, a discrete-event simulation to gain insights about the needed resources was developed. Results of the different applications are provided.

Keywords
Line feeding; kitting; materials supply system; automotive; assembly line; PDCA, Lean.

1 Introduction and Background

The automotive industry is facing new and pressing challenges: globalization, specialization, digitalization and the most current and important of them, electrification. In total, the automotive industry is expecting 127 battery-electric models to be introduced worldwide over the next five years, and that one in nine cars sold globally will be electrified by 2035 (Roper, P., 2018). That gives the industry less than five years to prepare and update electrical grid infrastructure, adjust business models, and roll out enough charging stations to meet demand.

In spite of the current challenges mentioned above there is a great quantity of variants and there are sure more to come. Theoretically, the number of alternative product models in the automotive industry can be billions in today's market. In such situations, the internal logistics of supplying an assembly line with mixed needs are even more complicated (Faccio et al., 2013). This type of environment becomes a great challenge for the material flow system due to the dynamic nature of demand for parts and materials. Any delay of parts and materials will stop the assembly line, on the other hand, too early delivered materials can accumulate beside stations, this area is very scarce and expensive. (Alnahhal, 2015)

The automotive industry works with an important KPI (key performance indicator) which is called Yield. This KPI indicates a percentage of products that are manufactured correctly and to specifications the first time through the manufacturing process without scrap, missing parts or rework. The lower this KPI the more additional costs regarding rework, late delivery to customer and extra hours of the operators. This means an efficient material supply is needed to constantly serve the production or assembly line, in other words, it’s crucial to be able to deliver the correct components at the correct time in the correct quantity in the required location. The flow will affect the quality of supplies, reduce costs and obtain delivery assurance (Lumsden, 2012).

A growing number of product variants often result in more components, these components need to be delivered to the assembly process. Delivering them in the traditional way with continuous supply and line side stores becomes a problem since the increasing number of parts demands an increase in line side storage space and this creates longer operator walking and searching times at the assembly line. One way to decrease these non-added value space and times is to deliver parts in kits.

In manufacturing systems, the practice of delivering components and subassemblies to the shop floor in predetermined quantities that are placed together in specific containers is generally known as kitting. Theory explains a number of kitting benefits and limitations, however most of the theory is found from research in parallelized assembly systems and assembly with small parts. (Gajjar, 2014)

This paper explains the process and results of a 5-month PDCA improvement project with the purpose of improving the material supply system in an automotive assembly plant in Mexico by optimizing and increasing the use of the kitting and also by introducing different IT solutions. It’s divided in six sections: starting with this text, Section 1 is the introduction and background, Section 2 provides a brief literature review on the importance of an efficient material supply system and on the benefits of automatization, digitalization and kitting methods and also defines the applied methodology, Section 3 includes the Problem Statement focus of this work and the context around it, the development of the project in it’s different phases and the results are undertaken in Section 4, Section 5 contains the results and finally conclusions and future actions are presented in Section 6.

2 Literature Review

In today’s global automotive industry, competition is becoming highly challenging. Products are becoming increasingly customized in order to attract customers. At the same time, reduced lead-time, lower cost and improved quality are required. Increase in the customers need on product variety is greatly affecting the material supply system and assembly systems due to the increase in the number of components. Due to many product variants, the complexity of material flow is increased which in turn requires more work space at the stations and increases in need of different assembly tools. (E Johansson 2006, Fasth 2009)

Johansson (1991) illustrates three different principles of material supply to the assembly line: continuous supply, batch supply and kitting, as shown in Figure 1.

	Selection of part numbers	All part numbers
	BATCH	CONTINUOUS
Sorted by assembly order	KITTING	

Figure 1. Principles of Material Supply

Nowadays companies are trying to use more and more kitting in their material supply systems. According to Johansson (1991), kitting means that the assembly is carried out with kits just feeding the kit containers rather than supplying every component container in the assembly system. (Bozer & McGinnis, 1992; Ding & Balakrishnan, 1990; Ding, 1992; Medbo. 2003)

A set of components for one assembly unit is supplied in one kit. This differs from batch supply where components are arranged by part numbers. The kitting supply process is best suitable for assembly systems with parallelized flows, product structures with many part numbers where there is a requirement of high quality assurance and for high value of components.
Some of the benefits of kitting are described below according to various authors:

