MASTER THESIS

TITLE:
Part presentation in Lean Production

Subtitle**:**
Traditional vs. Lean Part Presentation Methods
(Kitting, Tote Boxes & Gravity Flow Racks) in Tier1 environment…

A Master's Thesis submitted for the degree of
"Master of Business Administration"

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December 15th, 2010

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List of abbreviations:

PPM – Part Presentation Method
TPPM – Traditional Part Presentation Method
KPPM – Kitting Part Presentation Method
GFRPPM – Gravity Flow Rack Part Presentation Method
WIP – Work in process
CEO – Chief Executive Officer
OEM – Original Equipment Manufacturer
GBX – Gitterbox
IPA – Institute ….
LSS – Lean Six Sigma
DMAIC – Define, Measure, …
VSM – Value Stream Mapping
3P – Product Process Planning
IMVP - International Motor Vehicle Program
TPS – Toyota Production System
JIT – Just in Time
5S – Sort, Straighten, Shine, Standardize, Sustain
KPI – Key Performance Indicator
OEE – Overall Equipment Efficiency
SCOEE –
EDI – Electronic Data Interchange
TPM – Total Productive Maintenance
MRP –
P/N – Part number
NA – North America
CI – Continuous Improvement
POU – Point of Use
SWI – Standard Work Instruction
OPS – Order Picking System
SPM – Strokes per Minute
CAPEX – Capital Expenditures
FIFO – First In First Out
DOH – Days on Hand
COGS – Cost of Goods Sold
RAW – Raw material
PURCH – Purchased parts and components
FG – Finished Goods
SMED – Single Minute Exchange of Dies
IRR – Internal Rate of Return
LTA – Long Term Agreement
EBITDA – Earnings before interests, taxes, depreciation and amortization
EBIT - Earnings before interests and taxes
Sqm – square meter
SOP – Start of Production

Abstract:

There can be found a lot of sources in the literature which dedicate wide space to description of waste created in manufacturing processes. On the other hand there is very little literature dealing with specific logistic wastes. Everybody knows the saying: “You can’t make something out of nothing.” …of course, resources are the key ingredient to create anything – but the key issue is connected with the usage of such ingredients, usually unproductively or using the wrong ones, towards wrong output. In all the cases, waste is present – costs created, man capacity burned, alternative opportunities for value add/creation are lost and customers left unsatisfied. Seeing the scope of logistics, it might be understandable why the wastes in logistics are not that visible as in other functional company areas. Here are the main logistics sources of waste (Goldsby & Martinchenko 2005: 14):

- Inventory
- Transportation
- Space&facilities
- Time
- Packaging
- Administration
- Knowledge

One of the most important decisions regarding waste elimination in running production, as well as in newly planned production, is the part presentation of materials/parts on the line. Part presentation means the way how to supply materials from storage/supplier to the operators on the line. The performance of the production/assembly line as well as other performed activities will be affected by this decision. It is crucial to deal with timing of such decision – what will be part of the objective of this research. This research will analyze deep in detail several modes how to present parts to the production line. Here are some of them:

1. Traditional part presentation with its use of standard containers is the most used one, nevertheless not the leanest one. It causes high WIP size on the line as well as high usage of space.
2. Kitting stands for the system of feeding components and subassemblies on the production line. By proper application, a benefit of space and WIP size can be obtained, on the other hand a disadvantage of additional handling can be observed.
3. Tote boxes & Gravity Flow Racks. Tote box (called also Tote) stands for a small plastic box with a limited amount of parts wrapped already at supplier side. Gravity Flow rack stand for a specific purpose constructed rack at place of use. Flow rack is fed with tote boxes to present the parts to the operator at the cell in the arm’s reach. The benefit of this model is the elimination of additional handling and the presentation of parts at arm’s reach – on the other hand this system is selective seeing the dimension limitations of totes vs. parts, as well as the weight of a tote.

1. Introduction

Firstly, there will be space dedicated to the background of the research topic in this chapter. In the Purpose and Problem identification session an explanation of topic motivation will be listed. Last but not least, a brief literature review follows.

1.1. Background

In today's global world, every manufacturing company is daily competing for the customer satisfaction through quality, prices, core competencies, deliveries etc. On the other hand, their cost structure must be kept as low as possible in order to be competitive in regards to extern, or even intern competitors. Seeing the globalization of the automotive sector, every manufacturer is under tremendous pressure to improve own productivity comparing itself not only to local players, but to the whole world.

Furthermore, the global automotive industry is facing a very challenging period accompanied with consequences of the biggest crisis ever. Supplier revenues have dropped by more than 30% in 2009 compared to 2008. After an excellent performance in 2007 and part of 2008, the average supplier profitability is reaching an all time low. As a result, a significant number of suppliers have already or will have to fill in for insolvency… Top focus of all has been shifted towards ensuring sufficient liquidity in order to survive 2009-2010. Besides that, all possible restructuring, optimizing and Lean activities will have to be taken into consideration to thrive through these difficult time.

When it comes to Lean, first thought is usually about Japanese philosophy – Lean Production. Lean philosophies, which were initiated in Toyota Production System, are seen as this revolutionary change in the mindset, which manufacturers in the search of perfection are thirsty of, with its effects to the actions as well as to the visions. (Dennis, 2002) A majority of the manufacturing companies that tries to become more efficient, sooner or later end up with some sort of lean thinking (Womack & Jones, 2003). Lean philosophies help companies not only to control their production but also help them to combine the improvements in operational and commercial aspects and manage them to find the way that provides long-term business success and the employee capability to continuously propel that company to further improvement. (Dennis, 2002)

Seeing the fact that core business and value creating activity in OEM/Tier_1 supplier is production, every CEO should consider production and all supporting processes as a tremendous opportunity for improvements and savings. One of those supporting processes in Production is Logistics, where this master thesis will be oriented. As it is important in every production process, so it is also in Logistics – definition of value added operations and afterwards, orientation to make these processes as lean as possible.

One of the most important decisions regarding waste elimination in Operations & Logistics is the part presentation of materials/parts on the line. The importance of part presentation model consists in its effect/influence on overall efficiency and control of the production system.

Part presentation means the way how to supply materials from storage/supplier to the operators on the line. The performance of the production/assembly line as well as other performed activities will be affected by this decision. There are several modes how to do it.

Traditional use of standard containers is the most used one, nevertheless not the leanest one. It means that every part necessary is brought to the production line in traditional steel containers (GBX – Gitterbox) and quantity which is not related to the line or customer demand, but to the fit of the steel box. Seeing this, it causes high WIP size on the line as well as high usage of space in the production area.

On the other hand there is a much leaner mode to present parts – Kitting. This word "Kitting" stands for the system of feeding components and subassemblies on the production line. Crucial for Kitting containers = Kits, is that they're filled with different parts of limited quantity so that a benefit of space and WIP size can be obtained. On the other hand, usage of Kitting is connected with additional handling/re-packaging of goods, coming from suppliers in standard containers, into a specific kit.

This inconveniency can be avoided by next type of Lean part presentation, by using Tote boxes & Gravity Flow Racks. Tote box (called also Tote) stands for a small plastic box with a limited amount of parts, which are wrapped already at supplier side, so that the re-packaging and handling isn't needed anymore. Gravity Flow racks stand for a specific purpose constructed rack at place of use – at the production line. Flow rack is fed with tote boxes to present the parts to the operator at the cell in the arm's reach. The combination of Totes & Flow racks is probably the leanest way how to present parts in production, under the assumption that the tote boxes are filled with purchased / WIP parts directly at the place of production. This means there is no additional re-packaging needed to present the part.

According to Goldsby & Martinchenko (2005: 14), bellow mentioned are basic logistics wastes which can be minimized and eliminated by proper usage or combination of part presentation models.

- Inventory
- Transportation
- Space and facilities
- Time
- Packaging
- Administration
- Knowledge

However, there are some cultural distinctions in understanding the main reasons for implementing Lean Part Presentation. Japanese have clear understanding for main benefits, derived from long-term practice, which are quality improvement, learning process and inventory. On the other hand, European implementations have preferred space / layout savings.

1.2. Objective of Work

The objective of this work is to present an evaluation of Traditional & Lean Part Presentation Models in Production environment. Analysis of available literature as well as best practices out of the topic Logistics – Part Presentation in automotive company, will be implemented and lessons learned will be derived out of that … Part of the research will give some experience out of a case study from automotive Tier1 supplier.

The main research questions of this work:

- The arguments behind the implementation of lean part presentation methods
- Show the impact of different lean part presentation models on main logistics waste types : Inventory, Transportation, Space and facilities, Time, Packaging, Administration, Knowledge
- Show the interdependencies in-between Lean philosophies and Lean Part Presentation

1.3. Literature

This work is mainly based on previous researches in field of part presentation models (traditional; kitting; totes & flow racks), in field of logistics & warehousing, material picking, feeding, lean production systems as well as lean assembly lines and work flows. Second basis for this work is my extensive know how & experience of Operations & Logistics field, not only within Tower Automotive group, but also other automotive OEMs & Tier1 suppliers, local as well as abroad placed.

There are plenty of publications within the topic of Lean philosophies, Lean Production Systems and Lean Part Presentation models. Here is the list of those which has been mainly used in this work: Sheldon & Donald H. (2008); Liker & Jeffrey(2004); Goldsby & Martichenko (2005); Womack & Jones (2005); Baudin (2004); Harris et al. (2003); Medbo (2003); information, studies and booklets of IPA / Fraunhofer Institute; Manager Tools, podcast sessions; Collins & Porras; Liker (2005); Liker (2004).

1.4. Work Structure

Master thesis is subdivided into following section:

<u>The first chapter of the Master Thesis</u> will be oriented on introduction of the topic with some background related to it. Typical environment will be described.
<u>The second chapter of the Master Thesis</u> will be dedicated to the theoretical background of the Master Thesis topic. I will try to define internal logistics, its duties

and responsibilities from the point of view of literature as well as from the point of view of plant reality and best practice. I'll try to use and explain the best practices as well as the actual interconnection with Lean & Six Sigma implementations. This means a proper study of available / best practice literature as well as consultations with Master Thesis supervisor. By this means I will try summarize the theory know behind the main subject of the work.

The third chapter of the Master Thesis, I'll try to focus on real Part Presentation Methods from the real case point of view. I'll go in details for every type of PPM and state also some real experiences out of the real case implementation in the Tier1 environment. In every PPM analysis, some pro's and con's will be mentioned as well as conclusion for the singular PPM.

The fourth chapter of the Master Thesis, will deal with Business Case Study analysis out of Tier1 automotive environment, where details from this implementation will be stated. On the background of the real case I'll try to demonstrate the pro's and con's stated in the 3rd chapter and confirm the optimal way for the implementation.

The fifth chapter of the Master Thesis, will be dedicated to summarization of the topic and to general conclusion for the subject.

2. Theoretical Framework

In order to fulfill the research objective of the Master's Thesis it has been necessary to study theories about Lean Production Systems as well as about Lean Part Presentation Models. Basics for understanding lean philosophies will be drawn in this section as well as necessary theories for the empirical study will be shown. This chapter starts with the birth of Lean thinking – kind of short history. Afterwards the real content of the Lean methodology will be presented and main issues in implementation will be discussed.

2.1. The Origins of Lean Production

After Second World War, Eiji Toyoda and Taichi Ohno, pioneered the concept of Toyota Production System at the Toyota Motor Company in Japan. All Japanese companies as well as Toyota suffered this after war period and its effects, where resources have been missing and the industry has been destroyed and needed a complete re-birth. Many Japanese companies searched for inspiration in the developed western world. United States called for mass production to saturate the markets needs with inhabitants thirsty after years of scarsity during the war period. Seeing the Japanese, relatively, small market, limited resources – there was a completely different needs for manufacturing system, which needed to be flexible and less demanding in meaning of resources.

The rise of Japan to its current economic pre-eminence quickly followed, as other companies and industries copied this remarkable system. In the early 80' it has been commonly recognized in western countries that the Japanese production system outran the methods used in Europe or in the US. The productivity & quality far exceeded the commonly known theorems. Based on that, a project called "The International Motor Vehicle Program" (IMVP) has been started by Womack, Jones and Roos at Massachusetts Institute of Technology with the scope to analyze and compare the Japanese automotive way to the western one. The IMVP study confirmed the big difference in productivity as well as in quality. It tells following about Lean production:

"Lean production is lean because it uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half of the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever-growing variety of products" (Womack et al., 1990)

The IMVP study led to a famous book "The Machine that Changed the World" by Womack, Jones and Roos. If Lean Production is the basic of Japanese dominance, the clear answer to that should be to try to understand how to become lean in Japan and prove it outside. Manufacturers around the world are trying to embrace this innovative system, but they are finding the going rough. The companies that first mastered this system were all head-quartered in one country-Japan. However, many Western companies now understand Toyota Production System, which is not dealing with only manufacturing functions, rather than covering the whole range of activities from product development, purchasing, manufacturing up to logistics. All these areas make the basis of the Lean Enterprise. Main focus of all activities, to improve quality, productivity, shorten lead-times and minimize cost, should be the customer satisfaction.

2.2. Lean philosophies

In the Figure 2.2.a shown bellow „House of Lean" demonstrates a conceptual base and combination of lean production philosophy, techniques and principles.

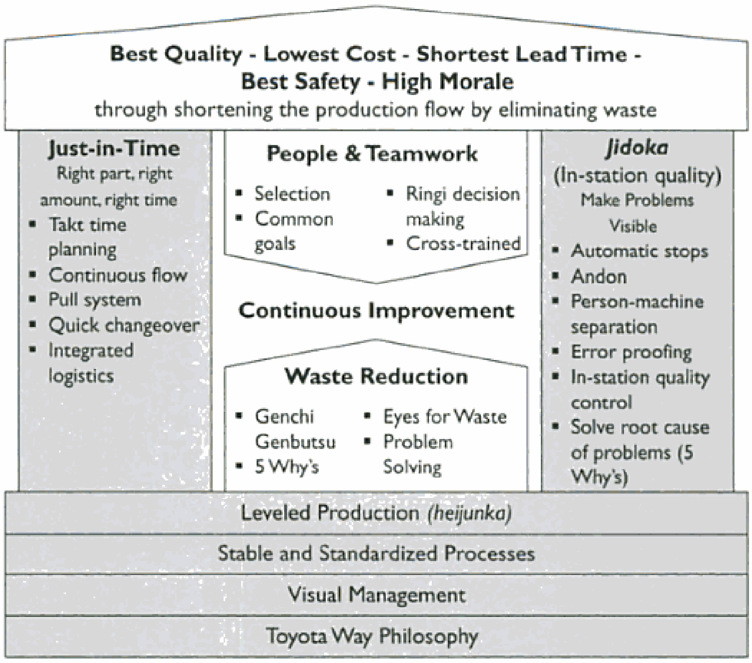


Figure 2.2.a - The Toyota Production System (Liker, 2004)

The TPS House is a structural system, composed of roof, pillars and foundations. The goals of the system are placed in the roof space and embrace the customer focus – Best quality for the lowest cost and in the shortest lead time, by continuous elimination of waste. Elimination of Waste – Muda is the core idea of the Lean TPS philosophy. Based on continuous improvement move, the effort to eliminate waste is a never-ending process. Next session will deal more in detail with the seven types of Waste.

There are 2 outer pillars, which represent Just in Time (JIT) on one side and Jidoka on the other side. Jidoka means an automation with human touch, or never let the defect pass to the other station. Finally, basement is composed of several elements as Heijunka – leverage of production in meaning of variety and volume. A leveled production schedule is necessary for the stability of the process with low inventory. "TPS is not a toolkit. It is not just a set of lean tools like JIT, 5S, Kanban, etc. It is a sophisticated system of production in which all of the parts contribute to a whole. The whole at its roots focuses on supporting and encouraging people to continually improve the processes they work on." (Liker, 2004: 34)

"Being as a system of thoughts and actions tailor-made for Toyota company and has been refined over the years, lean is not a method which other companies can implement directly to their system by simply practicing lean activities. Lean philosophy requires a total change of the mindset of the organization." (Womack & Jones, 1996)

2.3. Seven types of Waste

The base for understanding Lean is to define and understand the difference between value and waste. The basic question of TPS in this context is: "What is our customer (internal/external) expecting out of this process?" What are the value-adding steps in the process and which are those non value-adding? There are 7 types of non value-adding activities = wastes described in the Toyota Production System:

- Overproduction
- Time (Waiting)
- Transportation
- Over-processing or incorrect processing
- Excess inventory
- Unnecessary movement
- Defects

In the next seven sections, all waste types will be explained and analyzed in detail and some lean tools for their reduction will be stated.

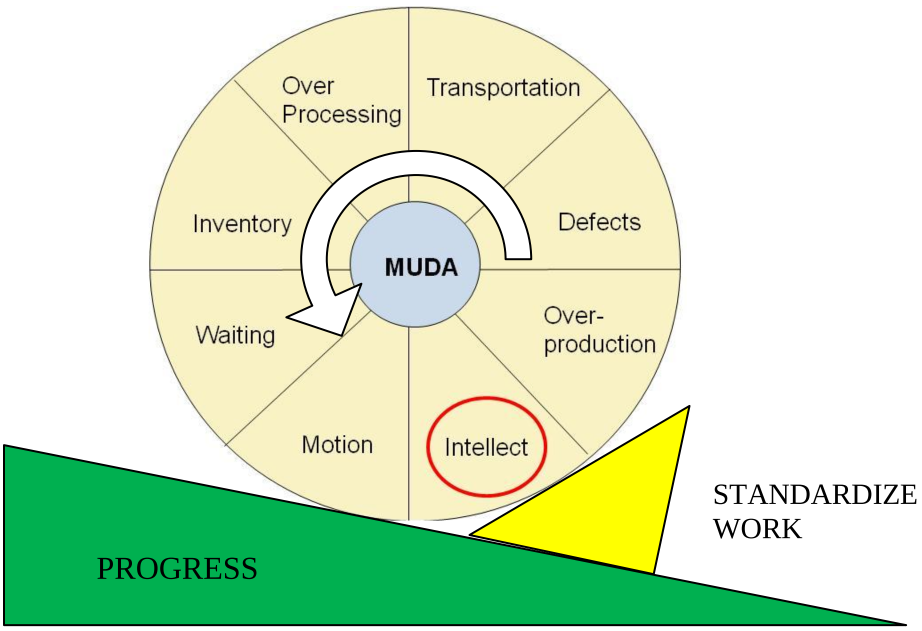


Figure 2.3.a – Tower Automotive Types of Wastes (Tower Automotive)

My company, Tower Automotive challenges one more important type of waste – the Intellect. This simply means not leveraging Intellect, or the waste of not using / including the inputs of people which are directly involved in the process for the solution of problems or even in the process of new product design…

2.3.1. Waste from overproduction

This particular type of waste is considered to be the most serious one, because it influences the creation of the other six wastes. Production of parts in advance or in bigger quantity as requested by the customer is evidently a waste. And this waste contributes to creation of other wastes as inventory in stock, or in production (wip / buffer), transportation and overstaffing. As described previously, the main objective of TPC is to create Value. In the value creation there are some costs connected, but there is no reason to tie up this money if there is no request and you can't sell this production.

The problem is that in traditional understanding, production leaders have been motivated by quantitative measurements or KPI's such as maximum equipment and resources utilization. There are several cases of leadership misleading practices – combination of targets for production composed of maximization of OEE and SCOEE KPI's. OEE - Overall Equipment Efficiency (based on working days in year = 250) main effort is targeted to reduce the downtime of the equipment to maximize the output of the equipment. On the other hand, SCOEE is the same calculation based on all 365days of a year (counting with weekends, bank holidays…). SCOEE tells you the real usage of equipment vs. the potential one. Translating all this into more simple words – OEE motivates you to have bigger output worked out of less hours, on the other hand SCOEE motivates you to maximize the usage of the equipment.

The main idea of lean concepts consists in the orientation on the customer. This means that the production should be subordinated to the customer request, external or internal, and products should not be pushed to the system… Production in advance creates the risk of the products to become obsolete and for more, the hidden defects stay hidden till the moment of use.

Overproduction is commonly known in productions which base their scheduling on forecasts. The customer orders in forecasts can be volatile, the bigger is the advance of the forecast, the bigger is the deviation. Therefore, the proper scheduling should be based on customer exact demands instead of forecasts. This could be a problem in case that the requested delivery time is shorter than the lead time of parts to be produced. The biggest challenge here is to make the production process as flexible as possible, the throughput of the production should be shortened to minimum, the set ups should be optimized as well and last but not least, forecasting should be as accurate as possible.

2.3.2. Waste of Time

This type of waste is usually a consequence of other waste types, for example overproduction, excess of inventory, over-processing etc. Waiting for manpower, part, tools, schedule directions, paperwork – having no work because of no stock, processing delay, equipment downtime, capacity bottlenecks - all these happens daily. Every manager knows the basic equation of a business man: Time = Money! But, every manager does participate on a plenty of unnecessary meetings, which are consuming valuable time. On the other hand there are meetings which are necessary and there is a waste of time again, while people requested are coming late… Have you ever tried to quantify your time waste on unnecessary meetings, or waiting on colleagues for a meeting? It seems very easy to map the wasted time using the stopwatch. But again and again we take part in the trap of time.

One of the most common demonstrations wastes of time are the products in the inventory. Obviously, in a production without one piece flow installed, products flow through the plant without completion of all value-add activities what creates WIP and waste of time. “Reducing inventory is an important issue when reducing waiting time” (Jones & Womack, 2003).

The best tool for the identification of value-add / waste in the flow through the plant is the Value Stream Mapping (VSM). All processes are mapped, lead time of purchased parts, inventory levels, setup times, throughput and processing times etc. The current state map reveals the real flow with all of its wastes – processing time vs. waiting time. Very often the truth about the time of value-adding processes is revealed, usually just a tiny percentage of the non value-adding processes. Based on this the future state should be designed.

To better understand the waste of time from the logistics point of view, we must understand the order cycle – the period in-between order transmission to its delivery. The five distinct steps of the order cycle are illustrated in the figure bellow:

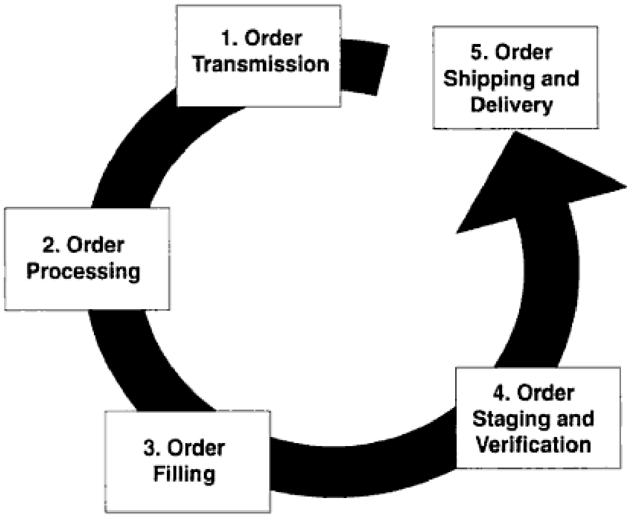


Figure 2.3.2.a – Order Cycle illustration (Goldsby & Martichenko 2005: 40)

Each step requires some allotment of time to complete, and each step experiences variance around the typical time allotment. When variance is found in the right tail of the frequency distribution then a waste of time is observed.” (Goldsby & Martichenko, 2005: 39)

2.3.2.1. Order transmission

Till an order is received – nothing happens in logistics. “The quicker the supplier can receive the order from the customer, the sooner action can initiate and the sooner the order can be filled and delivered.” (Goldsby & Martichenko, 2005: 40) Conventional methods in order transmission such as phone, fax, postal mail make the whole process very time-consuming. On the other hand, electronic modes of data transmission have changed the time consumption into an instance. “Electronic Data Interchange (EDI) has been hailed over the past few decades for its ability to facilitate communications between a customer’s computer and a supplier’s computer without human intervention and the error and variability inherent in human activity” (Goldsby & Martichenko, 2005: 41) Combination of EDI with World Wide Web offered a plenty of web-based communication opportunities.

2.3.2.2. Order processing

Once the order is received, the supplier has to analyze this order from 2point of views – willingness to fulfill the order and the ability to do so. “while the determination of willingness and ability can be rather involved process, many companies have automated these decisions with order management systems that can provide instantaneous consideration of all relevant factors and immediate order acceptance/rejection.” (Goldsby & Martichenko, 2005: 42) It’s crucial to serve the answer timely and correct, otherwise the energy and time could be wasted.

2.3.2.3. Order filling

In the moment the order has been accepted, the realization phase starts. Problems like missing parts in the warehouse; its poor organization; wrong part presentation; poor training of people; poor information exchange – can influence the lead time and variation. Clear rules must be present to deal with such problems in order to satisfy the customer expectations.

2.3.2.4. Order staging and verification

In the moment the order is gathered, it is forwarded to the shipping where the revision of content needs to be done – potential discrepancies need to be corrected. “…most warehouses will call on shipping clerks to verify the load, maintaining this step in the order cycle – a step that takes time and still cannot guarantee perfect service.” (Goldsby & Martichenko, 2005: 43)

2.3.2.5. Order shipping and delivery

Once the order is verified, it’s transported to customer. This time creates one of the decisive components of the lead time, because of its variance potentials. It happens very often that the truck is called for a certain time to be loaded, but the goods are not picked or verified. On the other hand, it can happen that the carrier will not show up at the requested time. Another typical time-waste opportunities in transportation is the delivery window was not fulfilled and so additional costs are generated by waiting of truck/goods for the next one.“…concern should be directed toward making not only efficient use of time a shipment spends on the road, on the rails, in the air, or on the water, but also toward eliminating the waste creating idle time, even if it is found beyond the scope of your direct responsibility and operations. Reducing time-constraining bottlenecks should be everyone’s job because we all end up paying for these wastes” (Goldsby & Martichenko, 2005: 44)

As we seek to minimize the wastes of buffer inventory and excess facilities, execution of the order cycle on a timely, accurate basis consistently must become not just the norm but the constant expectation… Designing robust processes that yield desired performance reliably at the lowest possible cost I not a simple luxury or even a competitive differentiator, but rather the requirements for sustainable growth and success into the indefinite future" (Goldsby & Martichenko, 2005: 45)

2.3.3. Waste of Transportation

Transportation waste involves all unnecessary movements of all material types (raw material, purchased parts, work in process, finished goods) where the value-add part is missing. Obviously, unnecessary transportation is usually a consequence of layout decisions. These form some kind of presumptions on which base the optimization can be done. That's why it is necessary to recognize the route-cause of the actual state and not concentrating the energy on consequence of the rout-cause. Very often, we can find the design of a factory layout which is based on mass-production basics, with equipment disposition based on functional basis. This means that press shop activities are concentrated in one area and welding, or assembling in another one. This means a lot of transportation in-between the functional areas.

In lean concept of manufacturing, products do flow through the factory layout with less movement in-between operations on different work centers. It is necessary to understand the overall concept, looking at the product from the product family perspective, grouping the work centers into one-piece-flow cells/areas to obtain as little transportation as possible.

Another important decision to be taken in meaning of transportation is the conveyance method – there are several ones and more than one type may be appropriate in the same factory. Here are the basic ones:

- Walking – a method where the material guy (often call water spider) I pushing a cart with parts – best used in case of light & small parts + the point of use distance is limited

- Forklift – a method where the forklift driver is able to operate a wider are, but there are several inconveniences like:
  - Expensive equipment
  - Wide communication aisles needed
  - Safety (injuries / damages)
  - Movement of large / full containers

- Tugger Train – a method which is probably the most effective one for considerable distances and volumes needed to be moved. The tugger can pull multiple carts with containing material for multiple delivery points, and it can make turns easily, especially when pulling quad-steer carts. In the best tugger designs, the driver stands instead of sitting. This makes for more efficient delivery as the driver moves easily on and off the tugger to place parts at their point-of-use. It makes for better ergonomics as well." (Harris et al. 2003: 47)

One of the used tools in lean manufacturing is the Spaghetti diagram. It is based on the drawing of all movements of humans, products and material on the layout so that it forms a clear picture of motions. Usually this shows a huge bundle of "spaghetti" which has to be optimized. Out of this an estimation of distances can be done for every operator (walking distance) or forklift (driving distance), as well as a time study for waste time spent on transportation in specific processes.

2.3.4. Waste from Over-processing or incorrect processing

As well as the Layout, the Process needs to be defined properly. Again, the focus should be from the point of view of the customer. The process must either add value to the product, or be necessary for the completion of it – otherwise every non value-adding part of the process should be eliminated. "Taking unneeded steps to process the parts. Inefficiently processing due to poor tool and product design cause unnecessary motion and producing defects. Waste is generated when providing higher quality products than is necessary. At times extra "work" is done to fill excess time rather than spend it waiting" (Liker & Maier, 2006:36) Taking into consideration that processes are a notable source of waste, every process should be revised and optimized as a part of the continuous improvement. Every kind of simplification should be considered, including change of design, tolerances or even functionality. Figure 2.3.4.a bellow shows the classification of processes and the correspondent behavior of the process owner.

Non value-adding steps in processes can be identified with a lean tool called process mapping. A Process map show visually – by using of graphical symbols – every step in the process. By this way actual / original process map is created and gives an opportunity of a helicopter view on the process as complex system of flows. This often shows unnecessary steps which should be part of the improvement.