- It saves assembly space in the shop floor. (Bozer & McGinnis, 1992; Medbo, 2003)
- It reduces operators walking and searching time in the assembly Johansson, 1991; Schwind, 1992)
- It reduces the frequency of assembling the wrong component in the end product and missing parts in the end product. (Bozer & McGinnis, 1992; Schwind, 1992; Sellers & Nof, 1989)
- It reduces material delivery to assembly stations by removing the need to supply individual component containers. (Bozer & McGinnis, 1992; Ding & Balakrishnan, 1990; Medbo, 2003)

In kits, all items must be presented in a logical order so they can be removed from the container as quickly as possible without damage. It is important to keep it simple and the kit itself is structured or laid out in a predetermined and effective way. (Lean Advisors, 2008)

Another important aspect involved in the automotive industry it the so called "Industry 4.0". This recent revolution represents the comprehensive transformation of the entire industrial production through the merging of Internet and information & communication technologies (ICT) with traditional manufacturing processes (Davies, 2015). Breakthrough innovations as the global communication network, e.g. Internet, and interconnected intelligent sensors are enabling technologies for production systems. Traditional assembly lines descended from the Ford model T one are no longer suitable for today industrial environment. A new generation of assembly systems (ASs) is sought to seize the opportunities that the fourth industrial revolution offers. (Bortlini et. al. 2017)

This project was based on the PDCA Methodology and Lean Logistics. The Deming cycle is a four-staged Plan-Do-Check-Act continuous loop model that offers a systematic approach to process improvement. (Kayode Ashogbon, 2012). Tague (2004) described this model as a four–step model for carrying out change. Just as a circle has no end, the PDCA cycle should be repeated again and again for continuous improvement. Simons DW (2006) mentions PDCA has got enormous applications: as a model for continuous improvement; when starting a new improvement project; when developing a new or improved design of a process; when defining a repetitive work process; and when implementing any change.

We also applied Lean tools throughout the development of the project in several stages of this PDCA Cycle model as shown in Figure 2. Lean has been defined as "a systematic approach to identifying and eliminating waste through CI by following the product at the pull of the customer in pursuit of perfection" (NIST 2000 cited by Bhuiyan & Baghel 2005). The idea behind lean thinking is the total eradication of wastes and the enhancement of value creation activities which meet the requirements of the end users through continuous improvement activities.

Figure 2. Development of the project according to the methodology

3 Problem statement

The material supply system is a key system in the operation of all manufacturing companies or assemblers. If the components required to produce or assemble something are not available in the line or work station, it will not be possible to fulfill the job, generating production stops, wastes, and delays, among other things.

The need to intervene this system within the plant was identified together with the company based mainly on a strategic indicator they had. This indicator is known as "Direct Run" or also known as Yield, this KPI refers to the percentage of units reported at the end of the assembly process without any missing parts or open defects. A missing part refers to any piece that must be placed outside the designated workstation to assemble due to the lack of availability in the correspondent workstation. The Direct Run is measured within the assembly area, but it is a key indicator for the entire company, since the operation is focused on the production of chassis and it would be expected that all units would finish the process with the quality and requirements necessary to be delivered to the client.

Two things affect the Direct Run, the units with missing parts and the units with non-conformities. The composition of the Direct Run was obtained for 2017, we can observe in Figure 3 that 41% of the units that affected the Direct Run were exclusively missing parts while only 12% of them had exclusively non-conformities and 33% of the units presented both missing parts and nonconformities. A total of 86% of the units produced are units reported at the end of the assembly process with missing parts or defects. The 74% of units with missing parts is clear evidence that the material supply system had different opportunity areas to attack.