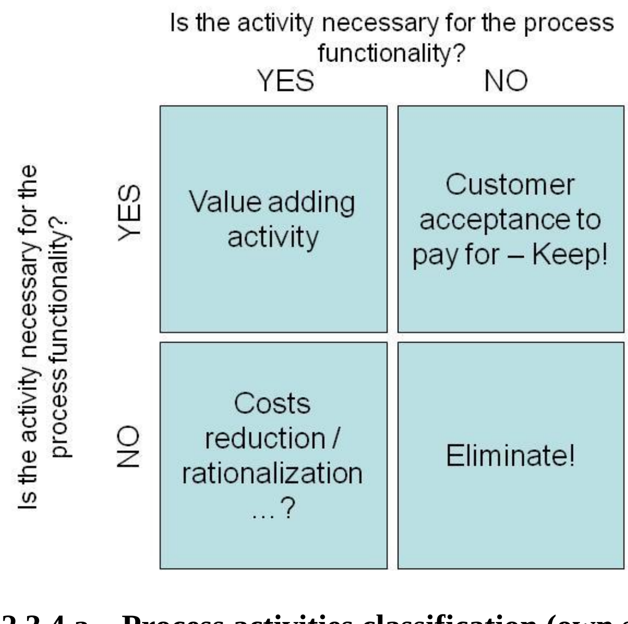


Figure 2.3.4.a – Process activities classification (own scheme)

2.3.5. Waste of Inventory

Logistics is all about management of inventory, regardless of inventory type : Raw material, purchased parts, work in process or finished goods, regardless of inventory state: in motion or standing. As it has been already stated, there can't be made something out of nothing – you must have some level of inventory to be able to sell anything. BUT…

The basic logistics formula tells: "…delivering the right product to the right place, at the right time, in the right quantity and condition, and at the right cost." Out of this, you could think that having the right inventory on hand and close to customer is the best way how to survive. Unfortunately, most of us are addicted to inventory and the crucial word "right" becomes everything else but right! "Inventory often represents somewhere between 5 and 30 percent of manufacturer's total assets… and like any asset, inventory has to be managed. It has to be acquired, received, housed, paid for, and insured – adding costs on top of the original purchase price for the goods of materials." (Goldsby & Martichenko, 2005: 20)

So, why we have inventory? The problem is that we need to advance the customer demands, with the quantity and on the place expected. Based on that, we make our best guess based on forecasts and anticipate the purchase of supplies. Normally, the forecasts are inaccurate, or even wrong – the more you go into future, the less accurate will the forecast be. Therefore, many companies have realized that short-term planning brings more benefits. Relying on actual demands there can be significant reduction of risk regarding the future inventory. The reduction of inventory affects not only CASH in your pockets. On the other hand, you should first reduce the reasons for the inventory and just at that point you should eliminate it.

Besides the fact that holding inventory is a waste, it also makes other problems not so visible.

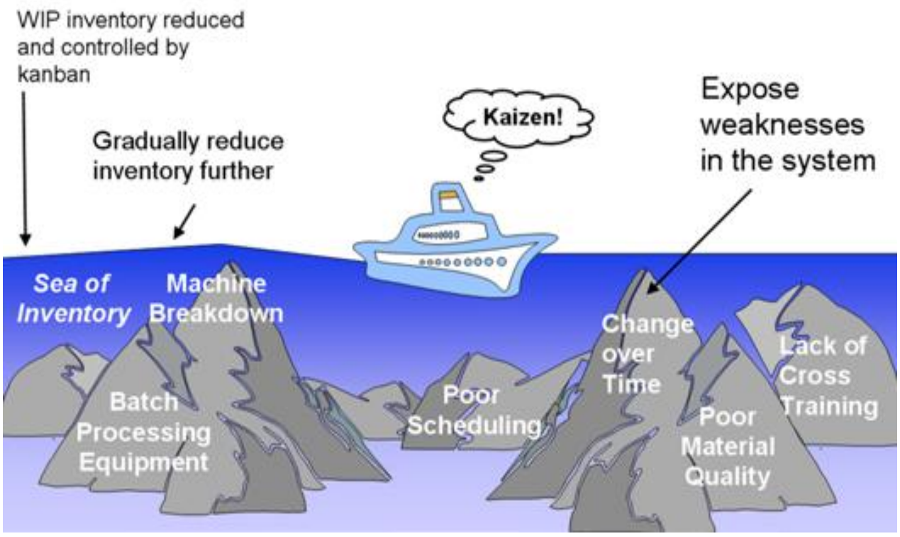


Figure 2.3.5.a – Problems hidden by Inventory (www.gembapantarei.com)

In manufacturing processes you can find 2 basic types of inventory. Work in process (WIP) and Part storages. WIP is the inventory in-between different production operations, while part storages are the components/raw material delivered out of the warehouse to the production line, waiting to be processed. In both cases the inventory level is formed by cycle inventory & buffer inventory.

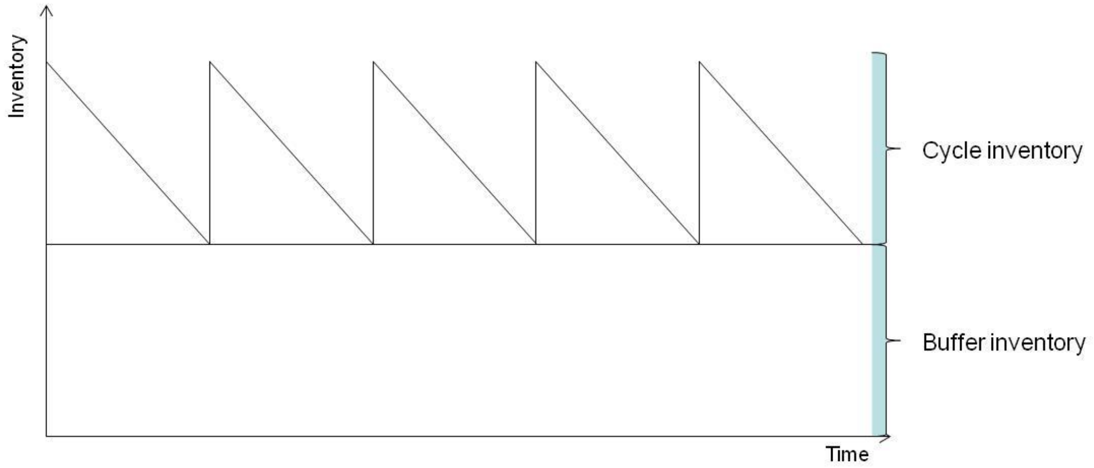


Figure 2.3.5.a – Inventory levels (own scheme)

Buffer inventory is kept to minimize the influence of variations in-between demand & supply – on the other hand it creates a sort of security to reduce the risk of running out of parts. Unbalanced processing time of different operations creates the need for WIP buffers. The reason for the variation can be following:

- Different product models
- Quality issues in material/components
- Processing issues
- Unbalanced skills of operators

Hopp & Spearman (2001) have empirically shoved the relationship between Production rate, throughput time and WIP buffers – see figure bellow.

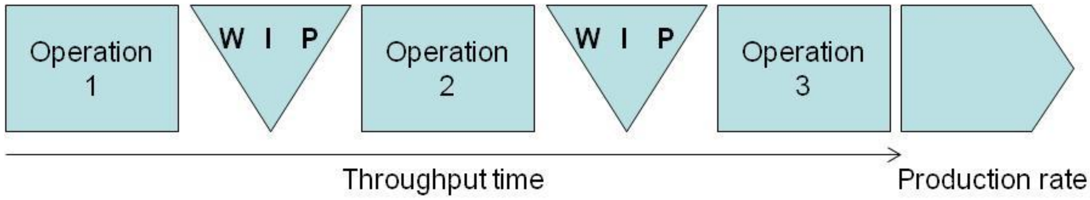


Figure 2.3.5.c – Throughput time, Production rate and WIP relationship (own scheme)

Production rate is the TactTime, defined by the demand of the customer. It means, if the customer orders 450parts per day, in a 450min. shift – tact time / production rate would be 1part per minute. On the other side, throughput time is the time of a product going through the production flow. In the figure 2.3.5.d you can see the the relation in-between production rate and WIP. The maximum production rate can be obtained when the WIP buffer increased to a level where it eliminates the variation of the operations process time. This means that the operation never gets starved –

waiting for precedent products, or blocked – waiting for the following operation ready. On the other hand, the throughput time is increasing with the increase of WIP, because the product is waiting to be processed. As a conclusion, the WIP amount should be a balance which allows the maximum production rate, but not over to create excess in inventory – see figure 2.3.5.d.

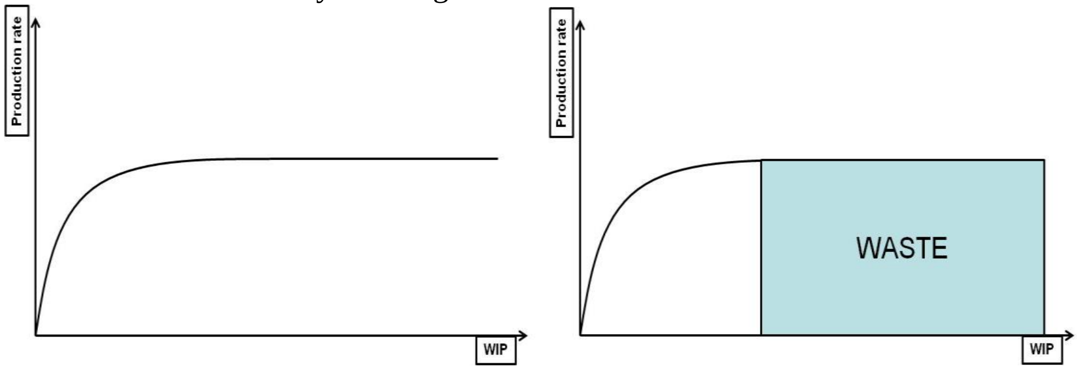


Figure 2.3.5.d – Production rate vs. WIP / excess of WIP (own scheme)

Cycle inventory is based on replenishment of the inventory level in defined cycles. The reason is the compromise in-between of set-up costs of one batch production and the holding costs due to the level of inventory. The optimum decision in-between forms so called economic batch size.

Some examples of positive effects of reducing the inventory:

- Cash-Flow improved
- Material handling costs reduced
- Obsolete material risk reduction
- Throughput time reduced
- Production flow optimized
- Quality improved
- More space & visibility
- Space rental costs reduced

…these effects are related to other sources of waste (time; quality; transportation; etc.)

2.3.6. Waste of motion

Every motion costs energy and time. Motion waste is relatively easy to observe. As in every session up to now, the main focus is on value-adding activities - motions and elimination of those non value-adding, as for example most common form - multiple handling. Crucial in this point of view is the early preparation which starts already in the project phase, where the design/layout of the production line is defined, equipment & fixtures designed and selected, compromise of automation vs. manual operations given, as well as operation procedures and processes defined, ergonomics & part presentation designed. As it has been already stated, the biggest challenge of the part presentation is to assure the smooth production without interruptions. Parts should be presented at operator's arm's reach in regular time intervals by warehouse operators.

2.3.7. Waste of defective parts

Production of parts without requested quality standards creates additional need to rework or even scrap the parts. In both of the cases the customer is not willing to pay for and that's why we have waste as result. Regardless of scrap/rework cost, there is a high potential risk to supply the defect parts directly on the line of the customer. This implies a much bigger danger to the supplier, which is the lost of customer satisfaction – in mid/long-term perspective can lead to loss of new business opportunities etc. According to lean concepts, every quality issue should be analyzed for root cause in order to address the source of the issue and not only the symptoms. As discussed before, apart from the fact that inventory is a waste, it hides also other problems and prevents their timely solution. In the production process, usage of big production batches increases the time of problem detection, which can be in some cases the whole production lot. On the other hand, usage of one-piece-flow makes the problem detected immediately and the process can be stopped and re-adjusted in the same moment.

2.4. Lean principles

Lean thinking can be summarized into 5major principles as shown in the figure 2.4.a:

Figure 2.4.a Lean Principles (Lean Enterprise Institute)

1. *Specify value from the customer point of view* : The basic thought in Lean philosophy is the definition of value vs. waste. A very compressed definition of value could be expressed as a specific product/service which the customer is willing to pay for because it fulfills expectations in meaning of quality, functionality, time and price.
2. *Identify the value stream for each product family* : VSM is a tool that allows you to map all processes through which the product has to flow, for example lead time of purchased parts, inventory levels, setup times, throughput and processing times etc. The current state map reveals the real flow with all of its wastes and bottlenecks –

processing time vs. waiting time. It designs the vision of the future state also…

3. *Make the value flow smoothly toward the customer* : Making the value flow means continuous flow of the product from the start till the end of the process, eliminating all possible downtimes & wastes. The ideal state of art is the one-piece-flow implemented in-between the processes. (Figure 2.4.b – Value – Flow – Customer)
4. *Establish pull system* : implementation of pull system for material & product flow control is a strategy to reach just-in-time. The customer sets the pace of production and the pull system coordinates afterwards the demands in-between workstations upstream way. The parts are moved only in case the rquest is forewarded.
5. *Search for Perfection* : Going through the previous principles again and again, you can optimize and improve without an end – this is the meaning of the continuous improvement.

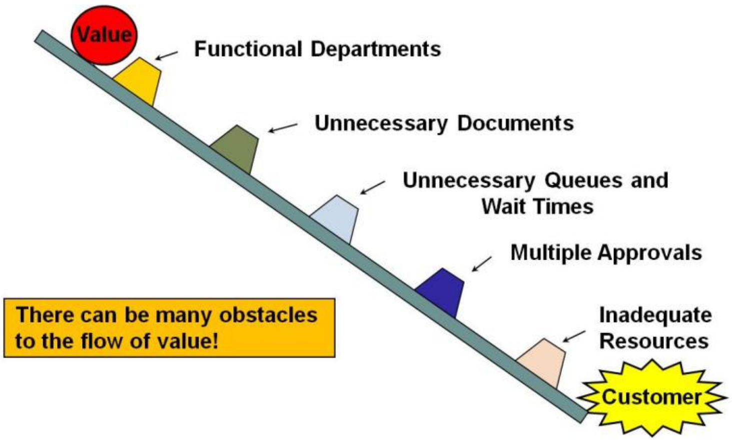


Figure 2.4.b – Value – Flow – Customer (Tower Automotive)

2.5. Lean activities

As discussed before, the „House of Lean“ demonstrates a conceptual base and combination of lean production philosophy, principles and techniques / activities. In previous sections has been already explained the philosophy and principles. In this one, basic lean techniques & activities will be explained.

The TPS House is composed of different blocks which represent those key activities which make up the lean method so successful. “TPS is not a toolkit. It is not just a set of lean tools like JIT, 5S, Kanban, etc. It is a sophisticated system of production in which all of the parts contribute to a whole. The whole at its roots focuses on supporting and encouraging people to continually improve the processes they work on.” (Liker, 2004: 34)

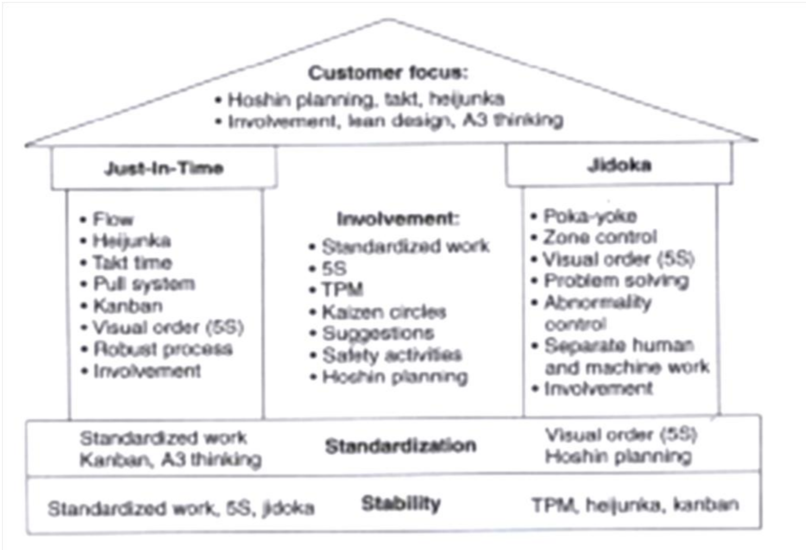


Figure 2.5.a Lean Activities (Dennis, 2002)

2.5.1. Stability

One of the basement blocks in the TPS House is the Stability. The Lean House must be built on stable basements. To reach the level of stability there is a long way – first of all we have to understand the basic elements of instability. In order to create value for customers, every supplier needs to manage effectively the four main variable, called 4M's:

- Man
- Machine
- Material
- Method

Every of these 4 variables needs to be analyzed in detail and the aspects of the instability have to be understood and then focused to improve. The man-related instability is first of all connected with the job description – job instructions need to be specific and clear. The job methods have to be developed as well. The Machine related instabilities are mainly connected with specific downtimes. For this TPS developed the model – 6 types of machine losses. Crucial for the solution of this variable are the preventive maintenance techniques covered in TPM method. Material related instability is mainly connected with material quality, handling and availability. Elementary in this context is the Pull system implementation and the decision of the material handling method.

Standardized process means a repetitive process, clearly defined and documented. The process of improvement is never-ending – continuous improvement – and so the standardized process should be the actually best known mode to perform the task. As soon as a new standard or procedure is identified, this one should work as reference for future improvement steps. Standardized processes are a precondition for a stable system.

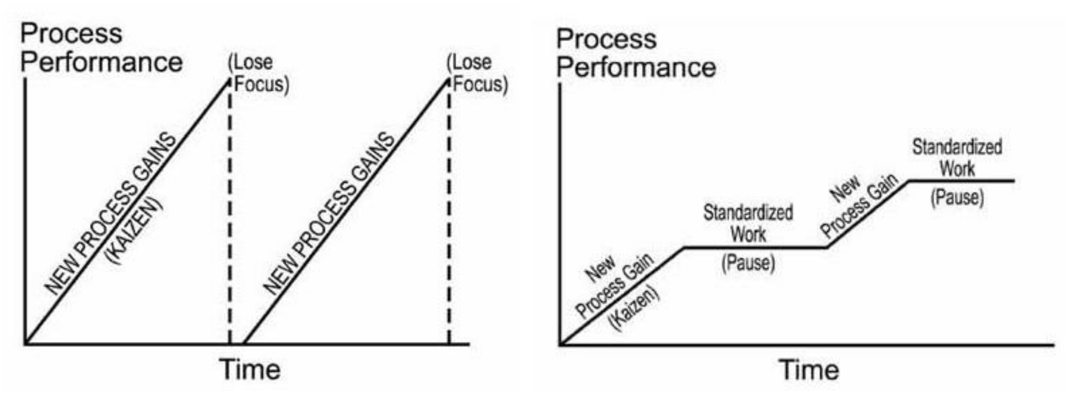


Figure 2.5.1.a – Standardization in Process Performance (Baudin 2004: 78)

Very important part of the stability building is the 5S system introduction. 5S can be defined as a process for creating and maintaining an organized, clean, safe, and high performance workplace.
"World class facilities develop beginning with the 5S's, and facilities that fail, fall apart beginning with the 5S's." (Hiroyuki Hirano)
5S system is composed of:

- SORT - clearly distinguish what is needed and what is not. Remove what does not support the Least Waste Way.
- STRAGIHTEN - organize the way the things are kept, making it easier for everyone to find and return items to their proper location in the sequence used. Mark / Label locations clearly.
- SHINE - keep things clean – floors, machines, desks, files, equipment – Neat and tidy
- STANDARDIZE - Maintain and improve the first 3Ss, "What causes deterioration"
- SUSTAIN - achieve the discipline / habit of properly maintaining the correct procedures.

5S is a habit issue – Sounds easy, but is difficult to implement and sustain. Commitment on all levels is needed to reach the necessary discipline.

5S is the first step to guide the organization to TPM, which is crucial for the improvement of equipment efficiency and stability. The presumption for the successful implementation of TPM is the change of mind of traditional production, where the functional responsibilities are given and so an operator doesn't feel responsible for the problem fixing. The desired perception is to involve all shop-floor people to overall responsibility for the equipment and success of the plant as the whole.

	Sort	Straighten	Scrub	Standardize	Sustain
LEVEL 5 Continuous Improvement	Cleanliness problem areas are identified and mess prevention actions are in place.	Needed items can be retrieved in 30 seconds with minimum steps.	Potential problems are identified and countermeasures documented.	Proven methods for area arrangement and practices are shared and used.	Root causes are eliminated and improvement actions include prevention.
LEVEL 4 Focus On Reliability	Cleaning schedules and responsibilities are documented and followed.	Minimal needed items arranged in manner based on retrieval frequency.	Work area cleaning, inspection, and supply restocking done daily.	Proven methods for area arrangement and practices are used in the area.	Sources, frequency of problems are noted w/ root cause and corrective action.
LEVEL 3 Make It Visual	Initial cleaning is done and mess sources are known and corrected.	Needed items are outlined, dedicated locations are labeled in planned quantities.	Visual controls and indicators are set and marked for work area.	Agreements on labeling, quantities, and controls are documented.	Work group is routinely checking area to maintain 5S agreements.
LEVEL 2 Focus On Basics	Necessary and un-necessary items are identified; those not needed are gone.	Needed items are safely stored and organized according to usage frequency.	Key area items are marked to check and required level of performance noted.	Work group has documented area arrangement and controls.	Initial 5S level is established and is posted in the area.
LEVEL 1 Just Beginning	Needed and not needed items are mixed throughout the area.	Items are randomly placed throughout the workplace.	Key area items checked are not identified and are unmarked.	Work area methods are not always followed and are not documented.	Work area checks are randomly done and there is no 5S measurement.

Figure 2.5.1.b – 5levels of 5S (www.pmaxinc.com)

2.5.2. Standardization

…another basement block of the TPS House is the Standardization. Every process has to be analyzed for value-adding and waste – in this way the efficiency can be improved. The basic tool for it is Standardized Work.

For the clear understanding of Standardized Work, there are 3basic components according to Bicheno (2004):

- Standard Work is not static, it should be updated when a better way is found
- Standard Work supports stability and reduces variations since the work is performed exact same way each time
- Standard Work is essential for continuous improvement

Before continuous improvement activities can start, the process need to be standardized to obtain the requested stability of the process. There are some cultural misperceptions in the understanding of standards. In western cultures happens often that these are understood as property of engineering department – on the other hand the Japanese understanding is that standards are the property of shop-floor people who perform the operation/standard.

Toyota president Cho described Standardization in this way: "Our standardized work consists of three elements – tact-time (time required to complete one job at the pace of customer demand), the sequence of doing things or sequence of processes, and how much inventory or stock on hand the individual worker needs to have in order to accomplish that standardized work. Based upon these three elements, tact-time, sequence, and standardized stock on hand, the standard work is set." (Liker, 2004: 142)

As mentioned before, the main elements of Standardization are tact-time, cycle-time, sequence and in-process inventory. Tact-time is defined by the customer demand – on the other hand, cycle time is the real measurement. The objective is to synchronize both of them. The work sequence should be described exactly – the flow of operations in order. The inventory in process – wip should be defined on the minimum necessary level to keep the operator/equipment running.

The Benefits of Standardization:

- Stability of the processes
- Transfer of knowledge / Learning of the organization
- Employee involvement & empowerment of team
- Kaizen
- Training process optimized
- Improved problem solving
- Less Variability
- Higher Productivity
- Fewer Errors & Correction
- Reduction of Transaction costs

2.5.3. JIDOKA

Jidoka is forming one of the two walls of the TPS House. Its definition by Toyota itself can be interpreted as "automation with human touch". This means in effect a combination of machines with high skilled workers which are able to detect and quickly remove the errors. The level of defects is one of the major downtime issues and thus it makes the production ineffective because the flow and pull system can't work properly.

On the other side, the risk of errors can be decreased to a minimum level by the means of preventive maintenance (TPM) and Poka-Yoke methods. Poka-Yoke devices are dedicated to detect the problem - based on common sense, targeting the source of the issue – typically very simple devices constructed for specific reason, place and use, with high reliability and usually low cost. Examples for Poka-Yoke devices could be following: guide pins, sensors, manual fixing gauges, limit switches, counters etc.

Hirano (1988) mentions 10 different types of errors:

1. Forgetfulness
2. Errors due to misunderstand-ding
3. Errors in identification
4. Errors made by amateurs
5. Willful error
6. Inadvertent error
7. Errors due to slowness
8. Errors due to lack of stan-dards
9. Surprise errors
10. Intentional errors

2.5.4. JIT (Just-In-Time)

…the other wall of the TPS House which is based on Pull principles, Kanban and Flow. "JIT is a set of principles, tools, and techniques that allows a company to produce and deliver products in small quantities, with short lead times, to meet specific customer needs. Simply put, JIT delivers the right items at the right time in the right amounts." (Liker, 2005: 23) It was developed and perfected by Taiichi Ohno of Toyota Corporation during 1960s and 70s to meet fast changing consumer demands with minimum delays.

The definition of JIT principle is relatively simple and self-explanatory - means that the production of what is necessary, in requested quantity and time. As mentioned previously, JIT concept is based on inventory elimination – what is basically possible only by embracing the whole range of lean principles and activities and putting them into action. Cycle inventory will be reduced based on one at time deliveries. Buffer inventory will be eliminated as well since the components and materials will be presented at the place of use exactly in the time needed. There is even higher level of JIT, called sequential JIT. This one means that parts are delivered one at time to the work center based on the product processed in the exact time window. An example of this system would be the delivery of engine to the assembly line. On the other hand, not all parts need to be sequential / JIT delivered. Small, inexpensive parts are usually batch delivered." JIT systems are fundamental to time based competition and rely on waste reduction, process simplification, setup time and batch size reduction, parallel (instead of sequential) processing, and shop floor layout redesign. Under JIT management, shipments are made within rigidly enforced 'time windows' and all items must be within the specifications with very little or no inspection." (www.businessdictionary.com) Here are some basic elements which make this system run:

- Pull system
- Leverage of production
- Continuous Flow
- Takt Time
- Kanban
- 5S – Visual process

2.5.4.1. PULL vs. PUSH

Pull is one of the basic blocks of the TPS House. Pull has the basis in the customer demand – which is in reality running from the order confirmation in the backward direction. The basic is that the production should run only in case the customer pulls the final good products. Materials, parts, sub-assemblies, and other necessary item are delivered just when needed, neither sooner nor later.

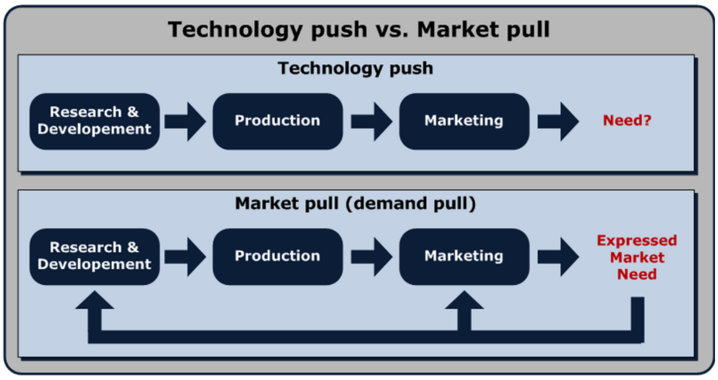


Figure 2.5.4.1.a – Push vs. Pull scheme (http://inventorspot.com)

"Let's understand this concept using the analogy of McDonald's Burger. When you visit McDonald's you do not find meal (the product) ready for you. You order your meal and production starts in a just-in-time manner. Why this happens? The answer is simple. McDonald's cannot afford to produce burger without knowing the various combinations in the demand of its customers. The production of burger begins in the reverse direction. You, as a customer, pull or trigger this burger production chain. Same holds true in case of auto manufacturing. (totalqualitymanagement. wordpress.com) The customer demands can vary given the intense competition in the auto-market. An auto-manufacturing company cannot afford to produce vehicles without incorporating customers' demands as quickly and efficiently as possible.

In the push system instead, the parts are forwarded to the next operation immediately as they're ready. Every work center pushes the products produced to the following operation regardless of the necessity or readiness of the work center. Accumulation of inventory often happens as a consequence of any issue on the line. Scheduling is based on mid/long-term forecasts through central – MRP systems. The actual situation / conditions usually vary from those in central system. As a result, waste is generated in meaning of time, inventory.

Nevertheless the Pull System seems quasi simple to be explained in terms of customer demand – it's not so easy in terms of production system. In the moment customer order (demand) confirmation, the organization starts to deal with production related activities and starts to send signals in the backward direction. Every preceding process sends signal one. These signals can come in the form of a Kanban. Kanban is a Japanese word for a card.

Figure 2.5.4.1.b – Kanban Card (http://totalqualitymanagement.files.wordpress.com)

2.5.4.2. Takt Time

Takt Time is the main pace of the line which is set up by the demand of the customer. In other words, if the OEM is producing 600cars a day and so calling off the 600pcs of a P/N, the takt time is the time period which enables the supplier/production work center, to produce requested amount of units in one day. If we consider a working shift 7,5hours x 3shifts = 81.000sec divided by the daily demand of 600 = 135sec takt time in 3shifts working day. This means, the supplier/work centers must be able to deliver/produce a final product every 135sec. This figure is the main driver of the PULL system.

2.5.4.3. Kanban

Kanban is an order signal in backward direction that is steering previous processes to produce only what is needed, in the quantity and at the time requested. Consumption is driving the demand. Kanban is not limited to work only within production and supporting departments of the factory, but also in the supply-chain itself.