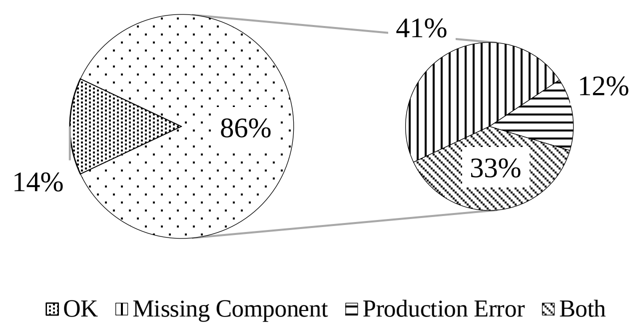

Figure 3. Indicator Direct Run

The units that don't end the process correctly the first time must be reworked later on in the process or at another time, this involves an extra use of resources like people, time and money. In 2017, a total of 35,071 hours were invested in re-works due to missing parts.

4 Development of the Project

As mentioned before, we used the PDCA methodology, which represents 4 steps: Plan, Do, Check, Acta.

4.1 PDCA Plan

In this phase of the project the diagnosis of the whole material supply system was made in order to develop the analysis with the information collected. Based on the analysis the objectives and the different strategies were determined.

Diagnosis

First of all, to get to know the whole system and be able to recover as much information as possible, we planned three main activities:

- Job Shadowing
- Value Added Analysis
- Brainstorming

The value-added analysis carried out in the line feeding system sought to understand the functioning and the current operation of the system and to determine the percentage of time that each worker spent doing value added tasks, non-value-added tasks and activities determined as waste.

Two samples with duration of one hour each were taken for each of the 5-different logistics operators. We decided to not use more than two samples since there were no specific routes or a certain standard way of working, thanks to this decision, activities varied a lot most of the time and each operator carried out his or her work the way each person wanted to.

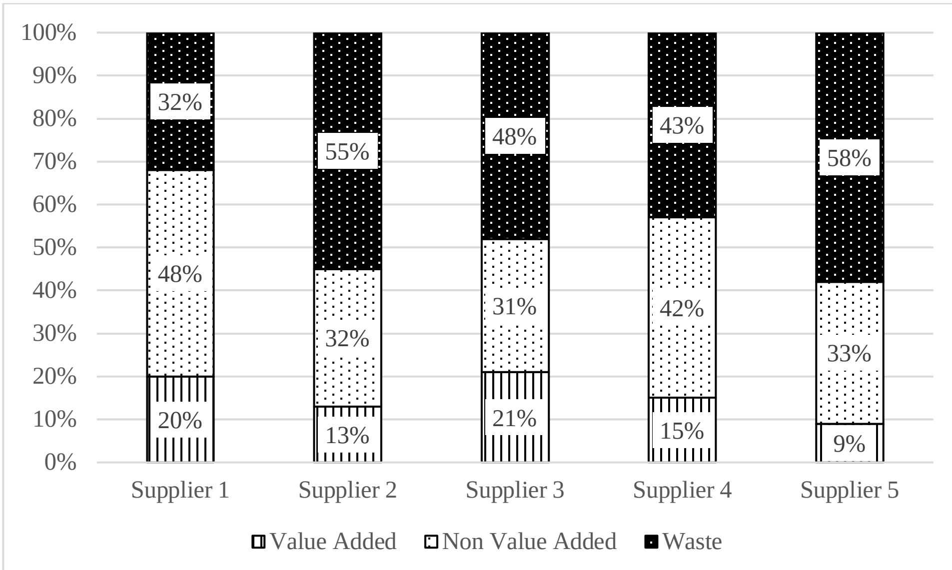

Figure 4. Value Added Analysis Results

Figure 4 shows the results of the analysis made, the most important message that Figure 4 gives us is that all the operators, regardless of the area they are responsible for, the experience they had or the team they were part of, spent more than half of the time doing non-value activities or activities not necessarily for their job. In conclusion, on average, only 15% of the time do logistics operators perform activities that correspond to their job or position and that really add value to the process.

Analysis

After there was sufficient information available we could prepare an accurate analysis in order to identify the different root causes of the problem.

It was decided to use the cause-effect diagram or the Ishikawa's Diagram and by means of this be able to obtain the main root causes of an important number of units with missing parts at the end of the line. The final Ishikawa's Diagram resulted in a total of 133 different symptoms.

We were able to identify 16 root causes thanks to this analysis, from these 16 root causes only 5 of them were intervened or worked on, these were the ones that formed part of the materials supply system. These 5 root causes are: (a) There is no appropriate method of assortment to the assembly line; (b) There is no appropriate division of tasks; (c) There is no material control system; (d) The existing infrastructure is not enough or adequate; and (e) The method of kitting is not the adequate.

Objective and Scope

The scope of this project is limited to the units belonging to the three high runner models, these models represent around 38% of the total production. The main objective of the project was the reduction of the units that finished the assembly process with missing components, improving by consequence the Direct Run indicator. To be able to reach this objective 4 different strategies were developed. 1) Material Supply Method, 2) Material Control System, 3) Kitting Method, and 4) Job Descriptions.

Strategy Design

We prepared several proposals for each strategy, each one of the proposals was designed carefully and specifically to reach the objectives, however, some aspects in common were: (a) benchmarking, we compared our situation with plants in other parts of the world; and (b) research, introducing the concept Industry 4.0, so we investigated the technologies that were being used nowadays to solve the problem that we were handling.

Material Supply Method

Demand alert: the proposal includes the implementation of buttons, sensors and an E-kanban system, each of these for a different type of material supply modality. The E-kanban system for the work tables where there is not so much space available and the containers are really small, sensors for the shelves with a two-bin system and buttons for the kitting carts.

IT Application for material supply process: this proposal consists in having a tablet for each delivery car, the tablet shows the delivery orders with the optimal information for its easy and fast delivery. This system will be linked with a scanner and will have a very easy visualization of the logistics operator's work plan and optimal routes.

Material Control System

IT Application: this proposal consists basically in the use of scanners to achieve the optimum traceability of the material flow and to be able to count with the certainty that the correct materials were delivered on time and in the right place.

ID by barcode labeling: to make possible the use of scanners various barcodes have been established both in the warehouse location and in the assembly area inside the plant. The company counted with two bar code printers which facilitated and made easier the printing process.

Kitting Method

New car designs: Six new trolley designs were created, built and delivered to the company. These designs took into account ergonomic factors, capacity, handling and ideal materials for construction.

Visual aid: Tags were designed for both the kits containers and large containers within the kitting area in the warehouse. These tags include the type of kit, model, date and other details.

Kits redesign: The kits were redesigned, that is, pieces were added, eliminated or moved from one kit to another, always taking into account the option that could provide the best results for the assembly operation.

Instructions for the development of kits: in order to achieve a standard arrangement within the kits, working instructions were developed to create the different types of kits.

Redesign of the kitting area: the layout of the kitting area was redesigned and a pick-by-color system was introduced. This system showed a different color for each type of model and facilitated the kitting process by eliminating long distances travels and inefficient practices. The layout was divided per kit and the components were ordered according to the assembly sequence. The final layout can be seen in Figure 5.

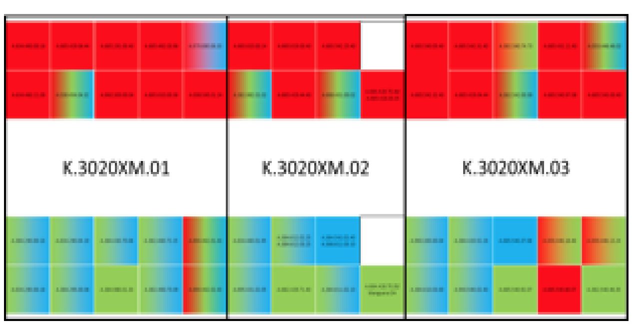

Figure 5. Layout Kitting Area Redesign

Manual "Material supply to assembly line": This manual covers all the kits from the three different models considered and the content of each kit, including pictures of the components for easy recognition and the required quantity of each.

Job Descriptions

Design/redesign of Job descriptions: The company had four types of positions, after the analysis it was decided that three of the Job Descriptions were to be redesigned and two new Job Descriptions had to be created from scratch.

Procedure development: Four new procedures were developed for several positions to standardize the work in the logistic team.

4.2 PDCA Do

To describe this phase, we summarized the implementation actions in Table 1. For each strategy, the specific actions made are listed (e.g. pilot, documentation, experimentation, etc.). Column 2 in this table indicates whether the effect on the number of units with missing components is direct or indirect.