Every part number (P/N) has a specific number of Kanban cards, which delimit the amount of that P/N parts in the system. The number of P/N units on the Kanban card is usually set to the quantity of material delivery container. The information included on the card are following: P/N code & name, storage position, location of work center, type of packaging and quantity in it, etc. Kanban is the method used to simplify the scheduling and fine-tuning of the production activities, with generally recognized flexibility of customer demands by +/- 10%. Day to day flexibility is driven by the final operation, where the higher/lower needs are communicated and Kanban system drives these requests through the system back up the line. The optimization can be done through removal of Kanban cards in the process, or by limitation of P/N quantity in one box. The targeted result is the speed up of the line and lead time reduction. Of course, this makes the system sensitive to breakdowns – every bottleneck of the line needs to be analyzed and improved.

2basic models of Kanban system:

- *Single-Kanban system* – convenient for companies with relatively small range of products with little demand variation. In reality, it’s a combination of push system for the production and a pull system for delivery at the point of use. The line operator is the one who drives the trolleys/parts to the line.

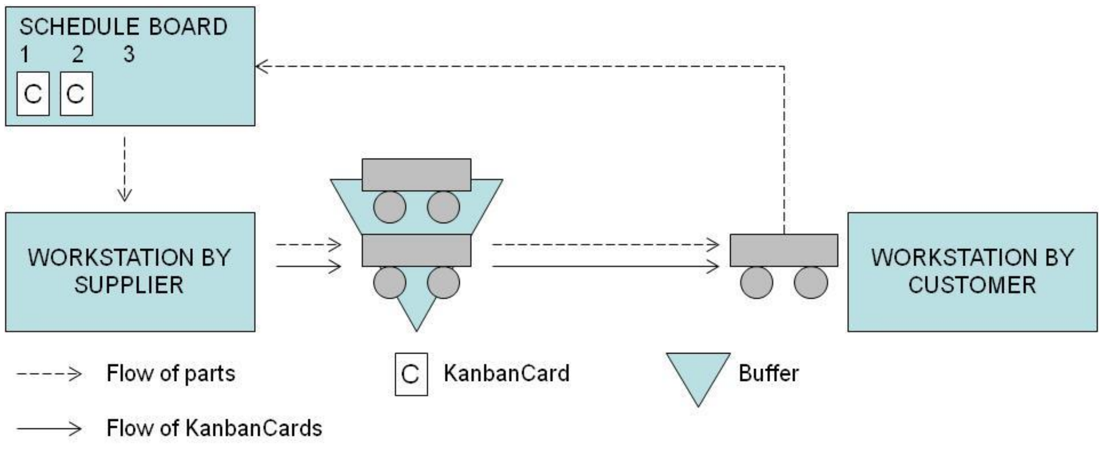


Figure 2.5.4.3.a – Single Kanban system (own scheme)

- *Dual-Kanban system* – "Each process (area, cell) on the production line has two Kanban `post-boxes', one for withdrawal and one for production-ordering Kanbans. At regular intervals a worker takes withdrawal Kanbans that have accumulated in his process post-box, and any empty pallets, to the location where finished parts (components, assemblies) from the preceding process are stored. Each full pallet has attached to it one or more production-ordering Kanbans which he removes and puts in the appropriate post-box belonging to the process that produced the parts. The worker now attaches a withdrawal Kanban to the pallet and takes it back to his own process area. When this new pallet begins to be used, its withdrawal Kanban is put back into the withdrawal post-box. At each process on the line, production-ordering Kanbans are periodically removed from their post-box and used to define what parts and quantities to produce next." (www.ifm.eng.cam.ac.uk)

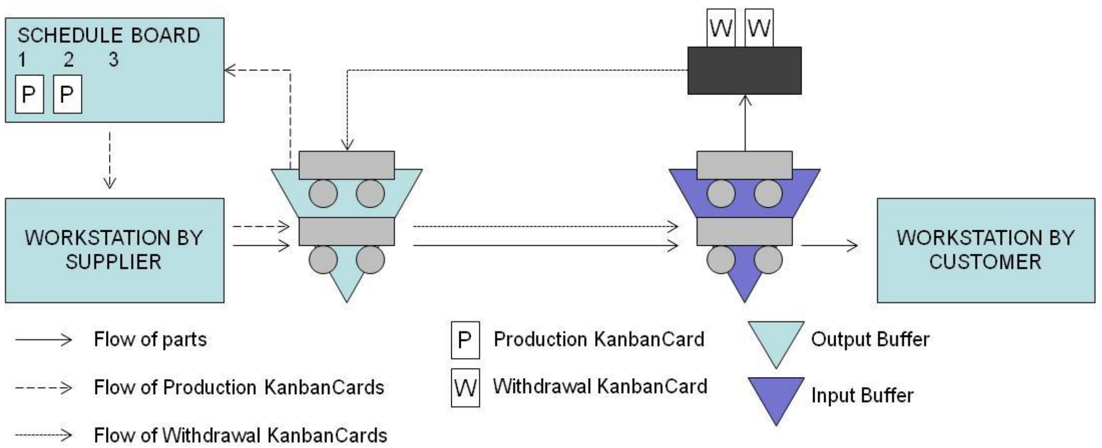


Figure 2.5.4.3.b – Dual Kanban system scheme (own scheme)

There are 2 types of Kanban cards used:

- *Withdrawal Kanban Card* - defines the product (quantity, type, storage location, work center location, etc.) which should be withdrawn from preceding process.
- *Production-ordering Kanban* - defines the product (quantity, type, storage location, work center location, etc.) which the preceding process has to produce.

Bellow you can find the chart showing how the Kanban method works in production:

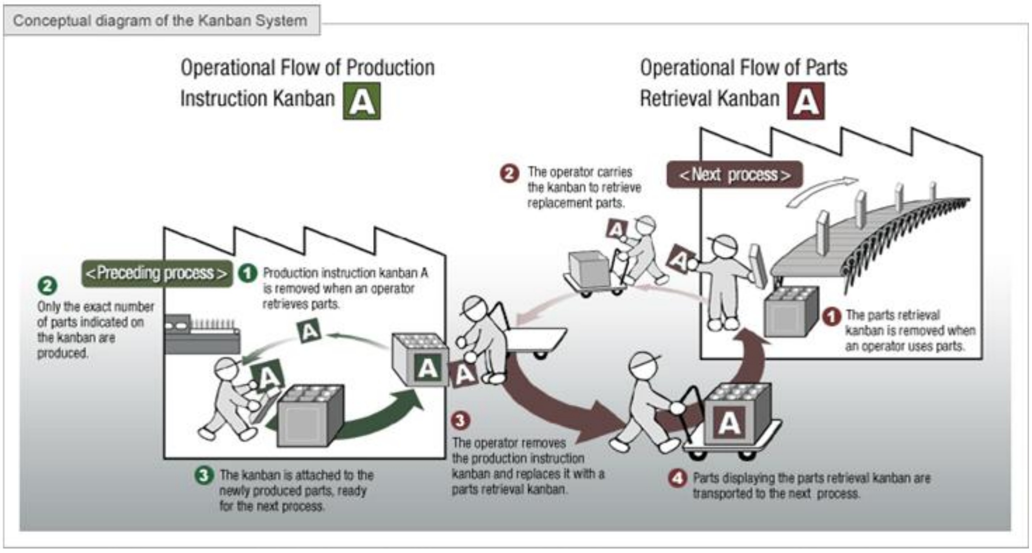


Figure 2.5.4.3.c – Kanban system diagram (totalqualitymanagement.wordpress.com/…)

There are two basic parameters which determine the Kanban system. First of all, the quantity of Kanban cards needs to be decided. The quantity is dependent on the replenishment lead time to cover the demand of the customer station.

The minimum number of Kanban cards can be calculated with following formul, where n is the number of units per card, D is the demand at the customer station in units/day), k is the number of kanban cards, t is the replenishment lead time in days, s is safety factor

$$k \geq \frac{t \cdot D \cdot (1+s)}{n}$$

2.5.5. One-piece-Flow

"If some problem occurs in one-piece-flow manufacturing, then the whole production line stops. In this sense it is a very bad system of manufacturing. But when production stops, everyone is forced to solve the problem immediately. So team members have to think, and through thinking team members grow and become better team members and people." (Teruyuki Minoura, former President, Toyota Motor Manufacturing, NA)

"Flow is at the heart of the lean message that shortening the elapsed time from raw materials to finished goods (or services) will lead to the best quality, lowest cost, and shortest delivery time." (Liker, 2004: 88)

In traditional Mass Production, the way to obtain the maximum productivity was to combine similar processes together and run big batches without necessity to change. In this way, large batches and as a consequence overproduction lead into high inventory levels – space and cost intensive. Additionally the lead time for every product has been very long. On the other hand, lean thinking brought change in philosophy and combined different processes into work cells, where the product was finalized in smallest possible batches – ideally in One-piece-Flow. As a result, lead time + inventory are reduced dramatically and the quality is improved.

Here are the main benefits of continuous Flow production:

- **Quality** – with one-piece-flow the quality issues are revealed immediately while in batch production this may take some thousands of pieces till the issue comes out. The advantage of flow is that every operator at the work cell is doing quality gate control himself and as soon as problem occurs, he stops immediately the flow and the whole system can be concentrated on problem solution.

- **Flexibility** – with equipment combined to cells where every cycle a final product is being established, you can get tremendous flexibility gain in comparison with traditional mass production style, where batches of semi-finished products have been produced and stored in-between. The equipment capacity has been saturated in this way for longer period without any interchange and by this way the lead time for a product has been very long. One-piece-flow combined with short tool-change times lead to higher flexibility and consequently to small batch sizes and decreased inventory level.

- **Productivity** – often happens that organizations which do run traditional way of production with big batches do not see the non value-add operations they do. In fact, if you see the production it does seem to be more effective since no change downtimes are necessary. But let's focus the key principle of Lean methodology – focus on customer and his demand. From this point of view, you can immediately recognize the waste. If your customer is asking for 1000sets a day and you produce 10x more in a batch, what are kind of waste operations are connected to this decision? First of all, additional handling in-between processes. Second, quality, while the batch is big and takes time to be able to discover the problem on the following operation. Third, stock of production and space in warehouse, what generates costs. Fourth, cash blocked in this production, while you can sell only the amount requested by the customer… Truly, one-piece-flow is for sure a significant increase in productivity compared to traditional mass production style.

- **Space** – taking into consideration the department / process organization of equipment (mass production), the space need for singular equipment with logistic (wip) spaces around creates a very low level of space usage. Imagine a line production where 5operations are separately performed by one operator at every operation. At every operation you have a container with entering component and one bin for the outcoming WIP parts, which has to be moved forward by handler/forklift to following operation after the batch is concluded. On the other hand, in one-piece-flow production you have usually the equipment organized into a work cell unit, very often a U-Shape cell. In such a constellation you have only one loading and one unloading point in the cell, while no handling in-between operations is necessary

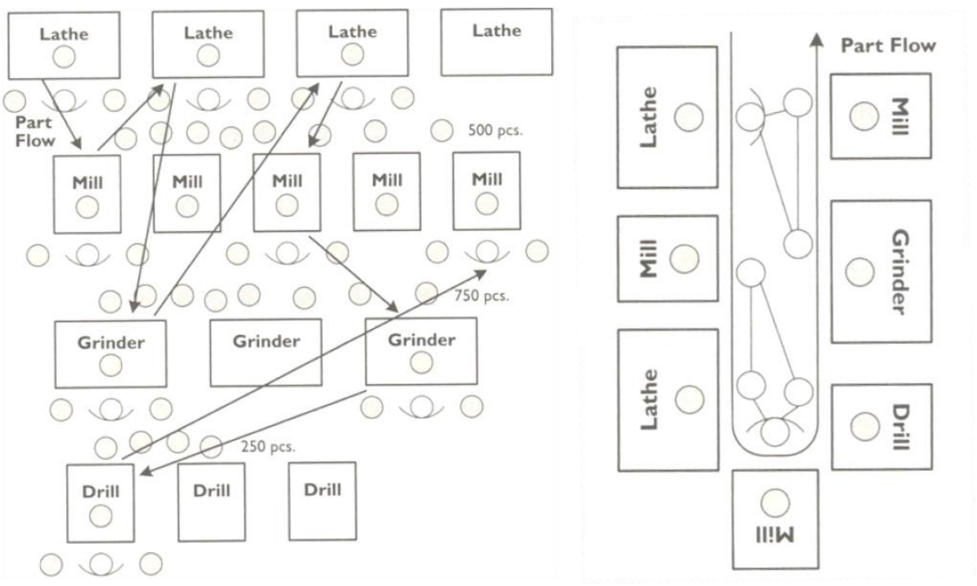


Figure 2.5.5.a. – Organization & Control (Liker, 2004: 97-98)

- **Safety** – to understand the safety benefit of one-piece-flow usage we turn back again to big batches of mass production. Reducing the batch size to minimum possible, the dimension and container capacity can be reduced significantly. The reduction of container size to totes/flow racks reduces the weight and therefore eliminates the ergonomics risk. By this way the organization can get rid of the biggest safety issue in plant, what is the forklift handling. The handling necessity in operations can be compensated by tugger trains which are suitable for frequent deliveries to the point of use, in-between working cells.

- **Morale** – seeing the fact that one-piece-flow implementation improves working conditions of workers at the cell, the morale is usually improved consequently. Less space occupied with material, better orientation and overview in the production area, less quality issues related to operator faults as well as less safety risks on the shop-floor – all this is affecting the morale.

- **Inventory** – as already stated before, space in warehouse costs money. Parts sitting in the warehouse cost money as well – seeing the fact that the material has been purchased but not sold to the customer. The cash is being blocked in the inventory. Next, the risk of parts becoming obsolete can be reduced to minimum by the implementation of one-piece-flow.

2.5.6. Involvement

The fact that involvement is present in both of the pillars of the Lean House as well as in the roof is not an accident. The involvement itself is crucial for all of the lean activities that have been named up to know. One of the best known involvement activities is for sure Kaizen Circle Activities, where the team members have the opportunity to work together as a team on improvements, poka yokes etc. Working as a team, every team member can absorb the knowledge share of the others and improve own capabilities. This is maybe the best way how a plant can spread the knowledge in larger teams.

2.5.7. Continuous improvement

Continuous improvement is a methodology in lean manufacturing – meaning that the organization and every member of it should continuously work on improvements of all processes. The presumption of it is the rising expectations of the whole system – the customers, global competition as well as the costs of quality - are the key motivators to make the continuous improvement process to a MUST.

The preconditions for functional continuous improvement process are cross-functional or multifunctional teams.

2.6. Material Feeding Systems / Part Presentation Methods

The crucial question of this Master Thesis is following: “What type of Part Presentation Method is the most effective one, or better to say, the leanest one…?” This is one of the most important questions in every project decision making period. The decision based on it influences full range of other activities, as well as performance and efficiency of the line. What makes the decision far more important, that it takes part far before the work cell is being established and is usually taken by people who are deeply involved with technology and efficiency of the work cell equipment, but less with logistics and other service activities to the production. Summarizing, this decision impacts productivity as well as quality.

…and here we are again with the question: is the part presentation on the assembly cell a value adding, or non-value adding activity. We can consider an operator working in the cycle time of the cell. It is necessary to have the operator and equipment cycle times / activities equilibrated in meaning to achieve the best use of the technology used as well as the best value add by the operator. Every time the cell stops, a downtime is counted – in other words a waste is created. This means, that it is crucial to understand, what is the objective of an operator at the cell? What is his work task? …and obviously, what is not.

"Assembler time is expensive because operators work in series on the line, but materials handlers, on the other hand, work in parallel. … Regardless of what managers may believe about "non-value added" activities, the number of people handling and preparing parts is often increased in order to reduce the total amount of labor spent on assembly." (Baudin, 2004: 171)

Usually there is not a clear understanding of the part presentation influence on the productivity and quality. Let's consider the option that the parts are positioned not directly at the reach of the operator at the line and so the operator is constraint to walk from his loading position at the fixture to the position where the parts are positioned. This walking time spent for every working cycle can be measured and converted easily to money/cost formularization. Imagine the operator is producing 450sets of assemblies a shift (450min). Being constraint to walk 5sec every cycle means 37,5min downtime calculated on the 450sets customer demand. This means an 8,3% OEE reduction, or an additional necessity for overtime to offset the additional 8,3% time needed to produce the 450sets. By this meaning the already mentioned work cell vs. operator cycle time balance is crucial to obtain the designed productivity on the cell.

On the other hand, quality is very often the issue, when the parts have for example wrong orientation and the operator needs to handle it. Similarly as in the productivity issue, every handling activity is considered a waste and can be easily measured and transformed into cost formularization. On the other hand, it creates also relatively high risk of parts being confused or assembled in wrong orientation. By this meaning the impact on the quality must be part of the opportunity/risk analysis.

Summarizing the above said, the operators at the working cell or in the assembly line are working in pre-defined cycle/takt time which has to be balanced in-between equipment and man. Only in this way no waste is created. Based on this, the operator time is valuable and expensive, because influencing the line and following operations. On the other hand, the handling operators are working in parallel and so not influencing the other. So it is obvious that statement by Baudin about adding people into handling is true, while the manning increase is always lower than the case of adding personnel in production line, cause unbalanced operations and so waste. The main message is that the line operator should be executing only value adding work directly connected with assembly and all the other functions or tasks should be performed by supporting personnel, handlers who can work in parallel with line operators. This message is very often misunderstood by managers who consider all handling operations as non-value adding and so deny any increase of such activities. That's why you can often find direct line personnel performing handling activities and in many cases out of that influencing the takt time of the line.

"In most plants, the material manager is measured more on the efficiency of the department as a standalone unit than on its effectiveness in support of production. Changing this around is one of the key motivations for product alignment in the organization structure. In a lean production organization a product line manager has authority over not only the production line itself but its support structure as well." (Baudin, 2004: 176)

…back to the basic question of this chapter: "What type of Part Presentation Method is the most effective one, or better to say, the leanest one…?" And consequently, what are the main principles of Part Presentation?

According to Johansson (1991) there are 3main material feeding systems, which are categorized according to:

- The presentation of all or just a selection of parts at the assembly working cell
- Distinction of parts based on part numbers or assembly objects

	Selection of part numbers	All part numbers
Sorted by part number	**BATCH**	**CONTINUOUS**
Sorted by assembly object	**KITTING**	

Figure 2.6.b – Material feeding systems (Johansson: 1991)

All three of these systems can co-exist together under one roof and one can act as a completion of the other. Furthermore, there are plenty of variations within everyone of them, so there can be hardly found a pure/clean system.

Later on a 4th Material feeding system has been described by Johansson & Johansson (2006) – Sequential Supply System, which will be described onwards.

2.6.1. Continuous Supply

Continuous supply describes the system where the parts/components are presented to the POU in handling units and are replaced in the moment they're empty. This system is often also called line-side stocking. All parts are delivered to the assembly line in single containers. The benefit of this system is that no pre-processing is needed as well as that all parts are always present at the line. The line operator has by that always the opportunity to pick up a different part, if some quality concern is present. The major disadvantage of the system is originated actually by the beneficial side. It means, all parts available at the line in singular containers. Imagine a work cell with higher number of entering components – first of all, the cash is bounded in the inventory, second these containers occupy space around the cell, and last but not least, the operator is always walking around to pick up parts, what causes downtime. The fix station containers could be here replaced by some kind of two-bin kanban system…

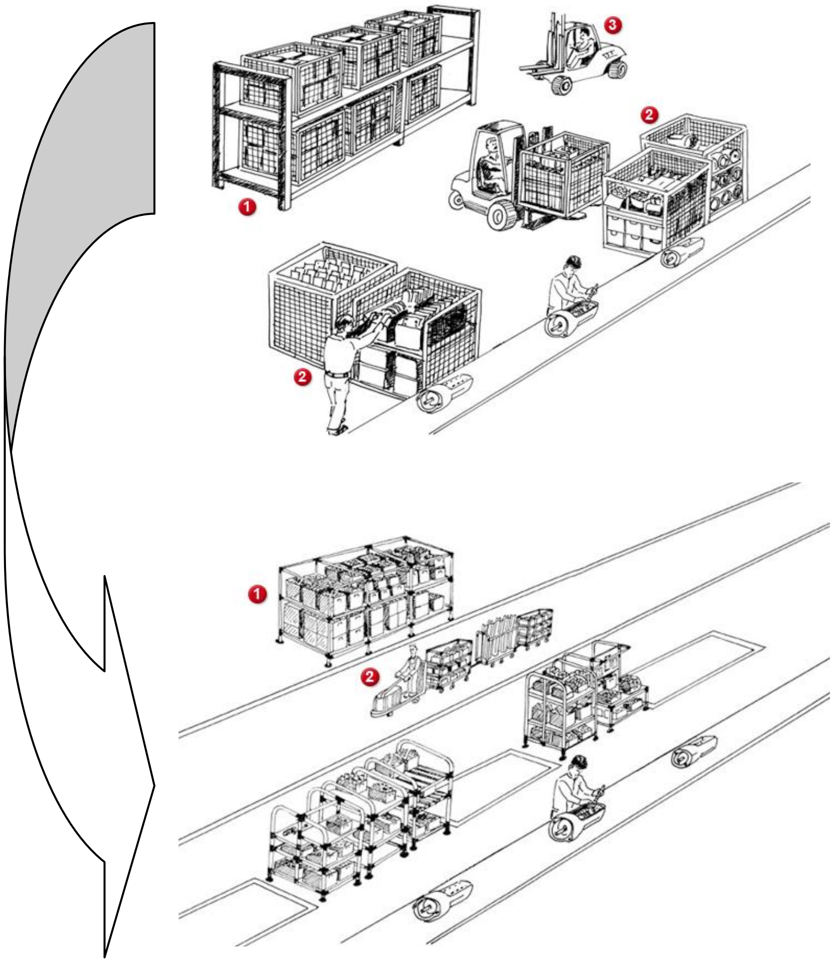


Figure 2.6.1.a – Line-Side system, Traditional vs. Lean (www.vision-lean.com)

2.6.2. Batch Supply

In the Batch Supply system, the parts/components or material are delivered for a specific quantity of assembly products. The batch itself can be understood as the batch of needed parts (in meaning of variety) as well as the batch of necessary parts (in meaning of quantity). In the first case the difference to continuous supply system lies in less or better to say just necessary parts are presented at POU in different time schedules. The rest of the material turns back to the warehouse when the batch is completed – in this way the necessity of parts counting arise…

2.6.3. Kitting Supply

In the Kitting supply system, the parts/components or materials for a specific quantity of assembly products are presented at the POU, sorted according to object. The major disadvantage of the system is the need for repackaging, since the parts are supplied from outside in traditional packaging containers. The Kitting method will be described more in detail in next chapter.

2.6.4. Sequential supply

In the Sequential supply system, the parts/components or materials for a specific quantity of assembly products are presented at the POU, selected according to object.

The main reason for development of sequential supply system has been the fact that the assembling process on the production line is done in several steps/operations, where only a few components are installed. Furthermore, the space necessity and liquidity bounded by the continuous supply system were too painful. Additionally, since sequencing can be done internally as well as externally from the assembly plant – the assembler usually decides to eliminate the effect of repackaging typical for kittings and so moves the sequencing responsibility to the supplier from outside.

According to a case study from industry done by Limere & Van Landeghem in 2008, out of 3500 part numbers analyzed, 52% were presented by the means of continuous supply system, 31% by sequential (sequenced at the supplier), 12% were repacked to kittings and 5% sequenced internally.

2.6.5. Main Principles of Lean PPM

According to knowledge from literature, the most mentioned key principles of Lean Part Presentation Methods are following:

- Removal of packaging materials before delivery
- Location within arm’s reach of the assembler
- Orientation
- Adjustment to specific part characteristics
- Matching quantities

The aim of all of these principles is simply to eliminate the waste created within the selecting, handling and presenting activities on the shopfloor. Every movement, every walking necessity, every process should be viewed from the value-add point of view. In the chart bellow there is the principle shown:

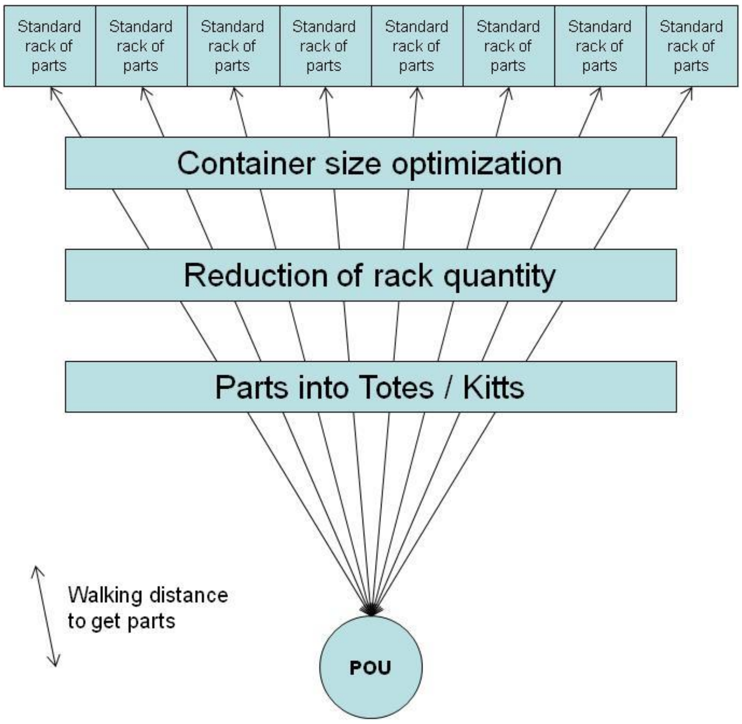


Figure 2.6.5.a – effect of new part presentation methods (own scheme)

2.6.5.1. Removal of packaging materials before delivery

Based on the necessity to protect the functionality or the visual aspect of the part, many parts of them are being delivered from supplier to the production plant in protective packaging. The purpose of it is to protect the part itself from the moment of production, till the moment of use – in this case moment of installation on the production line. When we consider just the production plant itself, the parts must be presented on the production line without any kind of packaging material, which could present a source of waste in meaning of time, if the removal activity would be performed by the line operator. There are different ways how to do and who should perform it. There is one general rule for who shouldn't be the case = assembly line operator. The reason is again waste creation, because the line is waiting. Knowing this, there is wide space to use in-between inbound warehouse and the production line. The best option would be the disposal of packaging at the entrance to the purchase warehouse, where the parts would be immediately unpacked and collected into racks, containers, kitts or totes in order to be ready for the part presentation at the point of use in production. Simply, the parts should be in condition for immediate pick up and installation.

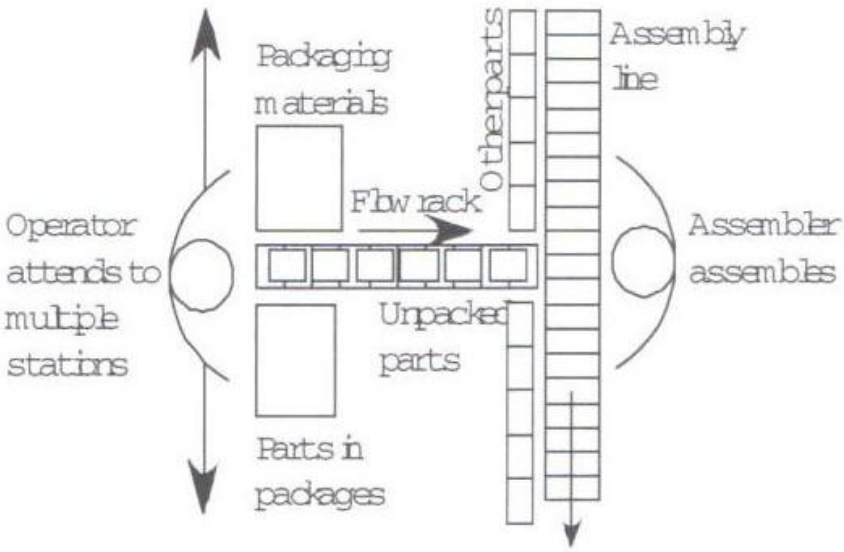


Figure 2.6.5.1.a Separation of unpacking from assembly (Baudin, 2004: 178)

2.6.5.2. Parts at arm's reach

As stated previously, parts should be presented unpacked, or better to say in condition to be immediately installed at the POU (point of use). The term "point of use" and its understanding has obviously very wide limits. Considering the experience within Tower Automotive, the term has been commonly understood as the area delimited by the work cell. Very often this means the necessity to walk several meters to pick up the part from the container. Operator usually try to walk less possible and so they try to pick up multiple parts and keep them in on hand to be able to operate with the other one – of course this means time increase of operation per item while the job should be performed with both hands. On the other hand, the operator might have placed the parts on the fixture or closely, and subsequently resulting into multiple handling. As already stated before, the best solution to these waste potentials would be the part presentation at arm's reach from the fixture. This would avoid any unnecessary or un-ergonomic movement resulting in waste. These are some examples of the methods which could be used:

- **Gravity Flow-rack systems**

Figure 2.6.5.2.a – Gravity Flow-Rack Systems (Tower Automotive, Slovakia)

- **Kitts**

Figure 2.6.5.2.b – Kitting systems (Tower Automotive, Slovakia)

- **Moving Part Trays**

Figure 2.6.5.2.c – Moving Part Trays (Tower Automotive, Germany)

2.6.5.3. Orientation

"Orientation plays a role in both picking and installing a part, and the objectives for both these activities are not necessarily in harmony. In picking, you want to maximize the number of different items available to the assembler. To achieve this, you orient each part so that its smallest dimension appears on the picking face. To make it easy to install, on the other hand, you present it so as to minimize the required motion by the operator." (Baudin 2004: 180)

The need for orientation of parts is dependant from its dimension, form, weight, and usage frequency. Here are some examples for every case:

- **Frequency** - fasteners (screws, bolts, etc.) are surely the most frequently used article on a car. Usually are delivered in small cardboard boxes or plastic bins without any orientation. In low volume production it can make sense that the screws are installed manually by the operator. In this case it happens very often that an incorrect screw/fastener has been installed, that the orientation itself was incorrect or even multiple fasteners instead or unique are installed – the quality may suffer. On the contrary - in high volume production, automatic feeders are used commonly. This equipment ensures the proper quantity as well as quality is installed, with the requested orientation.

- **Form/Shape** - symmetric parts are orientation free - take into consideration bearing balls. These do not need any kind of specific orientation and seeing the fact of high usage frequency, usually are fed in automatic mode and installed by automatic machinery/equipment.

- **Weight** - in case of heavy weight parts or components, it's necessary to distinguish if the part will be installed by a man, or by a robot/machinery. In case of man it is a must to give him the possibility to work with both hands as well as the opportunity to eliminate ergonomics issue by the usage of slides, shuts or conveyors.

- **Dimension** - in case of big dimension parts we have the same differentiation as previously – parts installed by man or robot/machinery. In case of man it is necessary to think about the proper way of orientation in meaning of catching the part and in meaning of installation as well. The dilemma of orientation in this case is evident – imagine one big stamping part (side panel) which is produced in press shop and stored directly in a specific rack in the way to maximize the usage of the rack, to preserve the quality of the part as well as to minimize the manipulation in the operations & logistics. On the contrary, this mode of storing parts might not be the ideal one to pick up the part from the rack for the final installation.

Summarizing the above stated, the main interest of orientation dilemma is to reduce the potential waste for direct line operator. Every part is specific and dependant from different limitations – based on which the decision must be made, if the parts orientation should be driven by installation or by the picking method. This dilemma is illustrated bellow:

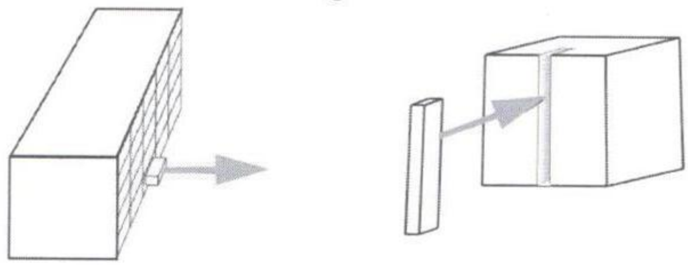


Figure 2.6.5.3.a. – The orientation dilemma (Baudin 2004: 180)

2.6.5.4. Adjustment to specific part characteristics

As already stated in the previous section, every part has specific conditions (dimension, weight, shape, usage frequency, etc.) which influence orientation and so part presentation method in generally. There are some specific items like door sealing or wire harnesses which need to be presented in special presentation devices, usually made to measure (different types of carrousels or carriers).

In case of stamping parts of certain dimension and weight, presented in standard steel containers, it often happens that operator needs to pick up parts out of these boxes within the time given by the cell takt time. It is happening frequently that people responsible for SWI's (Standard Work Instructions) monitoring the activity and time behind this pick up operation just superficially, not taking into consideration the difference between a full and almost empty container. The walking distance remains a constant, but the picking itself becomes a variable – the emptier is the container, the more time it is spent to pick up the part. Of course, ergonomics becomes an issue too. Of course, there is solution also to this case – so called PalletPal.

Figure 2.6.5.4.a – PalletPal (www.southworthproducts.com)

It is a combination of a turn table with spring/pneumatic/hydraulic lift table. In this meaning the operator is able to turn the container to the position he needs and the predefined height of the table is adjusted based on the weight of the container.

2.6.5.5. Matching quantities

The basic message of Lean methodology is the orientation on the Value-Add activities from the point of view of the customer. Nevertheless, it is not rare to observe many companies having confused understanding for it in-between the various departments, core or supporting, which are driven by specific/single dept. KPI's or targets which do not support the Lean methodology idea as a whole. This happens very often in-between Operations and Inbound Logistics/Purchasing.

Why is it so? Probably failure of understanding that a singular/partial win is not always leading to the profitability of the whole organization. Organizations which do not involve all singular departments into the process of creating value, can't obtain a long lasting profitability. Let's analyze more in details the motivation of singular dept.:

- Purchasing is usually driven by the best piece price – but there should be more than just this! When we consider this decision from financial point of view, we have an issue with cash… but let's consider more in detail the operations point of view – the best price / unit with the filling quantity per container far above requested level, packaging conditions not suitable for the operations… all this makes the price not the decisive point.
- Logistics is usually driven by the lowest transportation costs / unit and the lowest space costs in the warehouse. That's why logistics try to have the load density of parts in container at maximum level – again, this might not be the driving force for the operations and so for the profitability of the business as whole.

There are many companies where the purchased parts are being presented on the production line in packaging/quantities which occupy significant space around the point of use. Full standard containers with filling capacity for several days are being moved to production spaces with the idea behind to eliminate forklift movements to minimum! This presumption is completely wrong. Of course, more we go in detail, more we can focus on what is the proper way to feed the lines, are the forklifts the right equipment for it? Surely not. Forklifts are big, dangerous, costly, and limited to deliver the whole containers. Anyway, every part on the line has different usage and different frequency of replenishment based on the filling capacity of the container and the quantity needed for one set. Seeing the diversity of hundreds of parts coming to the line, having traditional packaging on lines causes chaos. Imagine parts A,B,C where all of them enter the installation process in the same amount of one. The difference is in the filling quantity and dimension of the parts. Consequently, the replenishment on the line will be different for every part and the space around the point of use will be based on the container dimensions.

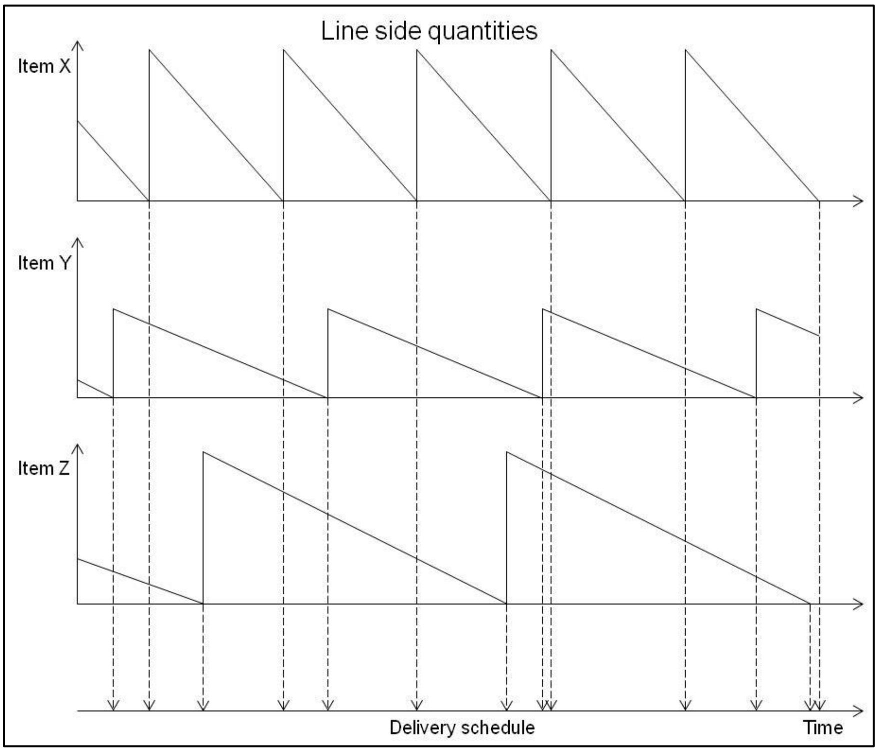


Figure 2.6.5.5.a – Random replenishment schedule (own scheme)

… as before stated, the main focus should be on customer demand. This is the true driving force of the whole business. The quantities on the production line should be calculated on the base of customer takt time. Let's suppose that the customer is requesting 1350parts a day (in a 3shift working day, 7,5hours per shift). This means the customer is requesting 1part every minute, so the takt time is 60sec. this should be the base for the upcoming calculations for every part number – optimally coordinating the replenishment schedules of all parts at the working cell to one – at example 1hours rate. This means, that the capacity of flow rack at the point of use should be exactly 2x1hour + 1additional container of that part. If this system adopted, it means that 1hour of production capacity is just being delivered to POU, 1hour is already at the POU in the flow rack, wherefrom the operator is feeding the line and 1hour of empty racks is on the lower level of the flow rack waiting to be picked up. Generally, Toyota is calling this system as 2hours line side + 1hour delivery.

In case of small parts like fasteners (screws, nuts, bolts, etc.) it is reasonable to think about multiple delivery periods, which are always a multiple of the original replenishment frequency. This method makes the line balanced by regular supplies of parts coming in predefined quantities and time schedules.

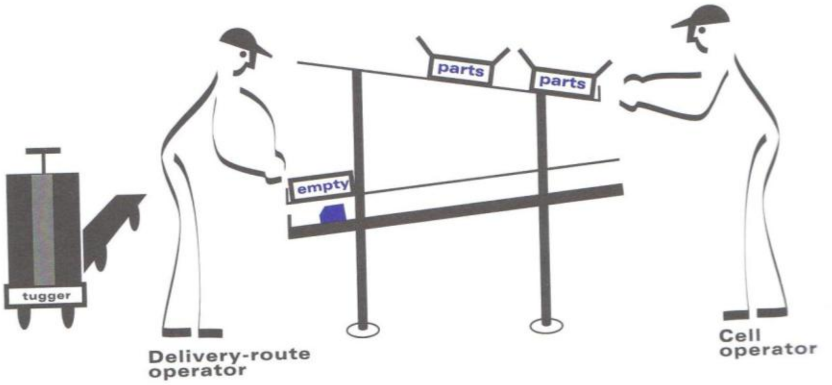


Figure 2.6.5.5.b – Flow Rack System (Harris et al. 2003: 50)

3. Part Presentation Methods

In this chapter I will focus on detailed description of Part Presentation Methods including experiences out of real implementations within automotive sector.

3.1. Order Picking

Order picking Activities are connected with parts identification in the warehouse, than movement of these parts to dedicated area to fulfill the customer order/request. As in every activity there is the supplier vs. customer relationship – in this case there is internal customer (operations).

Based on a survey from Warehousing Education & Research Council order picking activities represent up to 50% of the costs related to warehousing. The rest is distributed as following: 20% storage costs, 15% outbound logistics and 15% inbound logistics.

In literature we can find several classifications of order picking systems. But the most typical is the division into:

- Picker-to-Part - where the picker is moving to the market place, where the kitt is being prepared in single or multiple batch order. (the most used in the automotive industry) Parts are retrieved out of containers, or there might be an optimization with gravity flow racks – the productivity increases.
- Part-to-Picker, where the component containers are moved to picking bays where the operators pick the parts according the order. When the order is finished, the containers go back to warehouse. By this space and labour is decreased, on the other hand handling increased.
- Sorting, where dedicated personnel - sorters are dedicated to specific market place area where the retrieval of parts takes place. A conveyor usually connects the different retrieval locations. Productivity is higher than picker-to-part system since the operator's traveling time is reduced.
- Pick-to-Box, similar composition to sorting system. Market place area is diversified in multiple picking zones dedicated to single operators. These zones are connected by conveyors. Line end sorting not necessary anymore, because the order has been prepared already and so box sorting based on destination will be enough.

Based on the analysis of Dallari, Marchet, Melacini and Perotti, following charts can be taken as a guide in OPS selection. First differentiation stays in order size, lower/higher than 0,5m^3. From this baseline, two factors have been considered – picking volume vs. number of items. For better overview see the enclosed charts:

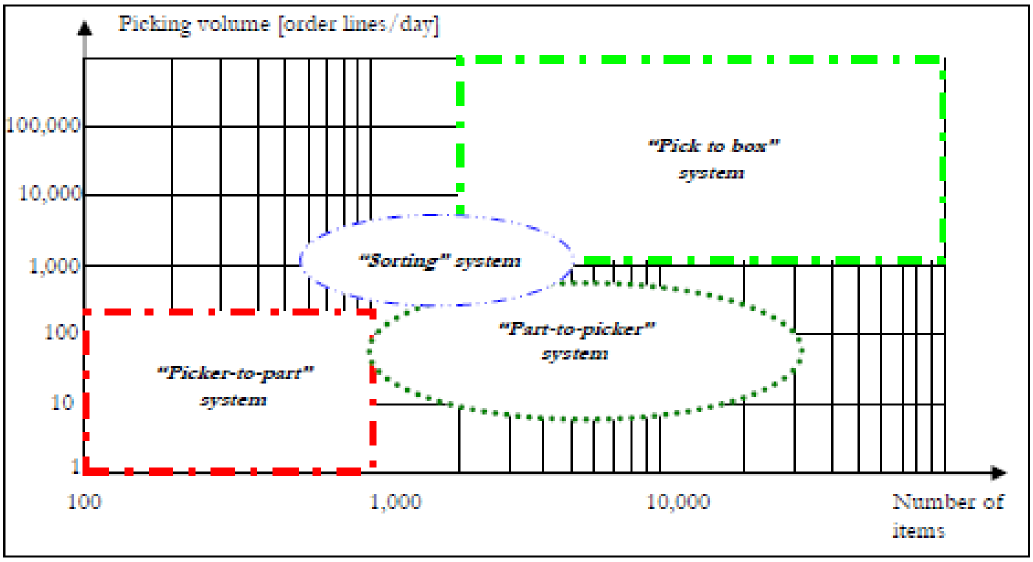


Figure 3.1.a – OPS with order size less than 0,5m^3 (Dallari, Marchet, Melacini, Perotti - www.liuc.it)

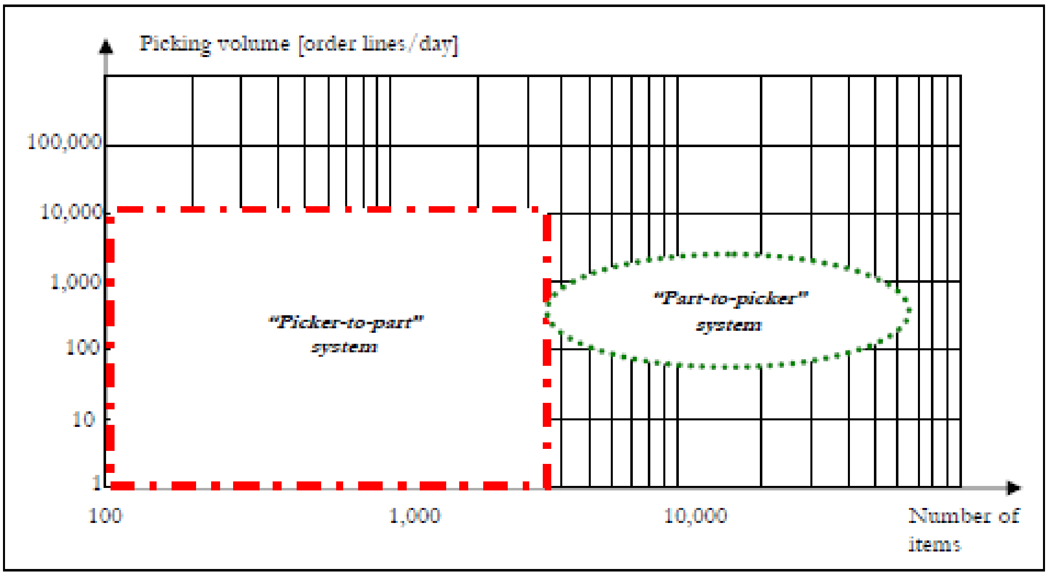


Figure 3.1.b – OPS with order size more than 0,5m^3 (Dallari, Marchet, Melacini, Perotti - www.liuc.it)

3.2. Traditional Part Presentation Method (TPPM)

Traditional way of part presentation in the production process is connected with deliveries of parts in standard / traditional containers, usually steel containers with the regard on the transportation efficiency. This means that the container dimension & capacity is selected from the point of view to fit as much produced parts into the bin as possible and so to be able to minimize the transportation cost impact per piece to the lowest price possible. As you can see bellow in the enclosed picture, by this method you have a substantial space impact in the operation areas, where all parts stay singularly in containers

Figure 3.2.a – TPPM (Tower Automotive, Slovakia)

Additionally, handling activities in TPPM are performed by traditional forklifts – as already mentioned, one of the biggest safety risks in every plant. Forklift truck is big, fast, has forks which are a very dangerous "weapon" in every factory and as a cherry on the cake, you have a driver using this weapon… imagine the above shown production in an assembly/welding area, where the forklifts deliver standard containers to the work cell from the back of every operator standing at the line. This is a substantial security issue. Additionally, it happens quite often, since the space is limited, that the forklift makes damages on the cell equipment, what leads in substantial downtimes. Seeing the safety score compared forklift/non-forklift driven operations within Tower International plants, there is a clear advantage of non-forklift. Broader analyze of external data and benchmarks could be part of future analyze.

As already mentioned, handling is usually performed by forklifts bringing fulls (entering parts & components) and empties (for final goods). The issue with the standard container filling capacity is that there might be the case where the container stays positioned in operations area around the cell for several shifts or even days. Imagine a very simple and small stamped part which enters the cell. From the press shop efficiency and transportation efficiency point of view, the part is packaged into a steel standard box (GitterBox - GBX) with the filling capacity of 1200parts. From the press shop point of view, the decision to maximize the filling capacity is absolutely correct. Based on the fact that producing at 15SPM (Strokes per minute rate) on a 800t transfer press makes the necessity to exchange the container every 80min. what reduces the logistics downtime in case of higher frequency of exchange. On the other side, warehousing, transportation and handling activities of one GBX with 1200parts filling capacity makes the logistics much easier. BUT, what does it affect in negative way:

- production lot size limited to multiplications of container capacity
- quality, in meaning of big lot sizes

- high risk of obsolete parts
- lower flexibility of the press shop line
- higher inventory level in meaning of cash
- substantial space increase/impact on the assembly line
- unbalanced filling capacities at the cell
- unbalanced handling of different parts at the cell

…additionally, the operator needs to pick up the parts from the standard containers and bring them to the loading station/fixture of the assembly line. This causes high walking rate of the operator at the cell and so lower cell performance or higher downtime rate. On the other hand, there has been observed one positive usage of standard or special big racks at the POU – in case of big parts which can't be kitted or re-packaged into smaller totes because of dimensions or weight. This is the case where the TPPM is the preferred one.

Seeing the previous said, there is a serious ergonomics impact of standard bins usage in operations. This makes it necessary to apply different types of ergonomics deivces like container lifters, lift tables, container tilters, pallet palls etc.

Figure 3.2.b – Southworth's ergonomics devices (www.southworthproducts.com)

From the space perspective, every company is focused on minimizing the space factor for the logistics spaces & routes in operations areas. Having forklifts as the key handling equipment and TPPM with standard steel containers as the packaging method, this makes the factor for space necessity much more intensive. The normally known logistics index for forklift-driven operations with standard containers around the working cells is in-between 2,0~2,5 – what means that you need more than double of additional space to the real production space. This makes it very easy to calculate the investment/CAPEX impact in case of taking this kind of decision in the project start-up phase.

3.2.1. Pro's and Con's of TPPM

In the following lines there are the most nominated benefits of TPPM in so far studied literature, as well as in own experience as Operations & Logistics Manager of Tower Automotive:

- Efficient transportation & warehousing

- Less handling intensive
- In case of quality issue on one part, there’s always a substitute
- Longer replenishment frequency
- No re-packaging needed

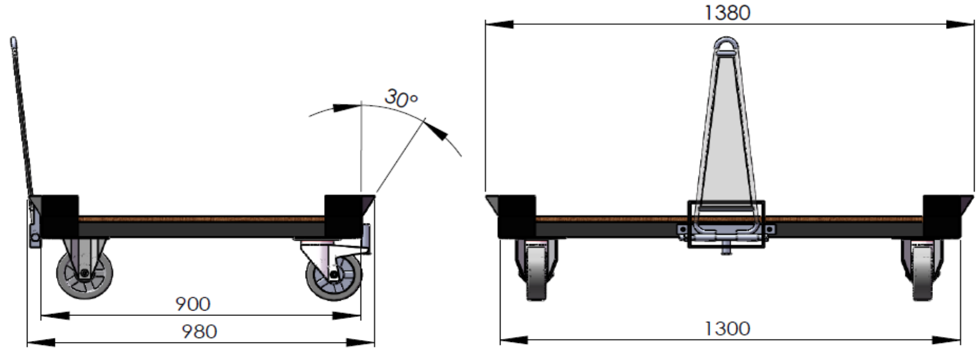
Bellow listed are the main disadvantages:

- Increase of operator downtimes (walking, searching, picking, etc.)
- Waste of production space in Operations
    - Logistics space ratio of 2,0~2,5
- Forklift-driven Operations
- High Inventory Level – Cash
- Unbalanced filling capacities at the POU
- Visual aspect on the shop-floor worsened - full
- Quality issues - long lead time till the error is identified (lot size)

3.2.2. Conclusions for TPPM

Taking into consideration of all above mentioned, TPP is the method which has a very limited application in today’s Lean Operations & Logistics areas because of the main disadvantage of space, which is directly CAPEX related and so relatively expensive. The throughput impact is negative on the cell in meaning of starved line.

There has been one generally acknowledged scope for TPPM in Tower Automotive – parts with big dimensions/weight which generally need a specific made-to-measure container. In this case it doesn’t make any sense to re-package the part, but to bring it directly to the POU, where it is operator’s task to pick the part out of the container and place it directly to the fixture. By this meaning, there is no other way to package the parts at the original process, because of dimensions, weight, safety or quality issues connected. That’s why such components are preferred in made-to-measure containers directly at POU. The only topic to improve in this case would be the handling mode. Seeing the fact that such a big container is usually handled by forklifts, and we clearly recognized forklift as NOT compatible with lean part presentation methods, the advice would be to load such container on a base cart / chassis and then have it transported to the POU by a tugger train.



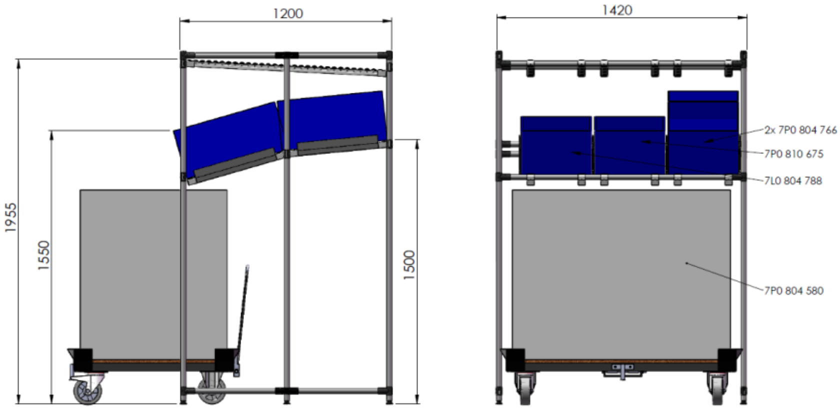


Figure 3.2.2.a – chassis/base carts used in Tower Automotive (Tower Automotive, Slovakia)

3.3. Kitting Part Presentation Method (KPPM)

As already mentioned before, Kitting supply system represents the method of delivering components in predetermined quantities and part number composition to the POU. These parts are assorted in specific, made-to-measure containers known as kitts. One kitt is usually foreseen for part presentation on one POU, one operation to which all loaded parts on the kitt fit in.

Figure 3.3.a – Typical Kitt in Welding Shop (Tower Automotive, Slovakia)

All components are usually well organized, in logical order, to be easy for pick up without damage. Every kitt is identified by a symbol or letter to visualize the POU area. The structure of parts loaded onto the kitt has to be also well defined seeing the impact on ergonomics and line operator position on the line. Additionally, the proper quantity of kitts per station needs to be established. The common method used is triple kitt type – one kitt with parts being consumed at the POU, second kitt being delivered by a tugger train on route and third one being filled / re-packed with parts from standard steel containers. Based on the replenishment frequency and lead time for replenishment, there could be done an optimization of the kitt quantity per station down to two. The issue is just to be able to perform the re-packaging / kitt preparation activity with the necessary transportation to the POU within the time given by the filling capacity of the kitt. Seeing the fact that parts needed in for a particular kitt are delivered to the warehouse in standard transportation containers, there is the need for re-packaging of these parts into the kitt directly. This is generally perceived as non value-add operation. That’s why it’s not recommended to be performed by the operator at the assembly line, seeing the fact that the line would be stopped in downtime. Usually is this operation performed by a picker in incoming good storage, or in a market place, what is the name for small decentralized storage area near POU. Re-packaging itself is considered to be the biggest disadvantage oof this method while it creates the necessity of additional space, man-capacity and so additional costs which are considered as a waste – the customer is not willing to pay for.

Generally there are recognized 2 basic types of Kitts – Fixed/Stationary Kitt or Travelling Kitt. The first one represents a kitt which is presented at POU / work cell and stay at this position till it’s empty. On the other hand, travelling kitt is serving several work stations and is moving with the progress of completion of the product. There are 2types of travelling kitt – first, where the product and kitt are moved in the same container as the product is finished. Second, the product and kitt are moved in separate but parallel containers.

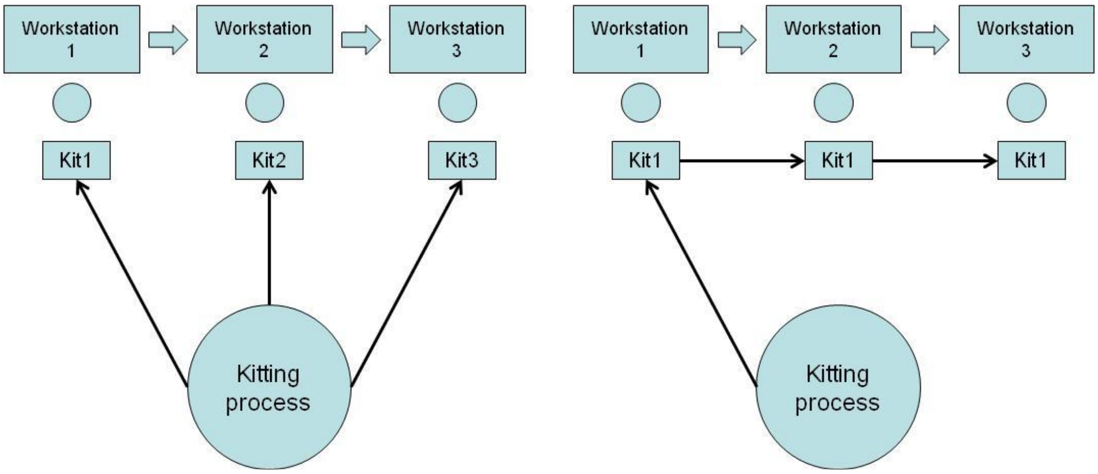


Figure 3.3.b – Stationary vs. Travelling Kitts (own scheme)

No matter which type is used, the kitt usually contains component variation to complete only single or multiple operations of the product – never a complete final good. This depends on the complexity of the product – how many components enter the process – as well as on the dimension of installed components. The dimension itself separates components into kittable and non-kittable category, where the non-kittable parts should be delivered to POU in specific made-to-measure containers and should be presented in side-line method. Fasteners (screws, nuts, studs, bolts, etc.) usually do not make part of the kitt as they’re presented by bulk deliveries. The Kitt itself makes higher control of potential quality issues of the parts as well as damage risk reduction – that's why this method is suitable for presentation of high value components.

After dealing with the question of what should be kittable or not, I dedicate some space to the question "Who should do it?", while this is the root cause of the main disadvantage point of the kitting. It's clear that preparation of a kitt requests time and capacity of a man or even of an automated kitting device. Since this is not the case in automotive industry, I will dedicate more space to the first one. Usually, there are two options in the decision of WHO – it might be the operator of the production line at the POU directly, or an operator/handler from the logistics group, generally called picker.

In the first case there is the benefit that the preparation takes place in the same group of people who are responsible for the job of component installation / assembly itself. This means a benefit of kitt accuracy as well as potential balance of work load of the assemblers, who might have enough time for kitt preparation. In case the operator cycle time is saturated and balanced to the work cell/assembly line takt time, there's no space for additional work load of the operator without having downtime as consequence. Furthermore in this option, the communication and improvement process becomes direct and straightforward and by that efficient.
In the case of a picker, you have clearly a disadvantage in the potential mistakes and accuracy issues, as well as the miscommunication in-between the two teams, which are not geographically close to each other. On the other hand you do not waste the operator capacity dedicated to value adding activities.

Last, but not least – handling of kitts is very important decision as well. KPP is the method which can be assigned to non-forklift driven methods. The kitts are usually delivered to the POU by a tugger train. This means that there's less space necessary for the aisles in-between storage regal systems or for the communication aisles as well. The space necessity in operations area is substantially decreased due to the fact, that container quantity at the POU is reduced to minimum. This is possible because every kitt does have a complete composition of part number variety necessary to cover the needs of one or multiple production stations.

By these means there is only a limited quantity of single parts delivered to the cell, but in contrast to TPPM, in balanced volume. The balanced volume is crucial for the set up of regular tugger train routes with specific schedule. This means that the filling capacity of every kitt is designed for a particular time to cover the consumption of the line based on the takt time of the line. After consumption of all parts, an empty kitt will be replenished by a full one in precisely scheduled time window, in which the tugger train must deliver. By this way the quantity of racks is diminished to the quantity of kitts necessary at the station. Due to this fact the layout of the operation area can be optimized in order to get the cells closer to each other, reducing the previous large forklift aisles / communications into optimal aisles for tugger train – kitt deliveries.