Table 1. Implementation Actions

Strategy	Effect	Actions
Material Supply Method	Direct	Financial evaluation, Structure design, Decision making diagrams, pilot implementation
Material Control System	Direct	Definition, Financial evaluation, Pilot Implementation
Kitting Method	Indirect	Implementation, Process redesign, Layout Redesign, Structure design, visual fabric
Job Description	Indirect	Transition plan, Balancing, Simulation, Process definition

An important number of implementations were made during two Kaizen events between March 2018 and May 2018. Actions related to redesign, processes definition or redefinition were documented, passed through internal approval and some of them reached the approval during the duration of the project.

Due to the time limitation, the proposals regarding the IT Solutions that required a great amount of investment in time and money were included in a larger IT program to be executed next year. Therefore, a discrete event simulation exercise was developed in the software ProModel to evaluate and validate our proposal and a contingency action for the IT Application was developed.

Through this simulation we estimated the total man-hours needed to deliver the material to the assembly line according to our proposed work plan. The data used is shown in Table 2. This simulation runs under the following assumptions: (a) The assembly starts with kits on the line; (b) The necessary kits are inside the plant; (c) Supply activities are the only ones developed; and (d) There are no stops in the line.

Table 2. Simulation Data Input

Input		Source
Takt Time	~ T[a, c, b]	Kaizen Department
Distance	Measurements	Official AutoCAD
Tugger Speed	Average Speed	SUNAT
Delivery Time	Average	Value Added Analysis
Demand	~ Inverse Weibull	Statfit

The contingency action consisted of a kitting form, which was printed for every kit made, serving as a checklist. This kitting page contains all the components needed to make the kit and can be easily downloaded and printed from the SAP system. Throughout the kitting process, the picker needs to mark each and every component that he introduces in the kit finishing the process with his signature in this same form as consent. By following this process, in addition to making sure the kit is complete and with the correct components the company now counts with a person responsible for this material.

4.3 PDCA Check

This step in the methodology refers to (a) Check how well you accomplished the expectations; (b) Observe the effects; (c) Examine the results achieved, ask if the objectives from the plan were reached? (d) Look for possible deviations from the plan; and (e) Test the plan accordingly to the information gained during the cycle (Pietrzak and Paliszkiewicz, 2015).

During the duration of the project we were able to measure different results in addition to obtaining a great quantity of feedback from things that could be improved.

4.4 PDCA Act

Following our methodology, the purpose of this phase is to act upon what has been learned. Several improvements were made in some of the proposals of the kitting strategy involving the redesign of the visual aids and of the kitting cars. Also, protocols and documentation were developed for the extended implementation, such as: (a) decision trees to decide the best supply method for new components, (b) templates for all the visual aids made, (c) documentation of new processes and protocols to follow in case of a variety of situations having to do with components, and (d) manuals both for the supply transport of components and the kitting elements. As an example, Figure 6 shows a visual representation of a decision tree made in (a).

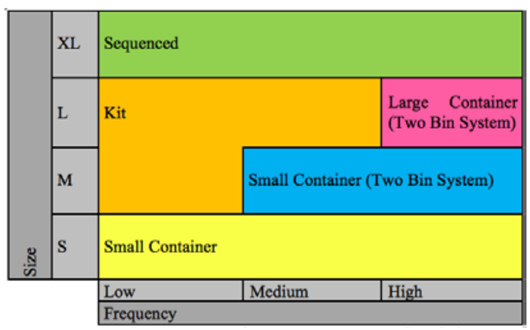

Figure 6. Decision Tree Visual Representation – Best supply method

Based on the information gathered during the entire development of the project and the status of the implementations from Table 1, Table 3 was developed identifying actions for further improvements.

Table 3. Actions for further improvement

Action	**Scope/Extern**
Replicate strategies in other models and half of the line	Scope
Implementation of technology proposals	Scope
Analysis and purchase of correct equipment for kitting	Scope
Evaluation and improvement of planner material system	Extern
Analysis and comparison of specifications	Extern
Implementation of complete warehouse control	Extern

5 Results

- An increase in 12 percentage points was achieved for the Direct Run indicator by decreasing 54% of the units with missing parts inside the 13 stations intervened, during a two-week period.
- There were important results inside the kitting area of the consolidated warehouse outside the plant.
- The process followed by the picker became more efficient than before and the pick rate increased 17%.
- We achieved certain improvements that affected the assembly line directly:
  - a) the nonvalue added activities were reduced in 1.36% in activities regarding the look out and gathering of material inside the assembly line,
  - b) 71m^2 were freed up inside the assembly area, and finally,

c) we achieved a reduction of 1065 m walked daily by logistic and production operators.