Based on the experience from Tower Automotive, the logistics ratio for kitting driven operation & logistics is in-between 1,55~1,8. Taking into consideration that the TPPM logistics ration is in the range of 2,0~2,5, there is a dramatic improvement of the space necessary for a project implementation. This huge improvement is present nevertheless the KPPM contains some amount of inefficiency / waste in itself, by the meaning of repackaging necessity in the logistics areas like marketplace or main warehouse itself.

3.3.1. Kitting preparation areas

There are 2basic locations, where the kitting preparation can be done in. First is the central warehouse in the area of inbound logistic, incoming goods – the other one would be a decentralized storage are called market place, located closely to the POU.

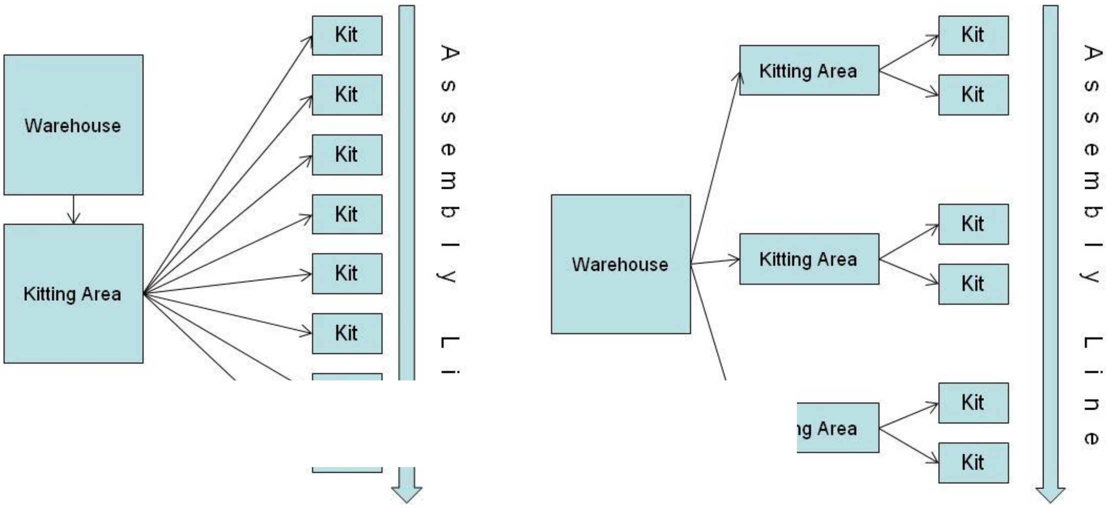


Figure 3.3.1.a – Centralized/Decentralized Kitting preparation areas (own scheme)

In case of kitting preparation are in centralized storage there is the advantage of unique space and so elimination of additional handling in-between central storage and supermarket. Another benefit would be the opportunity to saturate the capacity of a picker with preparation of various kitts at once. On the other hand, seeing the fact that the area is not close to the POU, it might cause some communication misunderstandings. Contrariwise, placing the kitting area close to POU and creating a market place, improves the communication. But it creates additional space necessity in operations area and additional manning, which might not be capacity-wise saturated.

Seeing the fact that the kitts are dedicated to on/several operations and these need to be supplied by kitts in certain schedule, it often happens that the preparation of kitts is performed as a batch. This means, once the parts in containers are being commissioned, several kitts are filled simultaneously – of course kitts of the same part number variation. After this commissioning is over, containers are brought back to the storage. If there would be more variation in batch preparation of kitts, this could have an impact on the kitt accuracy. Generally, batching can bring a higher efficiency in picking, but on other hand an increased administration and sorting operations can offset these benefits.

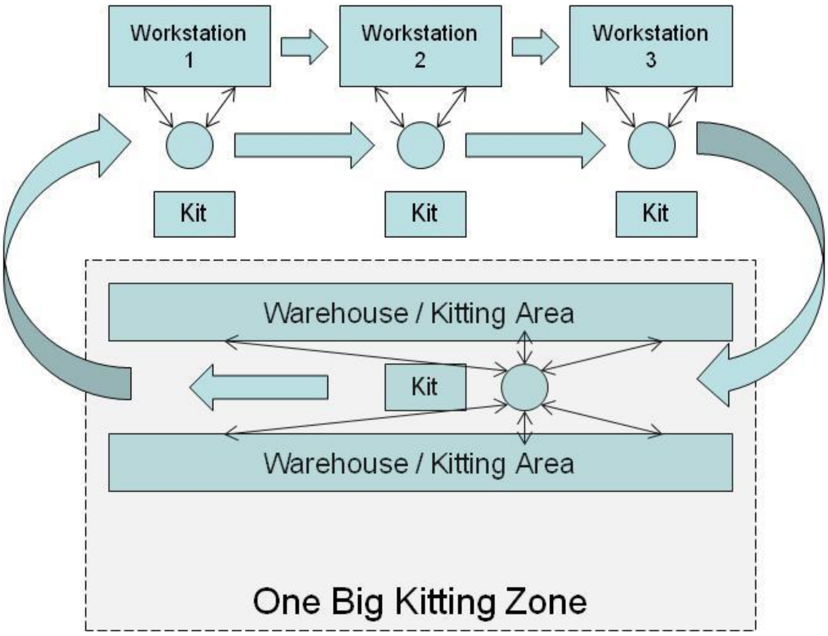


Figure 3.3.1.b – Centralized kitting preparation area + travelling kitts (own scheme)

As already described / shown in the centralized/decentralized kitting preparation area (see the figure 3.3.1.a), the kitt preparation / picking activity is performed within one picking tour. A detail in combination with travelling kitts is shown in the figure 3.3.1.b. The other opportunity would be to divide the unique market place area into several zones and process the kitt preparation step by step flowing the kitt through all of the zones to finalize the kitt. This is called progressive zoning and is shown in the figure 3.3.1.c bellow:

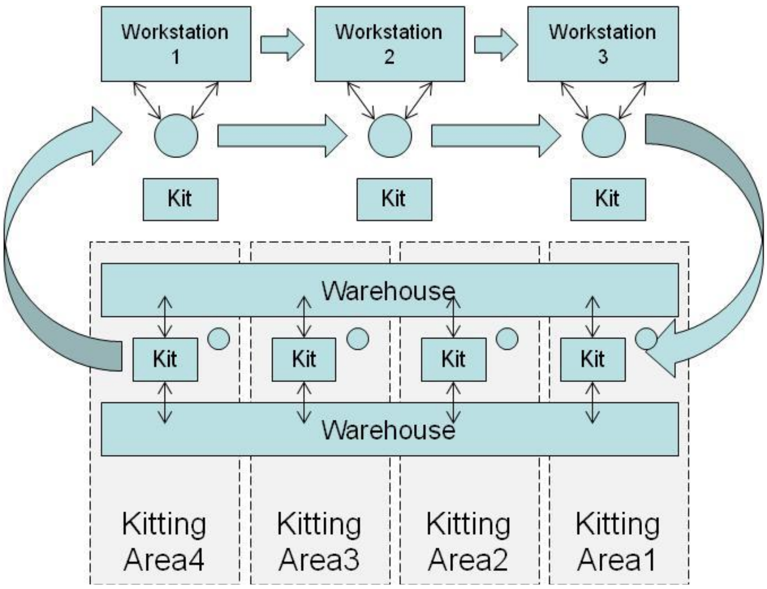


Figure 3.3.1.c – Zone picking, Alt.1 (own scheme)

In the following figure is shown an example of synchronized zoning, where all the zones deliver the requested parts for one kitt contemporarily – see bellow.

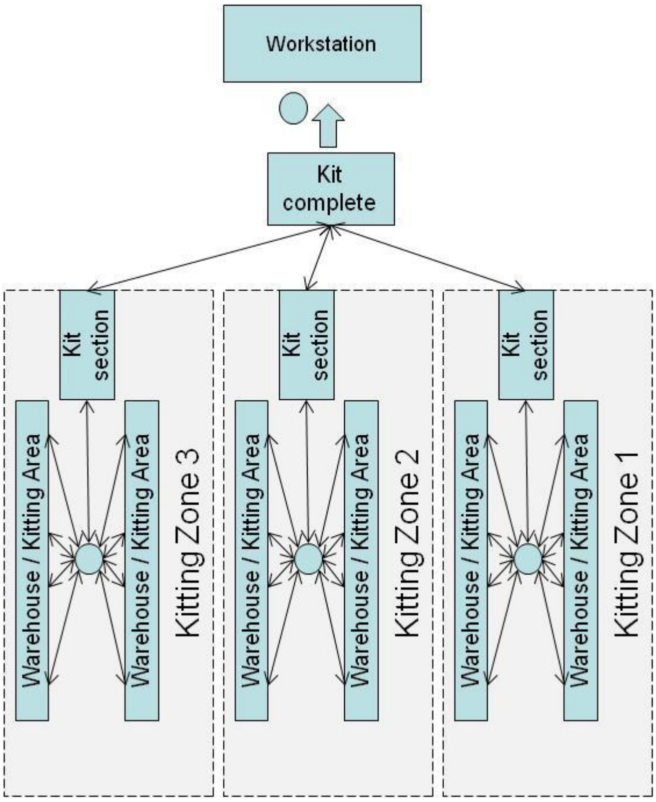


Figure 3.3.1.d – Zone picking, Alt.2 (own scheme)

3.3.2. Pro's & Con's of Kitting

Bellow listed is the most nominated selection of Kitting benefits in so far studied literature, as well as in own experience as Operations & Logistics Manager:

- Restriction of operator downtimes (walking, searching, picking, etc.)
- Saving of production space in Operations
  - Logistics space ratio of 1,55~1,8 (roughly 25,5% improvement to TPPM)
- Improved WIP control at POU
- Flexibility increase
- Improved shopfloor handling (kitt have multiple components instead of moving singular containers at line-side)
- Improved control and visual aspect on the shopfloor
- Improved quality, by better operator knowledge and immediate control
- Improved training process of new staff

…on the other hand, in case of wrong process management, the benefits can turn to disadvantage. Just imagine the case of missing or incorrect parts – this can result in quality issues. Bellow listed are the main disadvantages:

- Re-packaging, or kitt preparation means time and capacity waste

- Stock increase in case of anticipated preparation
- Defect parts in kitt may cause shortage of part on the line
- Additional scheduling necessary if kitts preparation anticipated
- Incomplete kitt causes downtimes (lead time/WIP/quality/productivity/etc.)

3.3.3. Conclusions

Based on the before mentioned facts, some conclusions can be done for KPPM. First of all we can affirm that KPP is in contrast to TPPM a non-forklift driven method, what means that there is a substantial reduction of safety risks in operations areas. As already stated before, forklifts are generally considered to be one of the biggest safety risks as they're can harm people as well as the work cells and equipment. Secondly, kitting is considered to be a method by which application we can obtain a significant reduction of logistics spaces necessary in operations. This is one of the most significant advantages indeed. By these means the replenishment schedule must be created to obtain a regular delivery at dedicated POU and so to have only a very limited amount of parts at the POU. Additionally, every kitt is exactly placed at the cell to be reachable within arm's reach of the operator serving the work cell. All this eliminates the potential waste created by the operator at the POU and so the overall downtime / throughput of the line will be improved.

Based on the before stated advantages and disadvantages a general conclusion can be done, that KPPM is generally very convenient method in comparison to the TPPM – nevertheless the re-packaging activity must be performed additionally. This activity could be taken as a balance activity for the handling personnel in the warehouse and so the manning increase could be reduced to minimum. Furthermore, kitting can be considered as an efficient solution for parts which can't be packaged in the original process into racks/totes/kitts desired at the POU and need therefore to be re-packaged. For this purpose, we use in Tower Automotive. some of the Lean Six Sigma methods (Standard Work, time & costs study, work balance opportunities, etc.) to analyze if the process of final packaging for the POU operation should be performed as part of the original process or as additional process in the warehouse.

3.4. Gravity Flow Rack Part Presentation Method (GFRPPM)

Last, but not least I'll try to go more in detail of the GFRPPM in this session. As already mentioned before, gravity flow racks & tote boxes are considered to be the base for the lean part presentation at the POU. Tote box (called "Tote") stands for a small plastic box with a limited amount of parts. To eliminate the inconvenience of the kitting method which stands in the need of re-packaging activity, in the GFRPPM is this task delegated down to the supplier of the component/part number necessary on the specific POU/work cell. By this meaning there's no waste created in the operations as well as logistics processes. The combination of Totes & Flow racks is probably the leanest way how to present parts in production, under the assumption that the tote boxes are filled with purchased / WIP parts directly at the place of production.

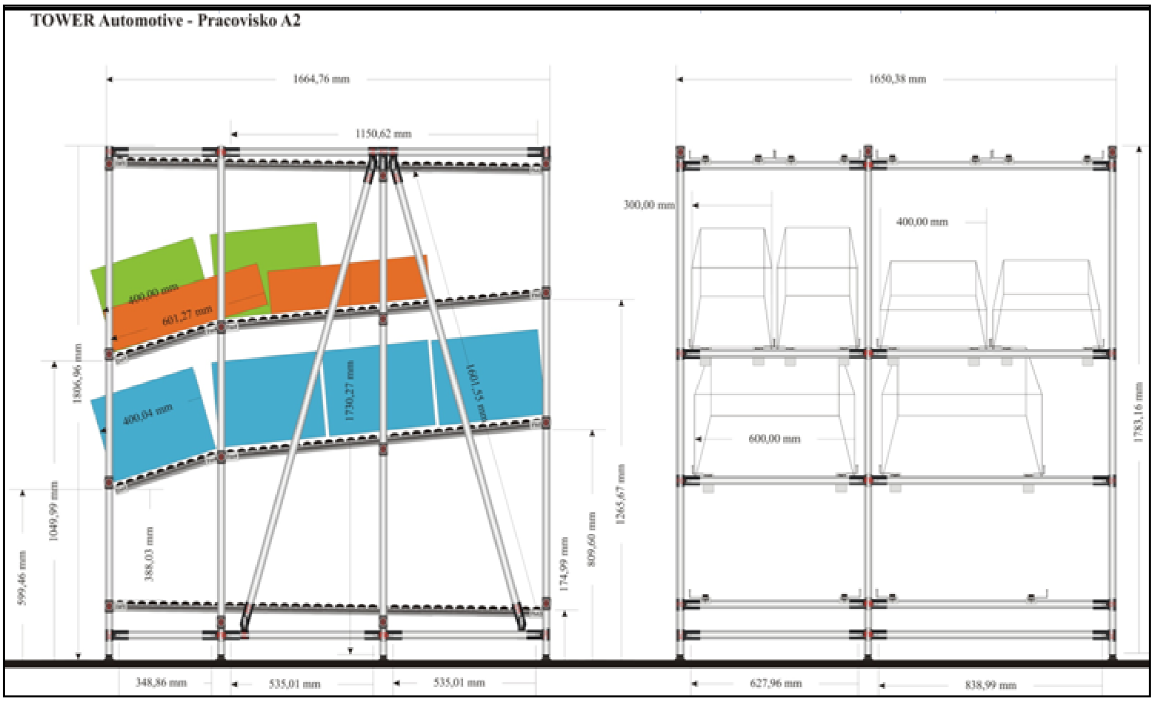


Figure 3.4.a - Gravity Flow Rack & Tote Boxes proposal for a specific work station (Tower Automotive, Slovakia)

This means there is no additional re-packaging needed to present the part. On the other hand, the need to produce parts in small plastic containers change the standard process of producing larger quantities of origin parts (stampings) into standard containers like GBX. There are several modes how to optimize the production process for small batches and frequent tote exchange – one of them is so called goat system. Gravity Flow racks stand for a specific purpose constructed rack at POU – in the production area.

There are dozens of construction methods to be used. I have experienced so called low cost flow racks having steel-welded construction, as well as sophisticated plastic or aluminum component based flow rack constructions. Generally there can be said, that both of them fulfill the lean expectations of the process, but only the component based (lego construction principle) method has the option to be re-assembled any time for some potential improvement optimization or in case of mid/long-term volume drops, these construction can be dismantled and the components can be used anywhere the need will rise or the volume will be shifted in.

Flow rack is fed with tote boxes to present the parts to the operator at the cell in the arm's reach. This means the flow racks must be installed into the work cell in the way that they make internal part of it – they must be as close as possible to the loading fixture itself. By this way the operator has really the advantage to get the parts at arm's reach and not to be obliged to waste his capacity by walking around. In this meaning we can use the full capacity of line operator for value-add activities and that's why in this case it becomes very important the balance in-between operator cycle time and machine cycle time in alignment with the customer requested tact time.

The basic principle of the GFRPPM is to deliver just the exact quantity necessary in order to guarantee continuous work of the work cell for an exact time period, based on the tact time of the cell. This means that everything on the POU is based on the tact time – dimension and capacity of the tote, dimension & capacity of the flow rack, schedule system of the route performed etc. Tact time is the driver of the decisions to be done on the cell and seeing the fact that the tact time is given by the customer itself, this confirms the previous mentioned statement that GFRPPM is from this point of view the leanest method to present the parts on the work cell.

To go more in detail, the tote dimension & capacity is selected from the point of view to fit as much parts as necessary for time to be covered on the line – time necessary for replenishment should be minimum double of the capacity delivered on one route plus a safety tote. The other limitation, since the flow racks are loaded by handling personnel by hand, is the maximum weight of the tote. In Slovakia the law is limiting the weight to be lifted by personnel to 15kg, in other EU countries it is even less. Given the tact time (and so the pieces consumed per hour), tote dimension alternatives and weight limitations, you can easily draw down different scenarios for 1, 2 or 3 hours line capacity and furthermore calculate the quantity of totes necessary as well as the dimension of the flow rack necessary. Seeing the fact, that you will need some CAPEX to invest, you can easily calculate the amount necessary. Based on my experience in Tower Automotive – Slovak plant, we base our capacity on the line to 1hour, what means in reality 1hour of material being prepared in the marketplace, 1hour being delivered / on the route to the POU and 1hour of material on the flow rack of the work cell itself.

From the perspective of handling activities, GFRPPM is a non-forklift driven method - usually performed by tugger trains. By this meaning, one of the biggest safety risks in every plant can be excluded from operations activities. What is crucial from this point of view is the scheduling accuracy, seeing the fact that there is always just a limited capacity delivered to the POU. It is crucial to design properly the composition / list of materials to be delivered to specific workstation as well as the driving routes, where several workstation deliveries can be combined into. Every delivery route must have defined stops (POU delivery points) for every part number as well as the precise time and materials delivered. The tugger trains are usually filled in marketplace areas, where the same principles shown in the KPPM are used to gather the material and prepare the delivery. Every tugger can pull several chassis / special flow rack carts to deliver parts to several POU points within one delivery route. It is of importance to limit the number of tugger train stops and try to combine one stop with several delivery points. This means that the tugger train should stop in an area wherefrom several work cell stations can be assisted. By this way time saving can be obtained. Tugger train operator takes the specific tote from the cart and loads it into the exact position of the flow rack. He is not allowed to enter the cell and disturb the work cell operator – there's no need for seeing the fact the flow rack loading position is situated on the outside of the cell, since the loading position on the inner side – as close as possible to the loading fixture. On his way back to the cart, he picks up an empty tote from the flow rack and loads it on the cart. This is the optimal way how to use the capacity of both of the operators efficiently.

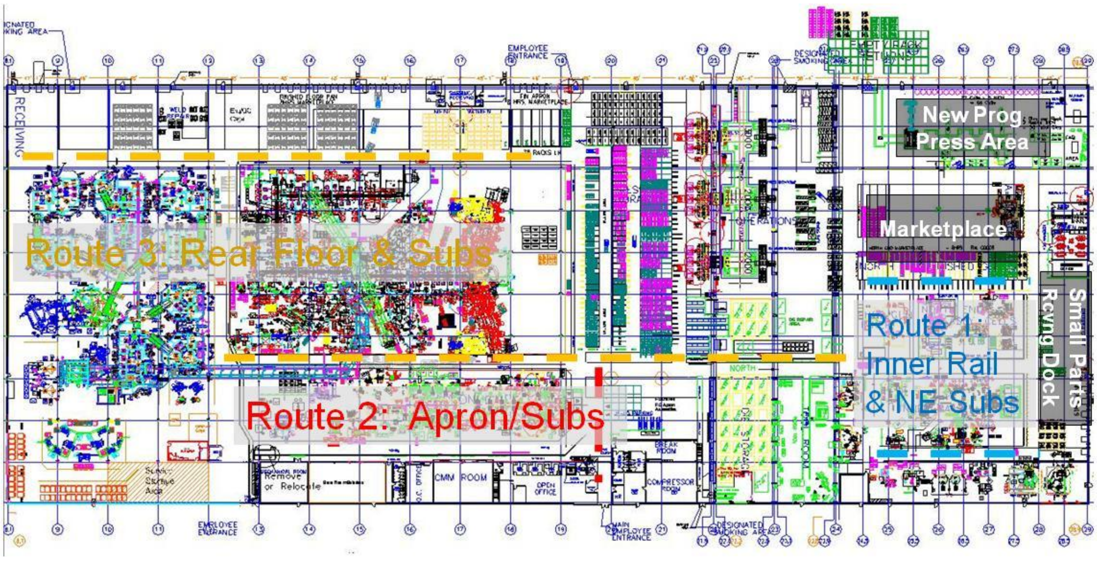


Figure 3.4.b – Route layout example (Tower Automotive, Slovakia)

It is very often used that the flow rack systems are installed also in the marketplace shelf systems to facilitate the tugger train delivery preparation. Components are delivered in totes directly from supplier, wrapped on standard Euro Pallet and stored in warehouse or on upper shelf system positions as standard containers.

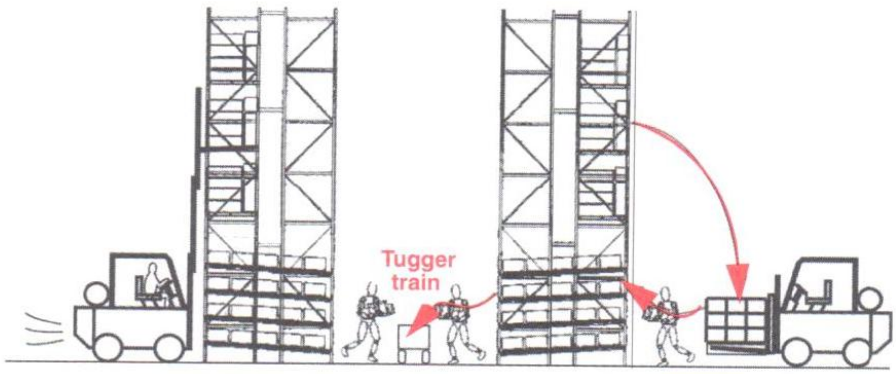


Figure 3.4.c – Loading vs. un-loading logistic activities simulation (Baudin 2004: 117)

On the lower – flow rack positions, singular totes are loaded from one side and unloaded from the other one directly on the tugger train delivery chassis/special rack. By this means, forklift manipulation is limited only into warehouse/ supermarket areas. Its task is mainly the loading/unloading of trucks and handling from/into warehouse position. The picture above shows the manipulation of forklifts in the warehouse in connection to the tugger train preparation process. You can easily recognize the loading aisle from outside to the inside, where the pick aisle is. By usage of this sytem you have perfect FIFO organization, where the parts are picked in sequence from left to right and top to bottom through the different levels and using a tag to mark the next pick up.

Based on the above said, we can obtain significant space savings in the operations area, where the materials delivered are loaded on flow racks installed inside into the work cell, and so using the space synergy of logistics/operations spaces needed. the aisles around the work cell for the handling activities / transportation can be reduced as well seeing the fact the forklift is substituted by tugger train. Overall, based on the calculations done in Operations of Tower Automotive we can speak about the logistics space ratio of approximately 1,2~1,3and in comparison to the TPPM or GFRPPM it demonstrates the maximum saving potential in meaning of CAPEX spending. Compared to the original TPPM with the ratio of 2,0~2,5, we speak about roughly 45% less space need for the implementation of a project.

Furthermore, based on the information mentioned before – weight limitation of the totes capacity, as well as parts at arm's reach and last but not least the adaptable construction of the flow rack itself, make this method very ergonomics friendly. There's no need for additional ergonomic devices as in TPPM (container lifters, lift tables, container tilters, pallet palls etc.).

Last but not least, we should mention the replenishment signal potential methods. Seeing the fact that we speak about progressive, lean methods, I'll not mention the push methods. GFRPPM is very well combined with different pull signals, as the following:

- Empty containers
  - in case there is an unique type of container per each P/N
  - in case the storage area of that particular P/N is within sight from the POU
- Andon signals
  - Material pulled on as needed basis
  - Create variable intervals with fixed quantity replenishment
- Kanban
  - Create fixed intervals with variable quantity replenishment
  - …see details in previous sessions

3.4.1. Pro's & Con's of Gravity Flow Racks & Tote boxes

Bellow listed is the most nominated selection of benefits in so far studied literature, as well as in own experience as Operations & Logistics Manager:

- Restriction of operator downtimes (walking, searching, picking, etc.)
- Saving of production space in Operations and Logistics areas
  - Logistics space ratio of 1,2~1,3 (roughly 45% improvement to TPPM)
- Improved WIP control at POU
- Flexibility increase
- Improved shop-floor handling
- Improved control and visual aspect on the shopfloor
- Improved quality, by better operator knowledge and immediate control
- Improved training process of new staff
- Substantial reduction of Inventory levels

Bellow listed are the main disadvantages:

- CAPEX necessary (change of containers into totes + flow racks)
- Change of cell layout necessary – safety/cycle time issues to be solved

3.4.2. Conclusions

Based on prior statements, there can be done some conclusions for GFRPPM. First, GFRPPM is in contrast to TPPM a non-forklift driven method. All the benefits out of that have been already stated before. Secondly, with the use of gravity flow racks as well as with kittings significant space reductions in logistics as well as in operation areas can be obtained. In the meaning, where the gravity flow racks are installed directly in the inside of the work cell, the space benefit can be even higher. The parts / components necessary at the POU are delivered in totes in exact quantities which cover designed time period on the cell working. That's why it is of crucial importance to develop a sophisticated replenishment schedule to obtain a regular delivery at dedicated POU and so to assure the full benefit of the system as well as a full capacity usage of the operator on the work cell. By these means, a very high level of OEE (Overall Equipment Efficiency) can be obtained – based on the experience out of Tower Int. plants we target up to 95% OEE, where the only downtime allowed is that one foreseen for the equipment maintenance. Having the flow rack installed within the cells, the operator can fully use the synergy and have the parts at arm's reach. All this creates a very favourable situation at the work cell, where almost all potential wastes created by the operator at the POU are eliminated and so the overall downtime / throughput of the line can be significantly be improved.

Seeing the advantages and disadvantages we can generally affirm that GFRPPM is the most convenient method in comparison to KPPM, TPPM – nevertheless it is probably the most capex intensive. This statement is only true in case where the change of PPM is performed as so the initial costs are relatively high. If this method would be planned and implemented in early project phases, there wouldn't be the need for a change and thus any need for double or additional spending. Additionally, it must be clearly stated, that this method brings the best performance as well as the highest impact on the downtime reduction overall. Furthermore, totes and gravity flow racks can't be considered as an efficient solution for every part/component type and every implementation. For this purpose, we use in Tower Automotive some of the Lean Six Sigma methods (Standard Work, time & costs study, work balance opportunities, etc.) to analyze the best method to be implemented seeing the limitations of the original process, of the component itself as well as of the work cell station.

3.5. Decision vs. Timing in Part Presentation implementation

As already mentioned previously, the work center / production line itself is influenced by several decisions which have to be taken in specific time period of production line establishment. I will focus more in detail on decisions which have inter-connection with Part Presentation.

Different Part Presentation Methods have been described in previous sessions. It is obvious that the impact shown will be in following fields:

- Space on production shop-floor
- Productivity & Flexibility of the line
- Inventory level
- Warehouse spaces
- Quality
- Handling on the Line + in-between Storage/Line
- Learning / Training process

Crucial in the decision making is the timing for the decision about the Part Presentation Method since the impact range is very wide. Out of my experience with Tier1 suppliers, this decision often comes too late and so the costs of this decision are going to be multiplied. This particular case happens very often in brown field implementations, where the original part presentation method derives out of historical implementations, generally influenced by the mass production methods. In this case the most used part presentation method is the traditional one, characterized by big steel containers with maximum load for the efficient usage of big lot sizes. The moment where the company recognizes the necessity for part presentation change to obtain more flexibility with smaller production batches, smaller container amounts and efficiency in logistics and following operation processes, is crucial for the company's results in future, since this decision will influence both CAPEX spending and profitability of the company. That's why the decision making should follow a proper analyze part by part, so that every part is evaluated by its potential to be presented ideally by totes in gravity flow racks, by kitts or by traditional meaning in steel containers with higher capacity. It's important to understand that en investment into un-proper PPM, for example an upgrade of TPPM into KPPM of an part, nevertheless it has potential to be presented by meaning of GFRPPM, will bring just an partial success with relatively high cost spending as it would happen if the decision making would be properly done for the GFRPPM immediately. The spending would be done only once and the valued-add effect would be the maximum.

Every mentioned impact field has direct connection to the CAPEX (Capital Expenditures) of the project / program as well as on the profitability of the business, since the impact on productivity affects directly the output of the line and so the profitability of the sales.

Which of the mentioned items are CAPEX related?

Space, nevertheless if it is in production or in logistics, needs capital spending to be built up and time needed for construction. Time and money are the most important assets every project manager needs to master, since there is very little time and limited or better to say budgeted cost spending. Let's take into consideration an already established Tier1 supplier who was nominated for a new OEM program. The evaluation of the CAPEX necessary has been already performed in the offering phase – the problem is that usually the evaluation is under the real needs, to be able to compete the business. There is a collision of two different motivations – OEM vs. Tier1 Supplier. This input is very sensitive for the final evaluation of the offer and that's why the need for additional CAPEX / additional spaces must be evaluated very carefully. And here come questions like following: …which part presentation method will be used for the project? What level of inventory do we plan? What handling equipment or solution will be implemented? Etc. all these questions need to be evaluated and decided before the real implementation starts. If it is the other way round, there will be a serious risk to have a negative impact on the CAPEX spending as well as on the profitability. Postponing the decision for the later phases of the project implementation has been proven as non-wise decision, since every change in the work cell layout which comes after cell supplier nomination, brings additional non-budgeted changes which generate additional expenditures.

Handling itself is also a CAPEX related decision, since it affects the acquisition decision for a forklift or non-forklift driven environment in the plant. Every solution requires different technology equipment as well as different space definitions for aisles in warehouse as well as in operation areas, etc. This decision goes hand in hand with part presentation method decision, since every type of PPM has different requirements / predispositions for the handling equipment.

In the Business Case Study chapter, details from real-life implementation will be listed with calculations which will show cost vs. saving opportunities.

4. Business Case Study Analysis – Tower Automotive, plant Malacky – Slovakia

Based on previous findings out of literature and benchmark analyses in the automotive sector, Tower Automotive decided in 2008-2010 to launch globally throughout all plants in Europe a Lean Part Presentation Project to optimize part presentation conditions in singular plants. Up to this moment, every plant has been proceeding in a relatively independent way, taking actions locally, mostly based on the local management driving force and local logistics manager skills and experiences. This approach led to quite big differences in strategy application in different locations and so the compatibility and synergies of the various implementations could not be obtained.

Tower Automotive, plant Malacky has been is a brown-field plant overtaken by Tower Automotive in 2001. Since then, the plant environment has changed dramatically. All commonly known processes & procedures have been applied and the plant has been brought step by step to a global Tower benchmark. Traditional one-direction "Top – Bottom" communication has been changed into bi-directional and the needs of the operator at the point of use have been understood as a key stone to achieve better / improved results.

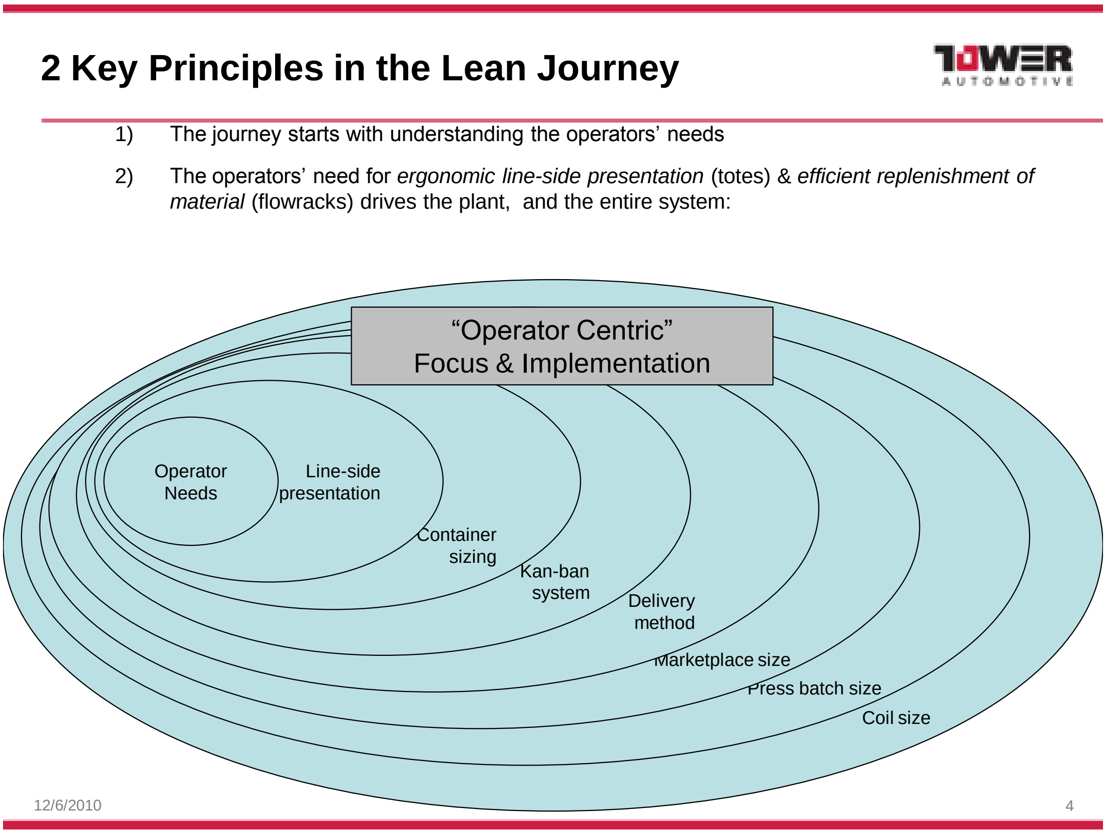


Figure 4.a. –Tower Automotive key principles in Lean journey (Tower Automotive)

From the part presentation point of view, the Malacky plant has been originally possessing the traditional part presentation method, which characteristics and pro's/con's have been described and explained previously. This method has been accompanied by higher production size lots of production and consequently by higher inventory levels in the whole plant. The production areas in assembly have been projected with higher space ratio for the logistics driven areas in production as well as in the inbound & outbound logistics and warehouses. The commonly accepted ratio has been in-between 2,0 and 2,5 – what means that every square meter of production area has been accompanied by 2,0 – 2,5 square meters of logistic areas in production. Imagine a new production program which needs 3.000sqm of production / assembly area. Calculating costs are 570€/sqm as a total expenditure for construction of 1sqm of production area, all inclusive. The calculation brings us to 1,710k€ CAPEX netto investment into production area. Considering the standard logistics ratio for TPPM of 2,25 (average of previously mentioned data), we come to an investment of 3,847k€!

As previously mentioned, the higher production lot sizes led to higher inventory levels in the warehouses. The commonly achieved level of inbound logistics has been in the range of 10 – 13DOH. DOH – Days on hand – means the actual daily inventory level (Raw/Purch/Wip/FG – singularly or common) divided by the daily COGS (Cost of goods sold). These numbers are reported daily as well as one overall monthly result. Outbound logistics has been achieving the level of approximately 4 – 5DOH. The WIP in production, based on the higher lot sizes, bigger containers for part presentation and lack of implementation of progressive methods as SMED, 5S, Standardized Work etc. as well has led to quite high inventory levels in the range of 6 – 10DOH. Summarized to a total number, the DOH performance with the implementation of standard part presentation has been in-between of 20 – 28DOH. Now imagine, the standard COGS in that period has been approximately 160k€, so the calculation is very simple: 160k€ x 28DOH = 4.480k€ as a daily amount in the warehouses of plant Malacky. The level of DOH and consequently of Cash bounded in the inventory has a tremendous impact on the plant as well as on the Tower group level. To make this more understandable, consider that this money is bounded in warehouse inventory and can't bring any additional value – it doesn't earn anything.

On the other hand, we can easily calculate the cost of this amount of money, which Tower Automotive would have to borrow on the market if it would not be able to fulfill its liabilities. Let's consider an interest rate of 7% p.a. as an actual standard rate on the market. Considering the calculated inventory level of 4.480k€ and the above mentioned interest rate, we target ~26k€ p.m. and totally 313k€ p.a. as interest to keep the mentioned inventory level. Furthermore, there is an alternative view on the cost of capital bounded in the inventory. The Cash bounded should be considered and evaluated as a lost investment opportunity. For this purpose Tower Intl. uses simple the IRR (Internal rate of return) expectation which equals 25%. In very simple words, every € invested is expected to bring 1,25€ back.

Summarizing the above said, the level of inventory achieved with TPPM would be a "verdict of death" in the crisis period as we have been through in 2008 - 2009, where the statement "The Cash is King, again…" has been confirmed widely, because many of companies have suffered the lack of Cash and so did have to fill for insolvency… and many other bankrupted.

On the chart bellow there is a simulation on finance figures represented by a new program in a Tier1 environment. First message out of the chart is clear: …the financial expectations in-between OEM and Tier1 supplier are contradictory. Imagine a Tier1 supplier stepping in a program with an OEM – the budgeted EBITDA expectations of Tier1 are of min. 8% per year based on 6year lifetime. On the other hand, the OEM expects so called LTA's (Long term agreements), or better givebacks out of sales – let's take into consideration 5% per year in 4yearly payments in-between 2011 – 2014. These two expectations are completely contradictory as the OEM's expectation influences the original EBITDA expectation of Tier1 and so the Tier1 must immediately after being awarded by a OEM business start to work hard on other saving potentials which could balance the 5% per year loss. And here it is the topic of lean environment implementations, like lean part presentation methods etc. based on the simulation bellow, the supplier needs to find opportunities of 5% in the first production year, then 4% in 2012, 4% in 2013, 3% in 2014 and last but not least 2% in the last year of the program lifetime. In this matter, the total givebacks would reach 20% on the sales, since the operational savings only 18%. The average profitability of such project would be in the level of 6% EBITDA.

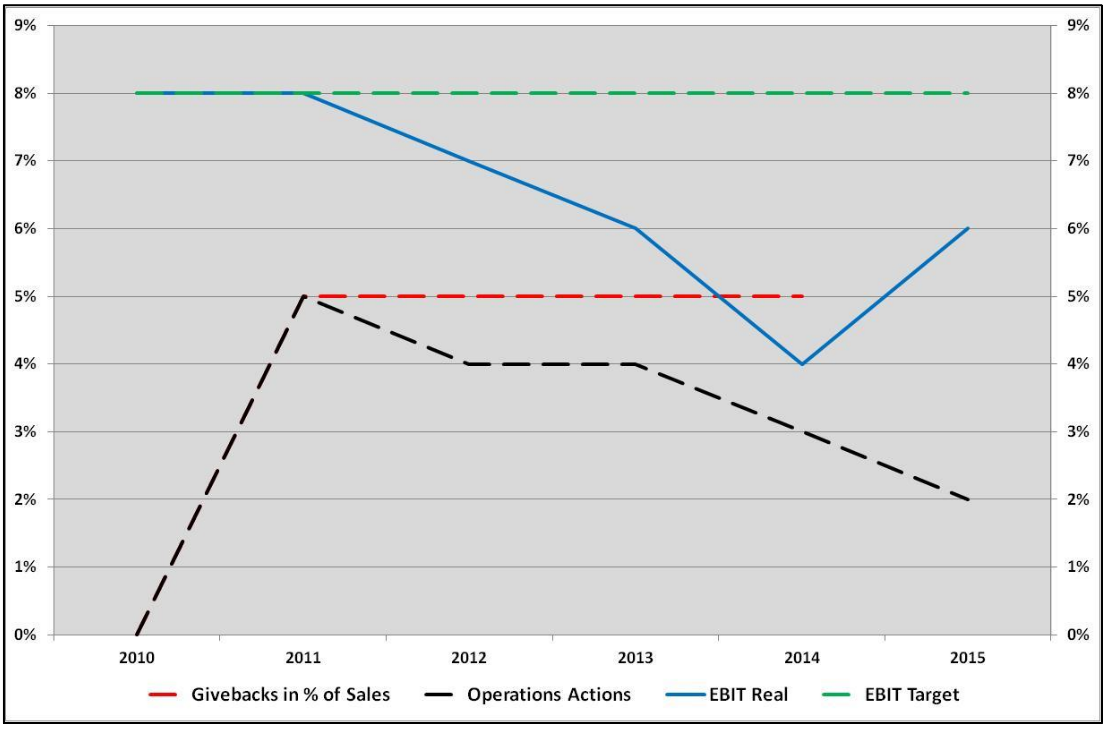


Figure 4.b – Givebacks vs. Savings necessary to achieve the targeted / real EBIT (own scheme)

As already mentioned before - in the following period up to 2006-2007, every plant has been proceeding in a relatively independent way, taking actions locally, mostly based on the local management driving force and local logistics manager skills and experiences. This period can be generally described as kitting oriented period, because the main focus has been given exactly to the change of traditional part presentation into the kitting part presentation, where possible. The driving force behind – inventory level and its impact on company financials – started to push on improvements. Seeing the fact, that this approach has not been coordinated as a global project, the approach led to quite big differences in strategy application in different locations and so the compatibility and synergies of the various implementations could not be obtained. The plant Malacky started to implement the kitting presentation method with the new program coming from Volkswagen. The implementation of the method has been extended to all assembly cells of the program, however the full benefit could not be achieved since the stamping division didn't move on in this direction and so the kitts were prepared in the logistics / warehouse areas of the plant, not at the place of production - no kitting preparation directly in the stamping area has been implemented, or by the external supplier himself. By this meaning the negative impact of the kitting part presentation method has been proved in full impact and the benefits on the assembly side has been counterbalanced by the handicap in logistics, where additional personnel had to be applied. On the other hand, the positive of effective production space usage has been obtained, since the big containers standing several days in production area have been changed to kitts with just several hours of production content. Furthermore, the dimensions of large containers and the variety necessary in comparison with the dimension of a kitt composed of the whole variety needed – this all contributed to a significant reduction of space necessary, not only in production area, but in logistics as well. Let’s consider the same example used above. …a new production program which needs 3.000sqm of production / assembly area. Calculating costs are 570€/sqm as a total expenditure for construction of 1sqm of production area, all inclusive. The calculation brings us to 1,710k€ CAPEX netto investment into production area. Considering the standard logistics ratio for KPPM of 1,675 (average of previously mentioned data), we come to an investment of 2,864k€! In comparison to the TPPM and all the remaining condition unchanged, we can speak about a saving of 0,982k€ - almost one million €! Of course, we need to consider some increased costs for kitts establishment, but according to Tower Automotive experience, all the expenditures did have less than one year payback period and thus considered as very competitive.

By this meaning the focus on the inventory has been shifted from production + logistics areas to logistics only. Much better overview of actual levels has been achieved and so a downturn could be applied. Tower plant Malacky has achieved in this period an overall DOH performance at the level of 17 – 20. Now imagine, the same conditions as mentioned in the TPPM application example - standard COGS level of approximately 160k€, and thus: 160k€ x 20DOH = 3.200k€ as a daily inventory level / Cash bounded in the warehouses of Malacky plant. Considering the same interest rates as in the previous example of 7% p.a. and the difference of inventory level obtained by the implementation KPPM of 1.280k€, we can state that the company didn’t have to borrow the Cash on the market and saved by this ~90k€ as an interest p.a. On the other hand, the calculation of alternative investment opportunity shows us, that not having the capital blocked in the inventory the company could have invested this money into an opportunity on the market with an expected IRR of 25% and so with a gain of ~320k€ p.a.!!! The achieved improvement with the KPPM has been significant, but the big jump had just to come with the implementation of the GFRPPM us…

In the period started in early 2008, Tower Automotive launched a global project focused on the operations & logistics improvements in all plants. Its main target has been to achieve the single digit days on hand performance. The immediate change to the previous implementations has been in the broader focus on all parts of the operations – assembly, press shop and logistics overall. The main push element has been the gravity flow rack & totes part presentation implementation in all suitable locations.

As explained in previous session dealing with GFRPPM in detail, the main advantage in comparison to the KPPM is the elimination of the repackaging necessity, since the tote filling is taking place in the previous production process – generally in press shop in-house or by the external supplier. The totes are delivered directly to the POU by the tugger train and are loaded by the tugger train personnel into cell flow racks, so that the cell operator doesn’t have to limit his dedication to the value adding activities at all. In the bellow shown calculation sheet there are detailed data for calculating the benefit of the GFRPPM implementation in comparison with the TPPM applied previously. In case of TPPM, forklifts and all connected processes have been evaluated. On the other hand, tugger trains have been evaluated for the GFRPPM. The detail shows that there are following significant saving potentials:

- Cost of equipment
- Quantity of movements per day
- Personnel costs
- Time necessary for manipulation

KLT part presentation		Containers part presentation	
cars/day	580		580
klt/flow rack cart	25	Paleta/VZV	1
vozikov na KLT/vlacik	1		
vozikov na palety/vlacik	2		
Paliet (EGB, 7xxx, atd/den)	25,8	Paliet/den	94
KLT/den	368	dielov za den	29000
Priemerna trasa (m) E-> stock	195	Priemerna trasa (m) E-> stock	195
Speed (m/s)	2	Speed (m/s)	2
Naklady na tahac €/h	10	Naklady na tahac €/h	10
Prac dni/rok	250	Prac dni/rok	250
Prekladanie 1 KLT (sec)	5	Cas prebalovania 5 ks dielov (sec)	10
Pocet prekladani (sklad->vozik, vozik->regal + to iste p	4	Prebalovanie (pocet dielov naraz)	5
Naklady na prebalovaca €/h	5	Naklady na prebalovaca €/h	5
Prekladanie/nakladanie 1 palety (sec)	20	Manipulacia s paletou za (sec)	20
Pocet prekladani za cyklus (sklad->vozik, vozik->regal	4	Pocet manipulacii za cyklus (nakl., vykl, + prazdn	4

Potrebny logisticky cas na dopravu KLT (h/den)	0,80		
Naklady doprava KLT/rok (€)	**1 993**		
Potrebny logisticky cas na dopravu palety (h/den)	0,70	Potrebny logisticky cas na dopravu palety (h/de	5,09
Naklady doprava palety/rok (€)	**1 747**	**Naklady doprava/rok (€)**	**12 729**
Potrebny cas na prekladanie KLT za den (sec)	7 360	Potrebny cas na prekladanie dielov za den (sec)	58000
Naklady na rucnu manipulaciu s KLT/rok (€)	**5 111**	**Naklady na rucnu manipulaciu s dielmi/rok (€)**	**20 139**
Potrebny cas na nakladanie paliet za den (sec)	2064	Cas potrebny na manipul s paletami (sec)	7520
Naklady na rucnu manipulaciu s paletami/rok (€)	**1 433**	**Naklady na manipulaciu s paletami/rok (€)**	**5 222**
Manipulacne naklady total/pa	**10 285**	**Manipulacne naklady total/pa**	**38 090**

Cell E potentional saving by using of KLT (€/year)	27 806

Figure 4.c - Saving calculation sheet for an assembly cell in Tower Automotive, Malacky plant (own calculation sheet)

Estimated logistics saving per year on the mentioned cell targets approx. 28k€ with an investment necessity for the GFRPPM implementation and equipment in the amount of 19k€ - this means that the payback period is significantly under the 1year level and so has green light for the realization. Considering the project lifetime of 6years we speak about netto saving of ~148k€. In this calculation I have taken into consideration only one work cell out of the project – summarizing the whole one we come to a lifetime saving far exceeding 1mil€ …

Going more in operational details, the throughput of the cell can be significantly improved and so the OEE performance of the cell can be driven up to the maximum levels, assigned by the technological limits of the cell given by the cell constructor. Taking into consideration the experience of Tower Intl. the standard welding cell equipment is targeted to OEE=90%, where 5% is dedicated to standard maintenance of that equipment and 5% to some operational inefficiencies. By the proper implementation and usage of GFRPPM, these 5% can be eliminated almost completely. Taking into consideration 7,5hours shifts in a 3shift/5days working environment and 250working days per year, we are speaking about 16.875min what

means 37,5 full shifts a year! Taking into consideration 47x operating personnel with an yearly wage of 14,4k€ - we can simply calculate the potential saving on personal costs of about 34k€/year, or ~200k€ in the program lifetime period.
Furthermore, we can calculate the saving on space cost obtained by a significant reduction of space necessary, not only in production area, but in logistics as well. Let's consider the same example used above in TPPM & KPPM. …a new production program which needs 3.000sqm of production / assembly area. Calculating costs are 570€/sqm as a total expenditure for construction of 1sqm of production area, all inclusive. The calculation brings us to 1,710k€ CAPEX netto investment into production area. Considering the standard logistics ratio for GFRPPM of 1,25 (average of previously mentioned data 1,2~1,3), we come to an investment of 2.137k€! In comparison to the TPPM and all the remaining condition unchanged, we can speak about a saving of 1.710k€! Of course, we need to consider some increased costs for gravity flow racks establishment and totes purchase, but according to Tower Intl. experience, all the expenditures did have less than one year payback period and thus considered as very competitive.

By the meaning of GFRPPM implementation Tower Automotive, plant Malacky has achieved in an overall DOH performance at the level of 10 – 12. Now imagine, the same conditions as mentioned in the TPPM application example - standard COGS level of approximately 160k€, and thus: 160k€ x 12DOH = 1.920k€ as a daily inventory level / Cash bounded in the warehouses of Malacky plant. Considering the same interest rates as in the previous example of 7% p.a. and the difference of inventory level obtained by the implementation KPPM of 2.560k€, we can state that the company didn't have to borrow the Cash on the market and saved by this ~179k€ as an interest p.a. On the other hand, the calculation of alternative investment opportunity shows us, that not having the capital blocked in the inventory the company could have invested this money into an opportunity on the market with an expected IRR of 25% and so with a gain of ~640k€ p.a.!!!

Summarizing the all above mentioned saving potentials, we obtain the following overview:

Nr.	Saving potential item	€/year	€/program lifetime
1.	logistics savings	196k€	1.176k€
2.	operations savings	34k€	200k€
3.	CAPEX	-	1.710k€
4.	inventory / DOH performance	179k€	1.074k€
	TOTAL	**693k€**	**4.160k€**

Figure 4.d - Summary of saving potentials by GFRPPM implementation in Tower Automotive, Malacky plant (own calculation sheet)

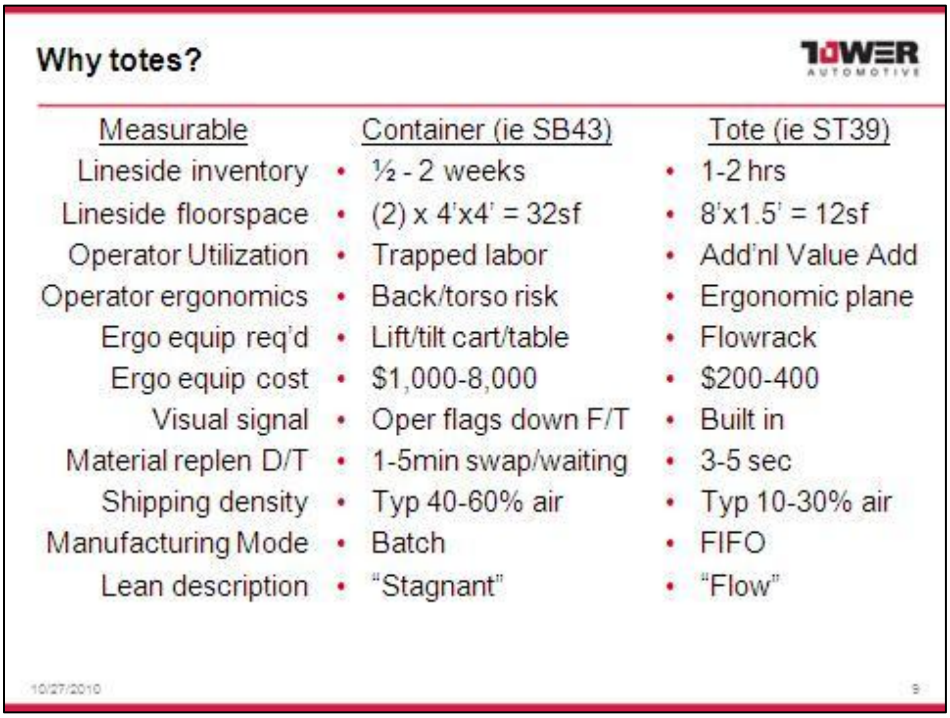
Taking into consideration the material spending necessary for GFRPPM, it can be confirmed that the project implementation has a tremendous saving potential in the logistics and operations processes. Coming back to the figure 5.b. – it's clear the contribution potential of such project to overall profitability of a plant in competitive automotive environment of Tier1 suppliers and OEM's.

Conclusions

Besides of conclusions done in previous chapters singularly for TPPM, KPPM and GFRPPM, there can be done some final comments and conclusions:

- There is no unique method which could fit all possible cases of implementation
- GRFPPM is one of the most efficient methods how to present parts in production environment
    - The main limitations for this method are dimension & weight of the part to be presented on one hand and the costs on the other
- KPPM is the second most efficient method for part presentation
    - The main limitation of this method is the necessity for repackaging and kitt preparation on one hand and the costs on the other
- TPPM is the traditional and less convenient method for part presentation as far for the throughput of the production, spaces necessary, logistics costs etc.
    - The main limitation for this method is the inefficiency hidden inside this method
- …there are several combinations present in every Tier1 plant because the implementation of unique method as rule could be of disadvantage.

Based on the above said, there is no discussion about which PPM is the most efficient one – the answer is quite simple GFRPPM.



Why totes?

Measurable	Container (ie SB43)	Tote (ie ST39)
Lineside inventory	½ - 2 weeks	1-2 hrs
Lineside floorspace	(2) x 4'x4' = 32sf	8'x1.5' = 12sf
Operator Utilization	Trapped labor	Add'nl Value Add
Operator ergonomics	Back/torso risk	Ergonomic plane
Ergo equip req'd	Lift/tilt cart/table	Flowrack
Ergo equip cost	$1,000-8,000	$200-400
Visual signal	Oper flags down F/T	Built in
Material replen D/T	1-5min swap/waiting	3-5 sec
Shipping density	Typ 40-60% air	Typ 10-30% air
Manufacturing Mode	Batch	FIFO
Lean description	"Stagnant"	"Flow"

Figure 5.a – Basic motivation behind GFRPPM implementation in Tower Automotive (Tower Automotive)

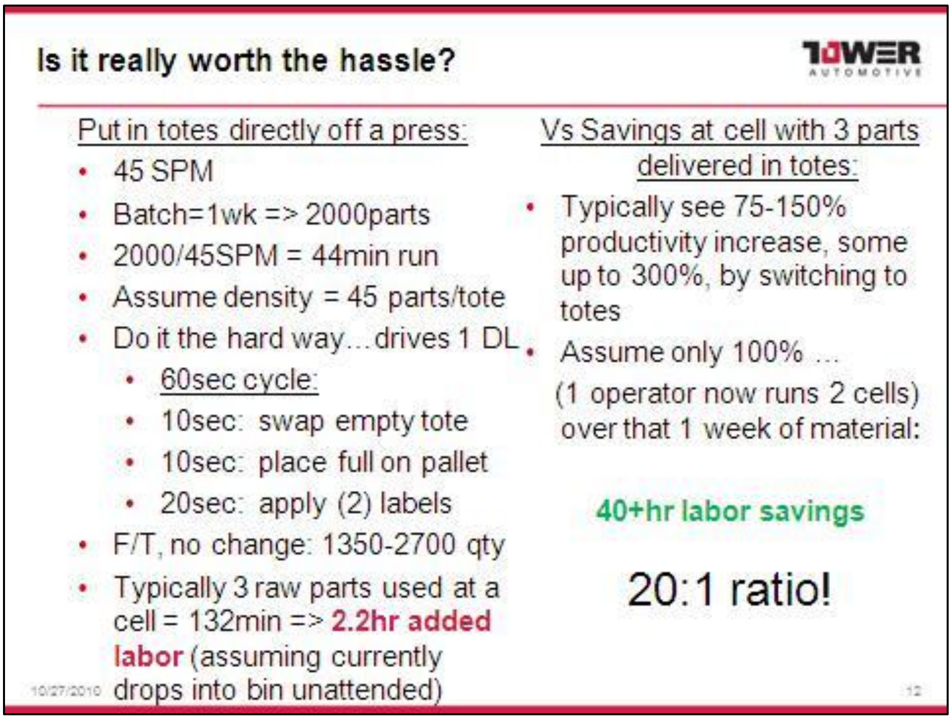


Figure 5.b – Basic motivation behind GFRPPM implementation in Tower Automotive (Tower Automotive)

The method hides in itself much more than just a presentation method – it drives the lean spirit through the whole system. If the method should be performed well, it forces the foregoing as well as the follow up processes to adapt to its basics and so influences the operations & logistics as the whole. So again, the question here isn't if the GFRPPM is the right method, but much more if the application or if the P/N is fitting the before mentioned limitations. To be able to answer the question, a deep dive analyze should take place before to give any solution. One of the tools to give a proper solution for a product, not only from the PPM point of view, but far more from the overall perspective (technology, personnel, automation, logistics, throughput, etc.) is the 3P Workshop.

It is of crucial importance for the product success that these kind of preparation meetings / workshops take place in the very early phase of the program. The main purpose behind is to be well prepared before the installation of equipment and the real post SOP volume make any change into suffering experience not only from OEM / Tier1 relationship point of view, but also from finance point of view. Every concept / PPM change in serie-working environment implies an additional cost spending into decisions done not properly before!

Based on my 6-years experience in Operations & Logistics environment in Tower Automotive, there is NO universal method for every type of application. That's why it is important to know the options and select the proper one based on the limitations and benefits of each one of them.