In addition to the above, the non-ergonomic activities from the kitting process were reduced 48 percentage points and the handling points involving this process were reduced by 2, in other words, before our work there were 6 handling points involved in the material supply system, running from the kitting process to the direct supply of the line, ending with only 4 handling points. With the simulation exercise we were able to validate our proposal of designing 2 new job descriptions. The optimal number of operator discovered was 2 instead of the actual 5. We also found out the utilization of each of these operators: Material preparer: 59% and Material supplier: 40%.

On the other hand, the IT solutions proposed were left pending but with a commitment to implement them during the development of a bigger project involving the automatization and digitalization of the entire plant. Once these proposals are executed the units with missing items will decrease even more.

6 Conclusions

The work in this paper describes different strategies carried out for the improvement of the material supply system of an automotive assembly plant located in Mexico. This improvement was achieved thanks to the design and the execution of different proposals involving lean principles, promoting the introduction of digitalization and automation, the optimization of the kitting method and last but not least the continuous improvements made in all four strategies following the PDCA methodology used.

Thanks to the application of innovative and well-designed solutions and to the collaboration of the Company by making changes and using Lean, the initial objective of increasing the Direct Run in 10 percentage points was exceeded obtaining a 12 percentage points increase. Based on the mentioned results the Company has decided to replicate this project in the rest of the stations and is working on a plan to approach the suggested improvement proposals in different work areas.

References

Alnahhal, M. (2015). *Efficient Material Flow in Mixed Model Assembly Lines.* Essen: Universität Duisburg-Essen.

Ashogbon, K. (2012) Achieving Business Process Improvement through Knowledge Management A case study with ABB Marine and Cranes. Finland.

Averson, P. (1998). The Deming Cycle. 10 June 2018, from Balanced Scorecard Institute. Web Site: http://www.balancedscorecard.org/BSC-Basics/Articles-Videos/The-Deming-Cycle.

Bozer, A. and McGinnis, L. (1992). Kitting versus Line Stocking: A conceptual Framework and a Descriptive Model. Michigan: The University of Michigan.

Brynning, N. and Kihlström, J. (2010). *Development of Materials Supply System Requirements.* Jönköping: Jönköping University.

Carlsson, O. and Hensvold, B. (2008). Kitting in a High Variation Assembly Line: A Case Study at Caterpillar BCP-E. Luleå: Luleå University of Technology.

Corakci, A. (2008). *An Evaluation of Kitting Systems in Lean Production.* Boras: University College of Boras.

Danielsson, D. and Krozer, J. (2011). Process quality performance for assembly processes. Development of a performance measurement system for manual assembly. Göteborg: Chalmers University of Technology.

Dögg, R. and Vladimardóttir, G. (2012). Material availability at point of use: Multiple-case study in the automotive industry. Göteborg: Chalmers University of Technology.

Eirin, L. and Knut, A. (2018). *An Examination of the Application of Plan-Do-Check-Act Cycle in Product Development.* Norway: Norwegian University of Science and Technology.

Eriksson, S. (2013). Visual Replenishment Methods in the Manufacturing Industry and Suggestion for a Decision Tool. Stockholm: Royal Institute of Technology.

Ezell,S. (2018). Why Manufacturing Digitalization Matters and how Countries are supporting Information Technology and Innovation Foundation.

Faccio, M., Yao, X., Cohen, Y. and Pilati, F. (2018). Design and management of Digital Manufacturing & Assembly Systems in the Industry 4.0 era. Springer.

Zhu, Y. (2018). Lean Philosophy in Inbound Logistic.

Gajjar, J. (2014). Improvement in Material feeding system Through Introducing Kitting Concept in Lean Environment of MSME: A Review Study. Gujarat: G.H. Patel College of Engineering and Technology.