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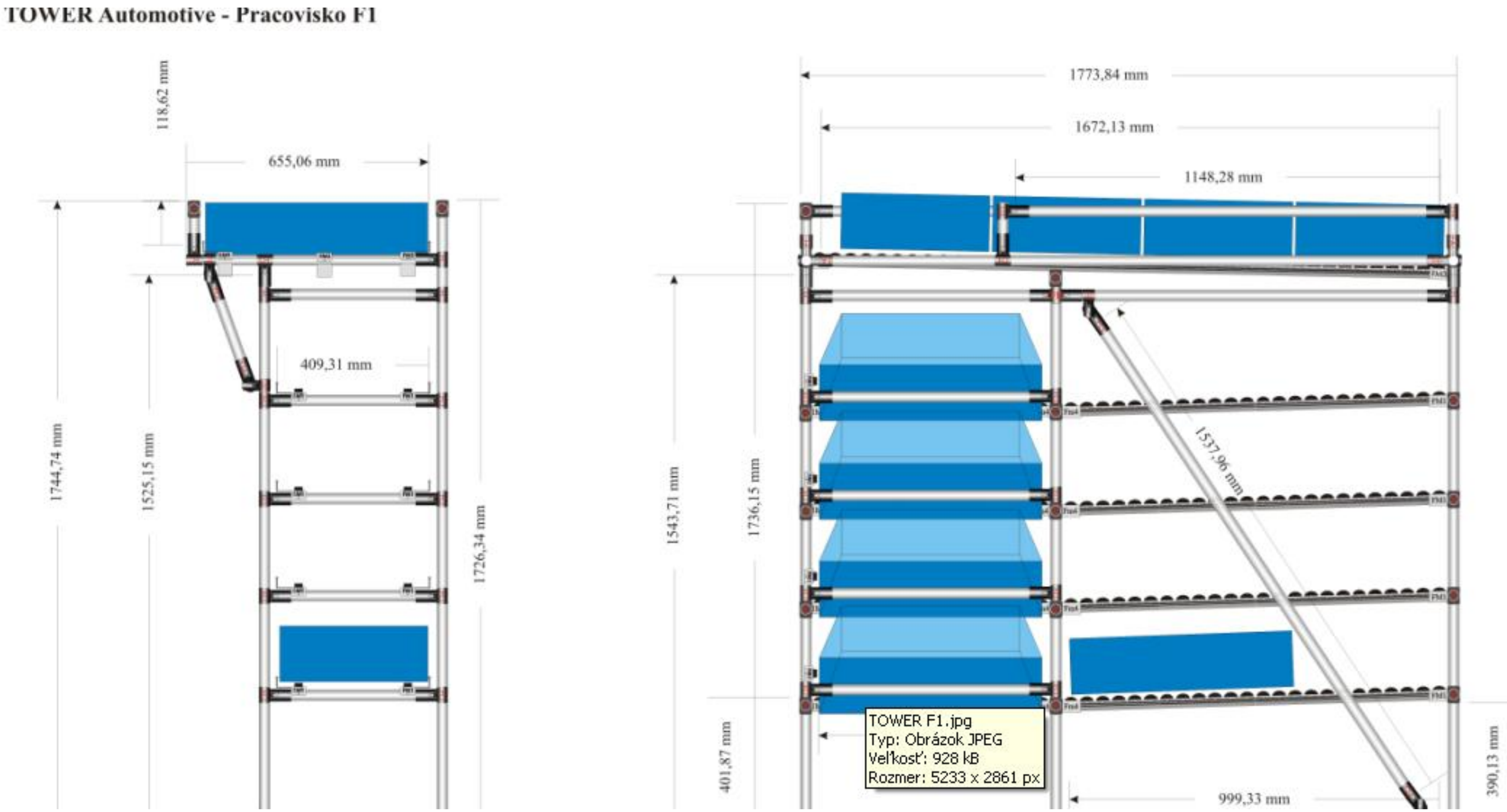
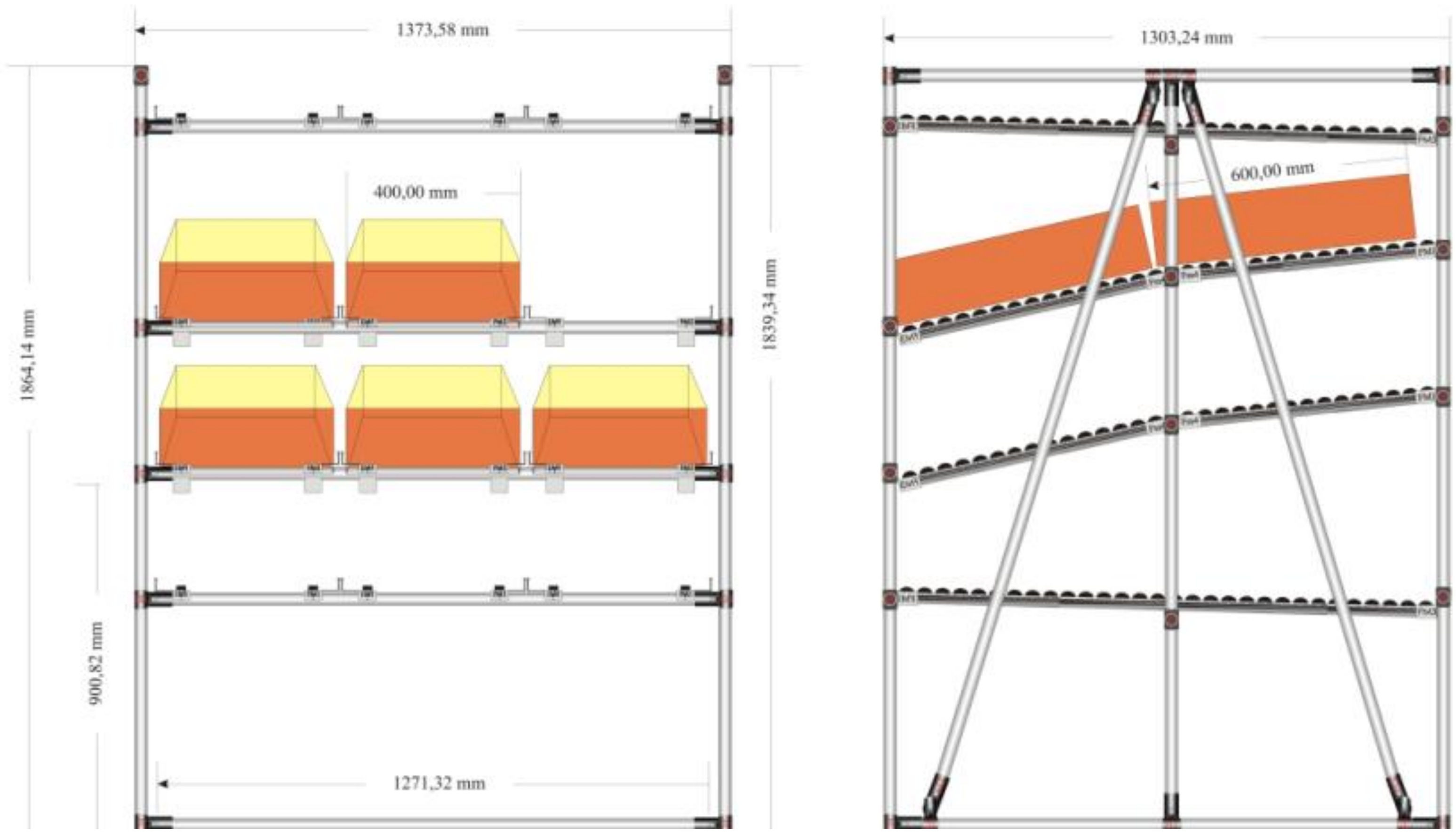
List of Appendixes:



Appendix A – Gravity Flow Rack simulation (Tower Automotive)

TOWER Automotive - Pracovisko F2



Appendix B – Gravity Flow Rack simulation (Tower Automotive)

Picture	P/N	RAD	P/N delivery type	Supplier	Cell Nr.	Side of shelf LEFT	Side of shelf RIGHT	P/N price	Weight	P/N usage in pcs	suggested pcs in tote	FG P/N	width	depth	height	max. pcs in tote (by weight)	Tote type	Tryout pcs	Type of KLT	width	depth	height	box weight	quantity in 1 KLT	0;1	1;2	2;3	3;4	4;5	5;6	6;7	7;8	Min. stock	Max. stock	Total weight full KLT
CLORADO NF														tote weight	1,5	max full weight	12																		
													P/N dimensions												TIME WINDOW										
	7L0804592	RAW	nákup	TAM	B1		X	0,19	0,058	1	27	7L0 804 592 A	34	26	92	181,0			4147					120	X				x				120	240	6,96
	7P0 611 841	[illegible]	[illegible]	Torino	E3	samostatne KLT vedla linky,umiestnene na pletive		0,1185	0,06	1	27	7P0 803 091	45	45	20	175,0			4147					60	X		x		x		x		60	120	3,6
	7P0 611 842	[illegible]	[illegible]	Torino	E3	samostatne KLT vedla linky,umiestnene na pletive		0,1856	0,06	1	27	7P0 803 092	45	45	20	175,0			4147					240	X								60	120	14,4
	7P0 802 143	RAW	nákup	opole	E3	X		0,59	0,393	1	27	7P0 803 091	204	223	60	26,7			6280					30	XX		XX		XX		XX		30	60	11,79
	7P0 802 144	RAW	nákup	opole	E3		X	0,555	0,393	1	27	7P0 803 092	204	223	60	26,7			6280					30	XX		XX		XX		XX		30	60	11,79
	7P0802939–7P0802937	RAW	nákup	Torino	E1	X		0,0963	0,017	1	27	7P0 802 937	55	45	20	617,6			4147					240	X								120	240	4,08
	7P0802940–938	RAW	nákup	Torino	E1		X	0,0828	0,017	1	27	7P0 802 938	55	45	20	617,6			4147					480	X								120	240	8,16
	7P0 803 087	RAW	nákup	opole	E3	X		1,094	0,708	2	54	7P0 802 755	274	120	153	14,8			7101					120	X		X		x		x		120	240	84,96
	7P0 803 088	RAW	nákup	opole	E3		X	1,029	0,708	2	54	7P0 802 756	274	120	153	14,8			7101					120	X		X		x		x		120	240	84,96
	7P0 803 105	RAW	nákup	Zwickau	E1	ulozenie mimo linky		12,324	6,53	1	27	7P0 803 091	1370	144	301	1,6			veľký diel / Gitterbox															0	0
	7P0 803 106	RAW	nákup	Zwickau	E1	ulozenie mimo linky		13,329	6,53	1	27	7P0 803 092	1370	144	301	1,6			veľký diel / Gitterbox															0	0
	7P0 803 107	RAW	nákup	Zwickau	E2	ulozenie mimo linky		7,907	4,25	2	54	7P0 802 035	1370	68	299	2,5			kovový rack															0	0
	7P0 803 108	RAW	nákup	Zwickau	E2	ulozenie mimo linky		7,517	4,25	2	54	7P0 802 036	1370	68	299	2,5			kovový rack															0	0
	7P0 803 511	RAW	nákup	opole	B1	X		0,155	0,085	1	27	7P0 813 518	142	63	50	123,5			6147					60	X		x		x		x		60	120	5,1
	7P0 803 512	RAW	nákup	opole	B1	X		0,155	0,085	1	27	7P0 813 518	142	63	50	123,5			6147					60	X		x		x		x		60	120	5,1
	7P0 803 557	RAW	nákup	Torino	E3	X		0,2026	0,17	1	27	7P0 803 091	41	20	36	61,8			3147					120	X				x				60	120	20,4
	7P0 803 558	RAW	nákup	Torino	E3		X	0,2154	0,17	1	27	7P0 803 092	41	20	36	61,8			3147					120	X				x				60	120	20,4
	7P0 803 569	RAW	nákup	opole	E3	X		1,274	0,828	1	27	7P0 803 091	428	172	217	12,7			7101					90	X				x				120	240	74,52
	7P0 803 570	RAW	nákup	opole	E3		X	1,199	0,818	1	27	7P0 803 092	428	172	217	12,8			7101					90	X				x				120	240	73,62
	7P0 803 586	RAW	nákup	Torino	E1		X	0,1617	0,08	1	27	7P0 803 092	73	60	2	131,3			4147					120	X				x				60	120	9,6
	7P0 803 732	RAW	nákup	Torino	B1	X		0,2183	0,085	2	54	7P0 813 518	47	69	46	123,5			6147					120	X		x		x		x		120	240	10,2
	7P0 803 831	RAW	nákup	opole	B2	X		0,842	0,21	2	54	7P5 810 503	119	100	72	50,0			6280					60	XX		XX		XX		XX		60	120	12,6
	7P0 803 832	RAW	nákup	opole	B2		X	0,859	0,21	2	54	7P5 810 503	119	100	72	50,0			6280					60	XX		XX		XX		XX		60	120	12,6
	7P0 804 417	RAW	nákup	opole	E3	X		0,952	0,564	1	27	7P0 803 091	265	139	37	18,6									X				x						67,68

Appendix C – Tote fitting by P/N (Tower Automotive)

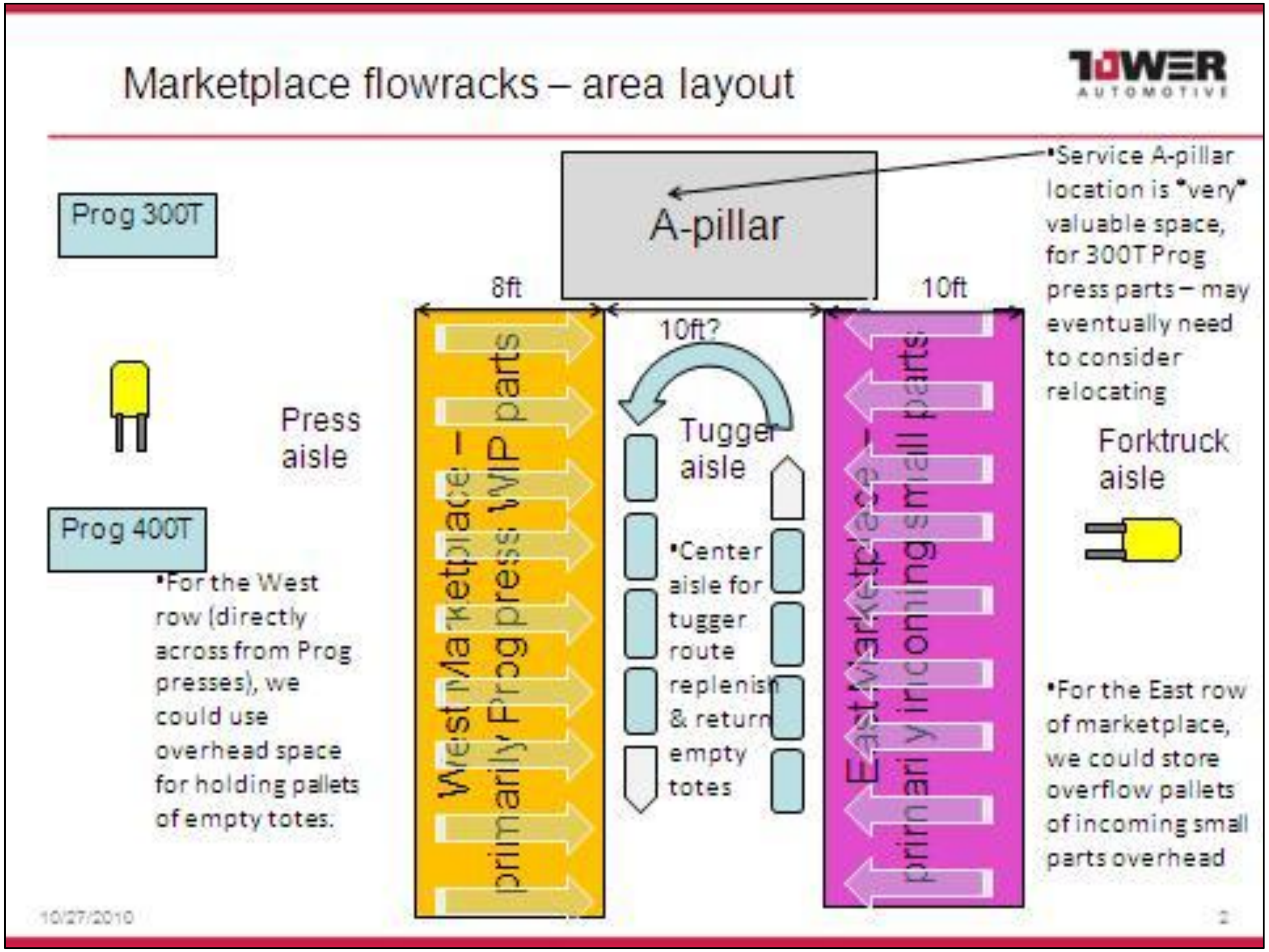
Chicago Marketplace flowracks

TOWER AUTOMOTIVE

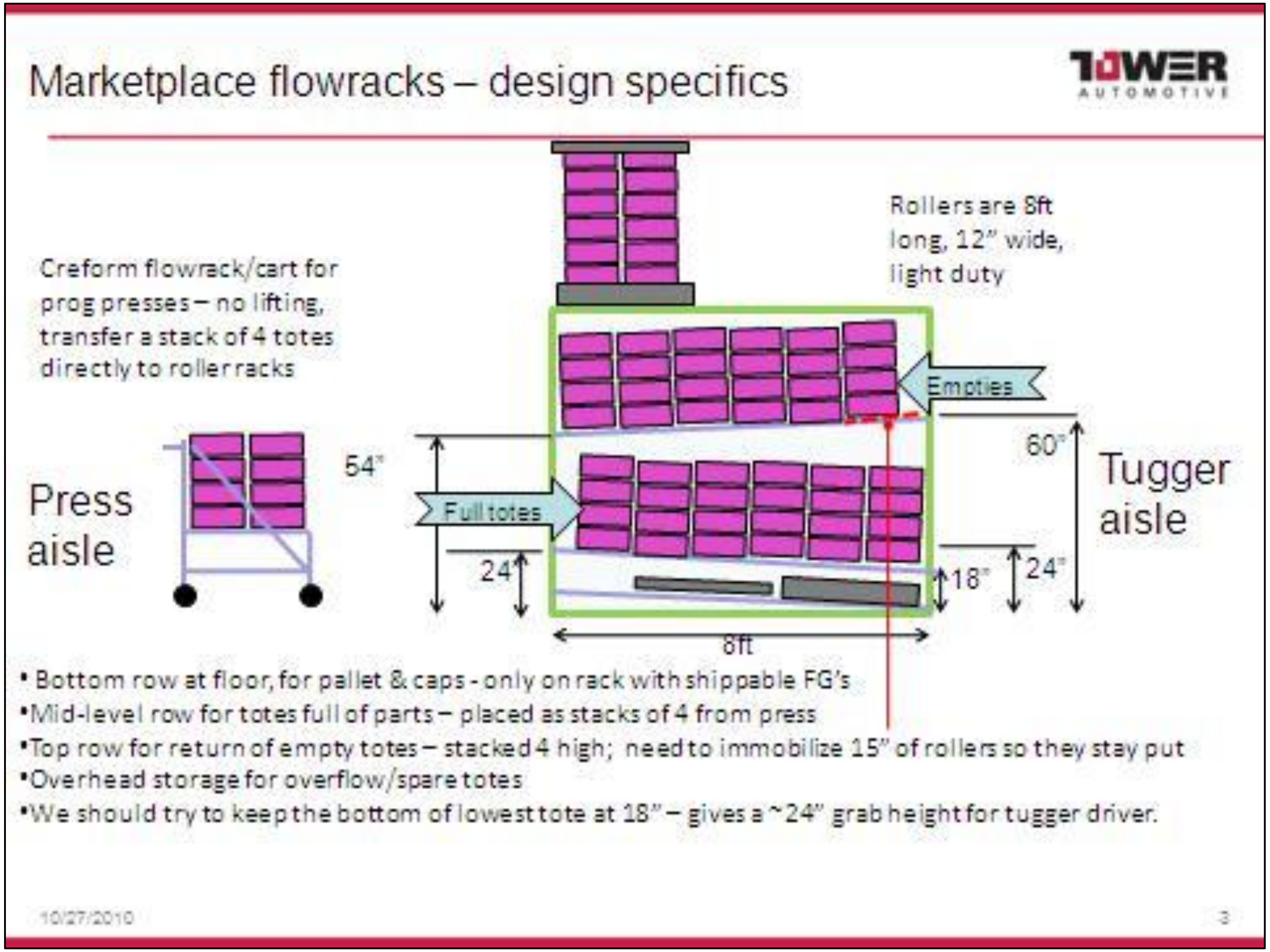
Didn't have any luck getting a picture of the TC marketplace before it was disassembled. Here is one of Bardstown's that we'd like to use as reference. Looks like 2 rows of totes on gravity rollers on bottom - and 2 rows of shelving for overflow pallets above. Although, the lowest one sucks ergonomically (looks ~6" off floor), and the highest one looks questionable – top tote (when stacked 4 high on shelf) is >6ft

10/27/2010 1

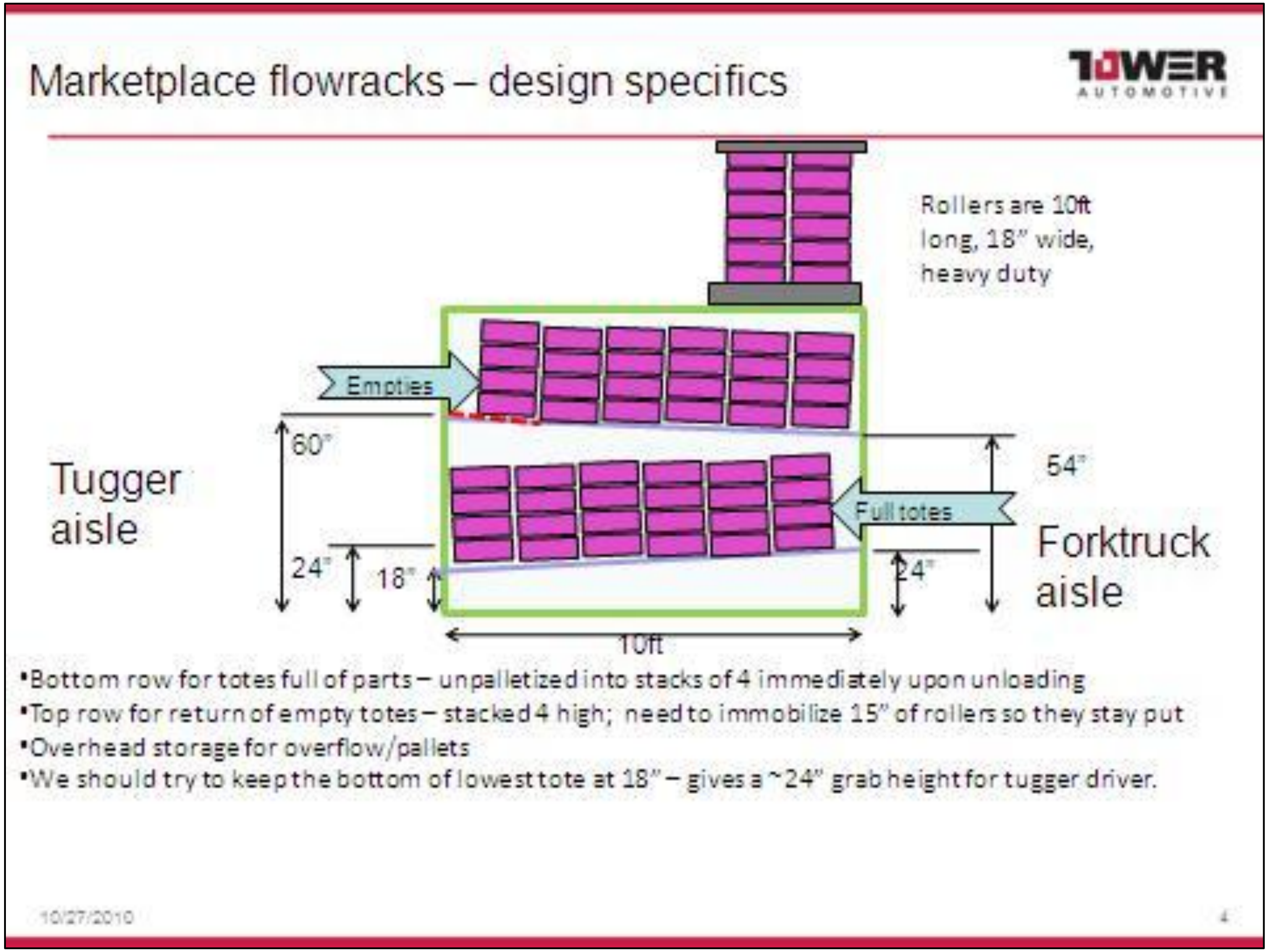
Appendix D – Gravity Flow Racks Chicago implementation (Tower Automotive)



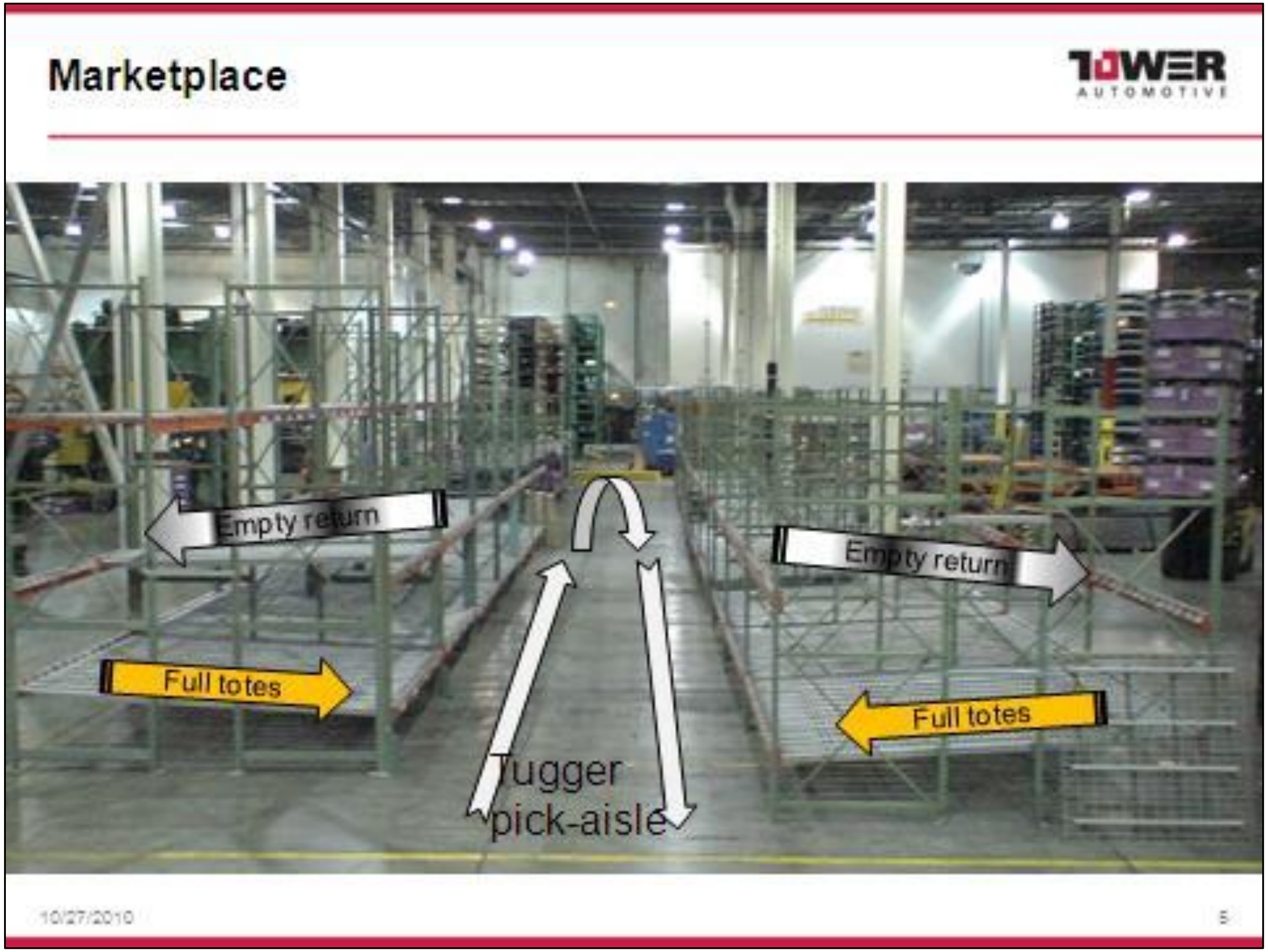
Appendix E – Market place simulation / Flow Racks / Tugger train (Tower Automotive)



Appendix F – Market place Flow Racks (Tower Automotive)