Gidey E*, Jilcha K, Beshah B and Kitaw D (2014). *Plan-Do-Check-Act Cycle of Value Addition* Addis Ababa: Addis Ababa University.

Gregor, M and Medvecky (2008) *Digital Factory--Theory and Practice* Agency for Support and Research and Development.

Jiang, J. and Zhu, Y. (2008). Improvement of Material Flow in the Production and Supply Chain of ADB Products. Stockholm: Royal Institute of Technology.

Léo, B. (2010). *Material Flow Improvement*. Göteborg: Chalmers University of Technology.

Matinlassi, V. Part Assurance in a Mixed-model Assembly Line: A Case Study at Scania Engine Assembly in Södertälje. Stockholm: KTH Industrial Engineering and Management ITM.

Moe, T. and Hung, S. (2018). Inbound Logistics in Sub-Saharan Africa: A Case Study on Current Practices and Challenges Singapore: Singapore University of Social Sciences.

Pietrzak, M. and Paliszkiewicz, J. (2015). *Framework of Strategic Learning: The pdca Cycle*. Warsaw: Warsaw University of Life Sciences.

Rauhanen, A. (2018). Improving the order-delivery process by examining the problem points in drop shipping. Jyväskylä:JAMK University of Applied Sciences.

Sali, M. and Sahin, E. (2016). Line feeding Line feeding optimization for Just in Time assembly lines: an application to the automotive industry, Intern. Journal of Production Economics, http://dx.doi.org/10.1016/j.ijpe.2016.01.009.

Sinkunas, V., Kazue, G., Mourao, G., Muniz, J. and Pozo, H. *Application of Lean Line Feeding for increasing productivity: A Case Study.* Sao Paulo: Centro Paula Souza.

Srinivasan, D. and Tesfay, G. (2011). Principles of Material Supply and Assembly Systems in an Automotive Production System. Sweden: Chalmers University of Technology.

Supakuwattana, S. and Chattinnawat, W. (2018). The Implementation of Material Flow Cost Accounting Analysis to Determine the Optimal Sample Size and Lot Size in Serial Multistage Processes. Chiang Mai: Chiang Mai University.

Tague, N. (2005). The Quality Toolbox. Wisconsin: ASQ Quality Press.

Taniguchi, E. (2014). Concepts of city logistics for sustainable and livable cities. Kyoto: Kyoto University.

Tuomola, E. (2014). Introducing an effective inbound logistics concept to the automotive industry. Jyväskylä: JAMK University of Applied Sciences.

Biographies

Paola Puentes Vera grew up in Monterrey, Mexico. Because of her passion for problem solving and numbers she decided to study Industrial and Systems Engineering in college. She is a recent graduate from Universidad de Monterrey with a minor in logistics. During her studies, she had the chance travel to Colombia acting as a volunteer developing sustainable projects for people in rural areas and she also had the chance be an exchange student in Germany, studying for 6 months at a German university and doing an internship in Daimler in the production area. She developed a thesis with optimization of line feeding approach applying different methodologies.

Astrid Gándara Martínez grew up in Monterrey, Mexico, and graduated from the University of Monterrey. Her great passion is solving problems through innovative solutions. Knowing that no single approach is the right one for every problem, she has been trained in a range of methodologies including lean methodology, PDCA and Checkland. Her educational background includes a B.S. in Industrial and Systems Engineering and a semester abroad in Germany. She has a certification in German Language and French Language.

Jenny Díaz Ramírez is currently a professor of the Department of Engineering at the University of Monterrey. She has worked previously as professor at Tecnológico de Monterrey, Mexico and Pontificia Universidad Javeriana Cali, Colombia. She is industrial engineering from Universidad del Valle, Colombia. She holds an MSc in industrial engineering from Universidad de los Andes, Bogota, Colombia, an MSc in operations research from Georgia Tech, US and the PhD in Industrial Engineering from Tecnológico de Monterrey. She is a member of the National System of Researchers of CONACYT, SNI Level I, since 2015 and recognized as an associated researcher by Colciencias, since 2016. She is the author and co-author of scientific articles on topics such as applied optimization and statistics in health systems, air quality, energy efficiency in transport and logistics.