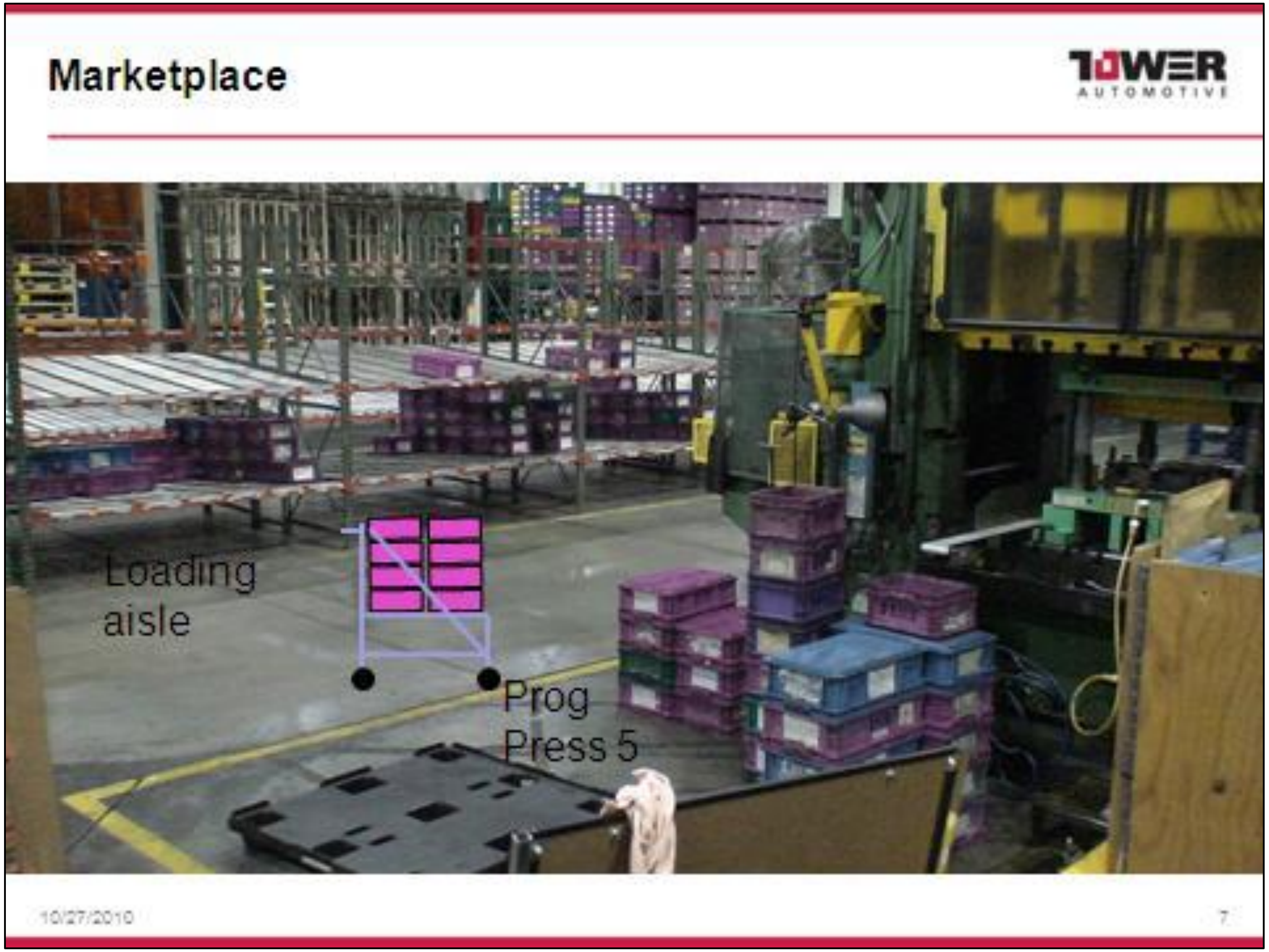


Appendix G – Market place Flow Racks (Tower Automotive)

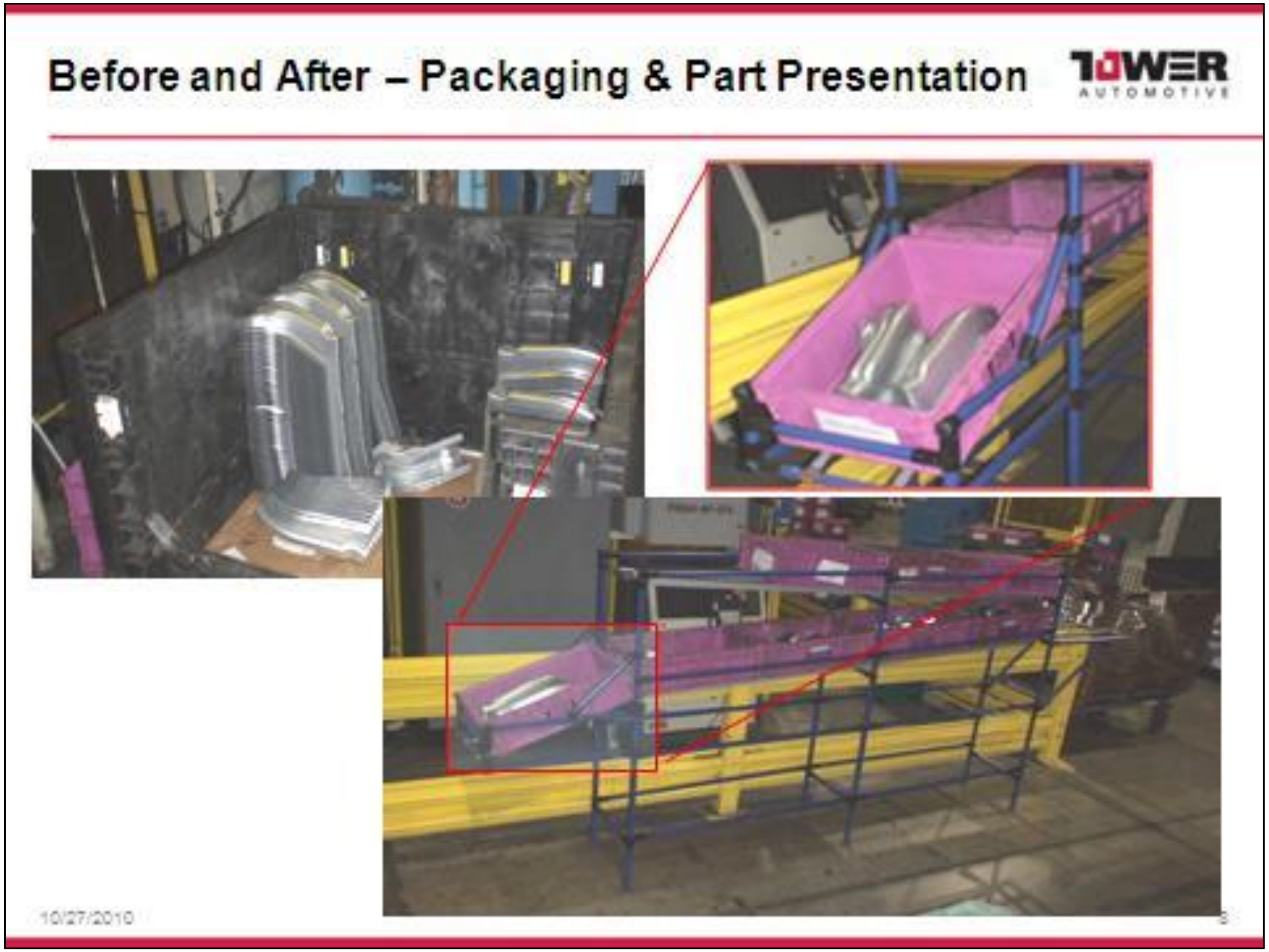


Appendix H – Market place Aisle simulation (Tower Automotive)

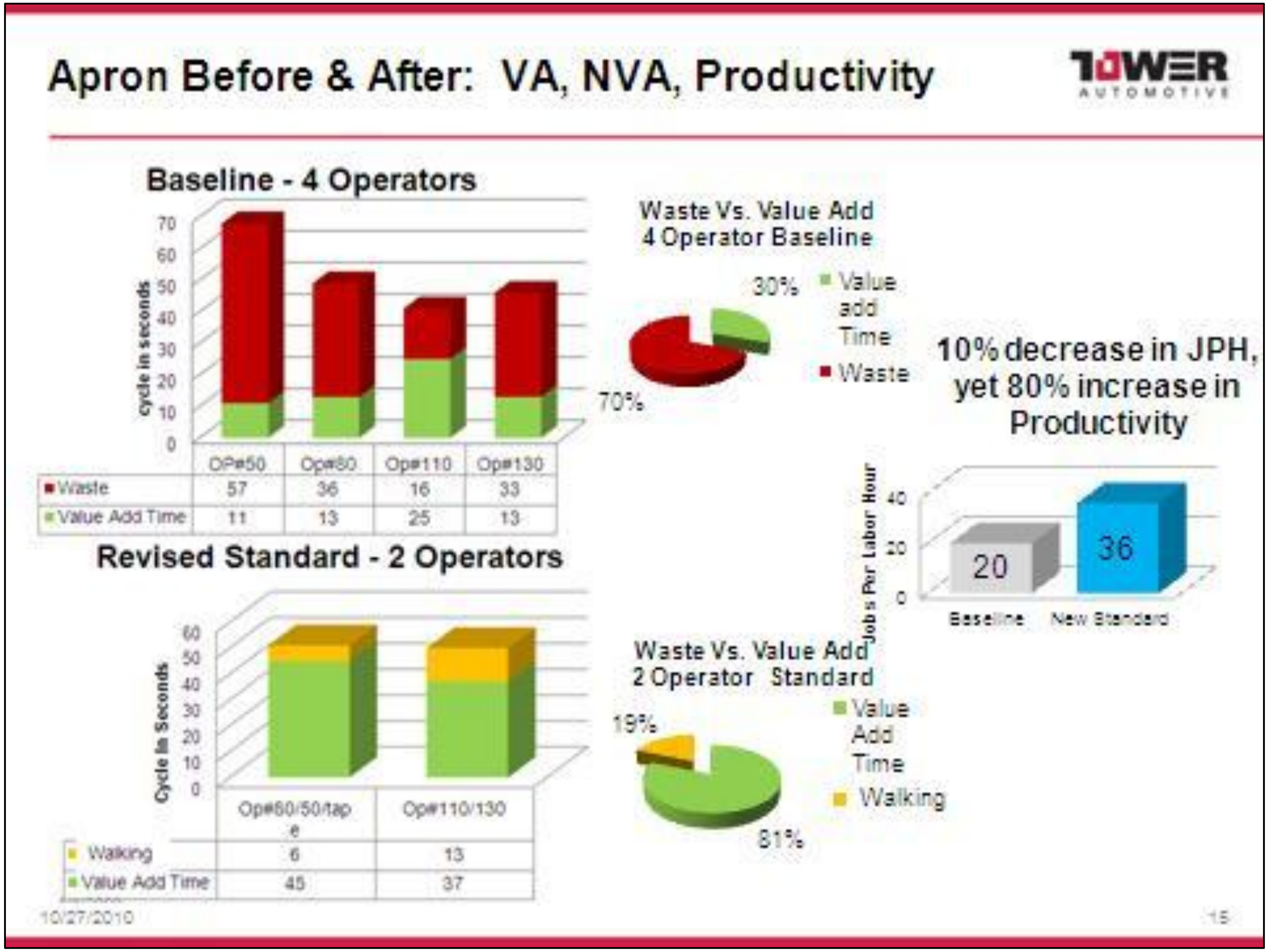
Appendix I – Market place Aisle / Pick up simulation (Tower Automotive)



Appendix J – Market place & Production area Aisle / Pick up simulation (Tower Automotive)

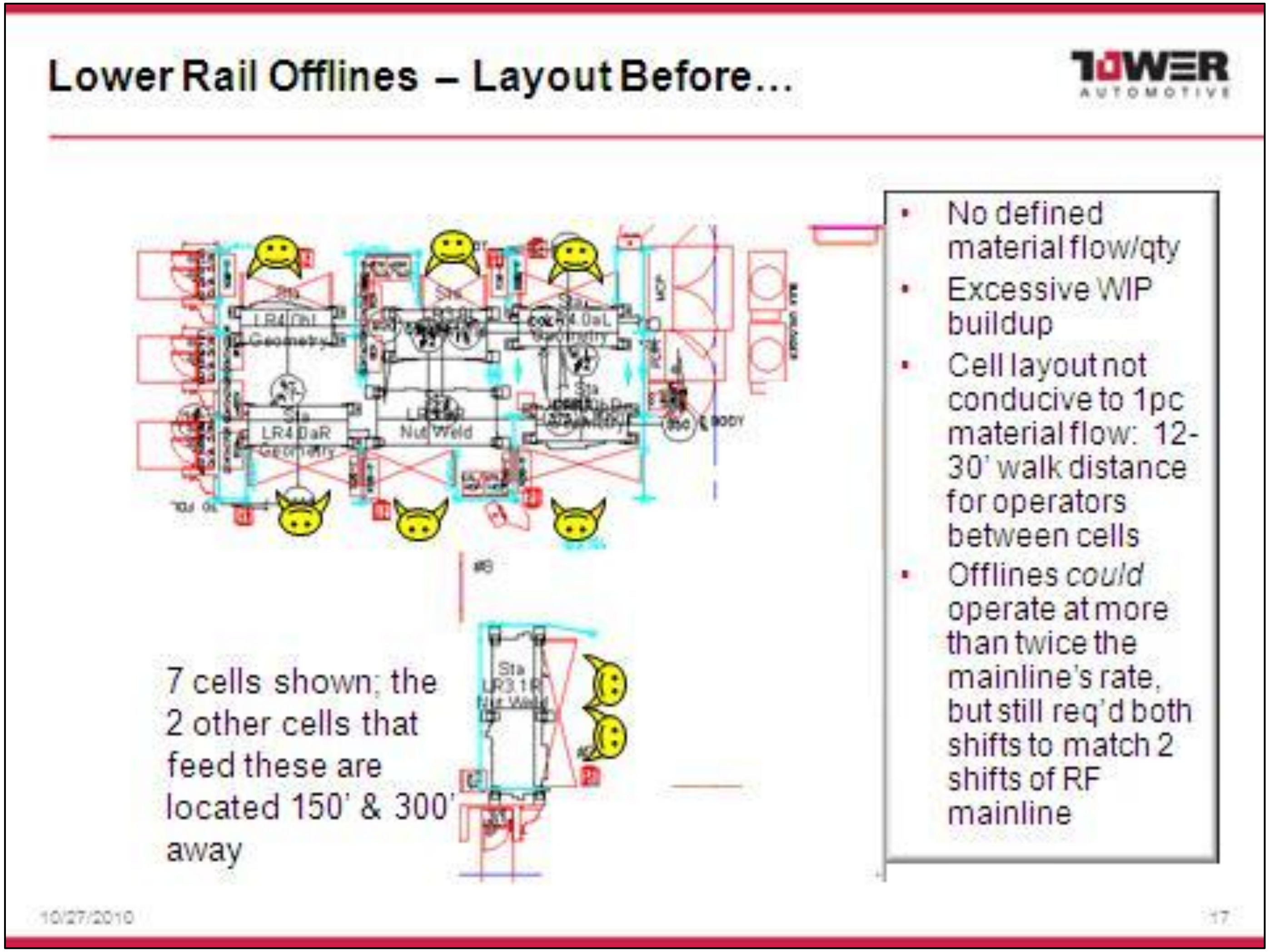


Appendix K – Part Presentation Difference (Tower Automotive)

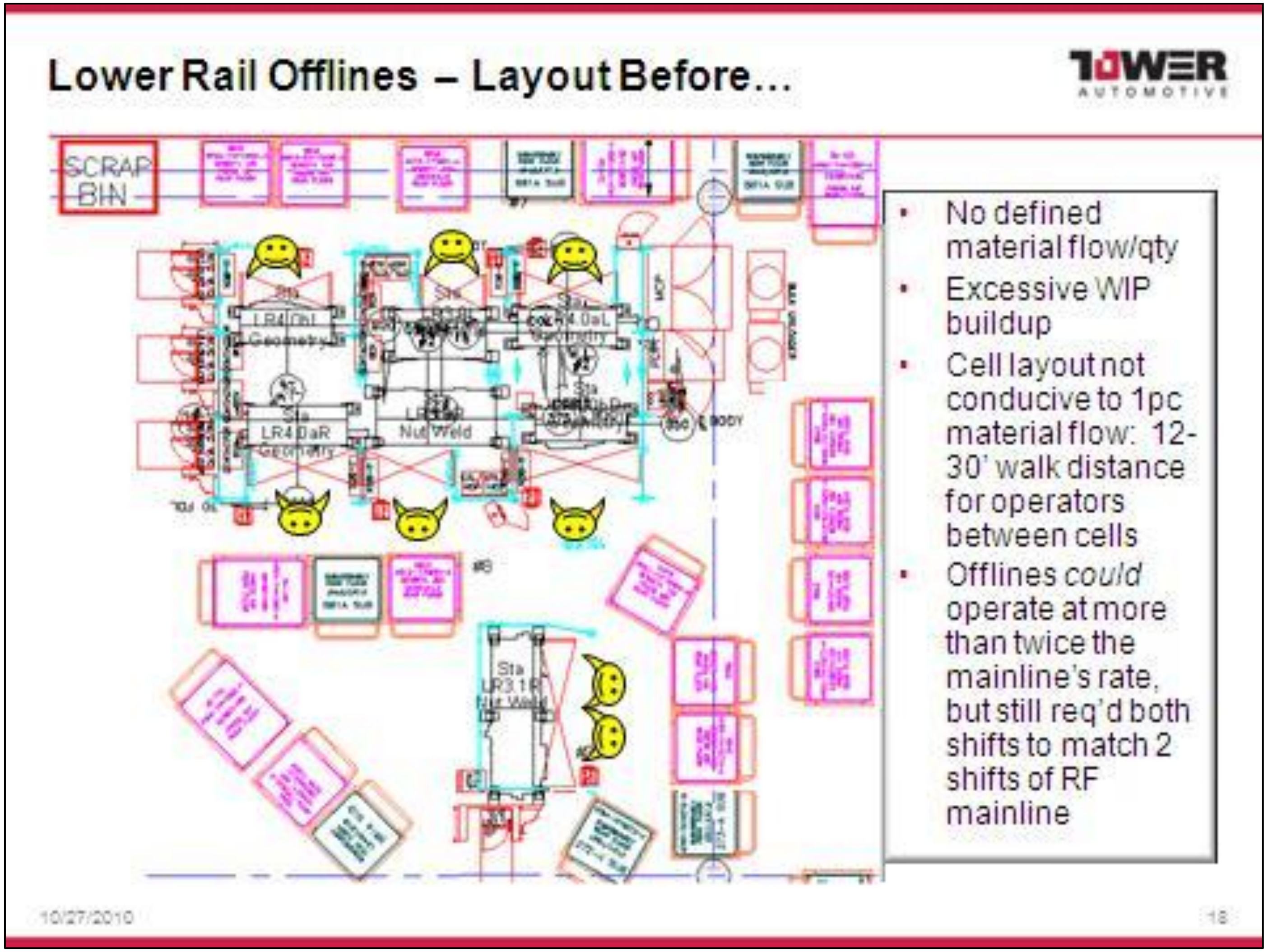


Appendix L – Part Presentation Difference (Tower Automotive)

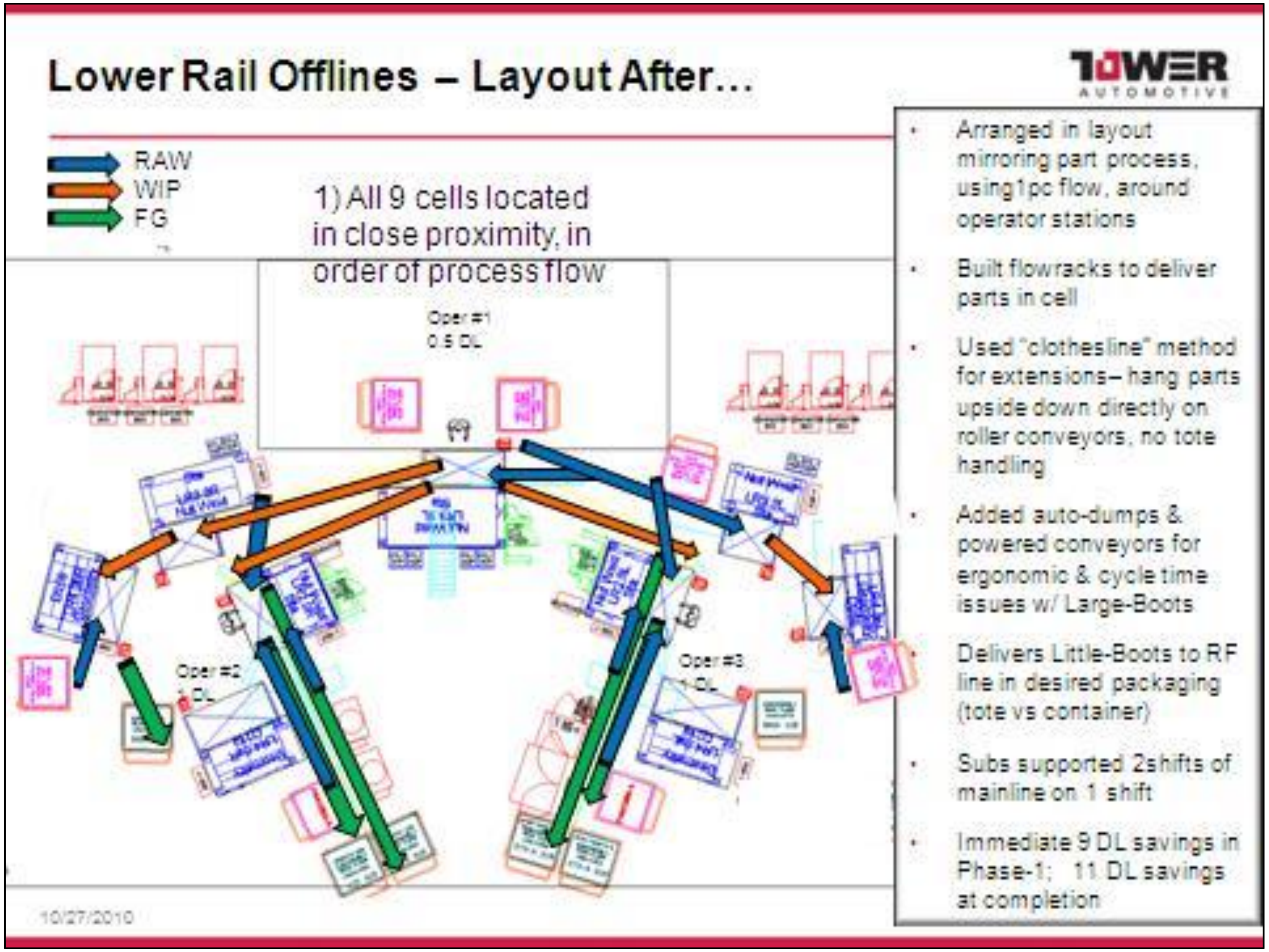
Appendix M – Next Step in PPM improvements (Tower Automotive)



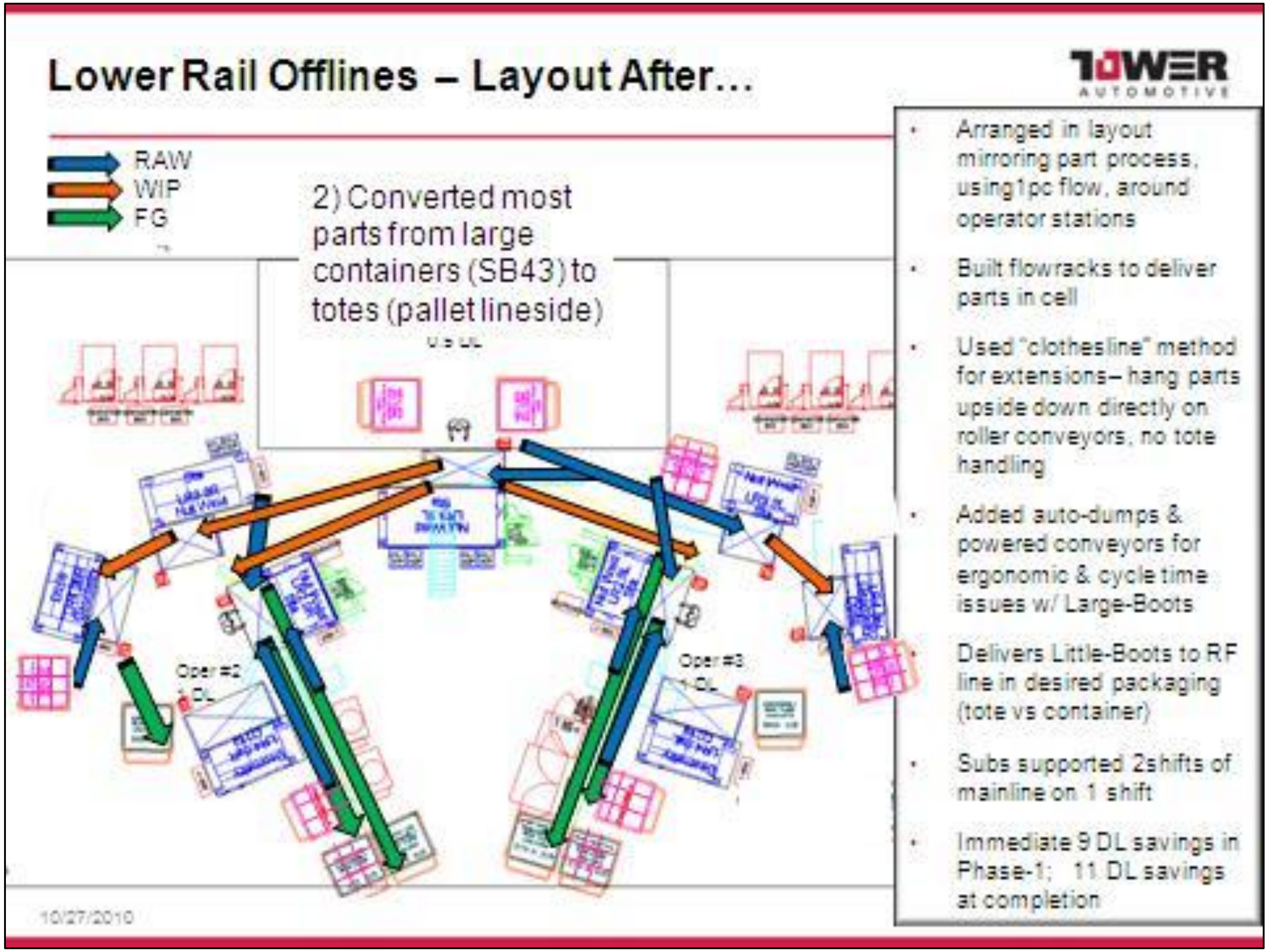
Appendix N – Layout change example (Tower Automotive)



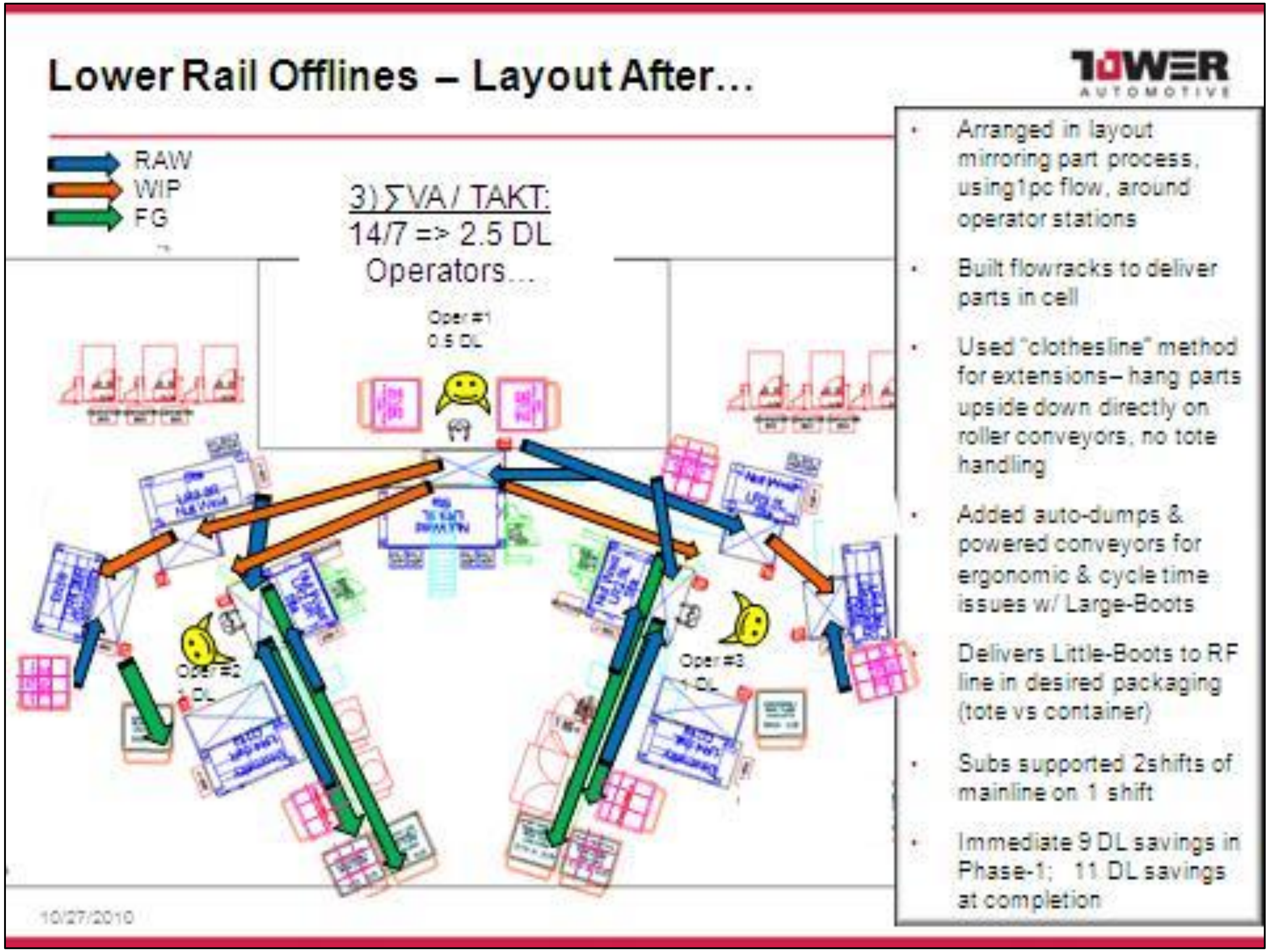
Appendix O – Layout change example (Tower Automotive)



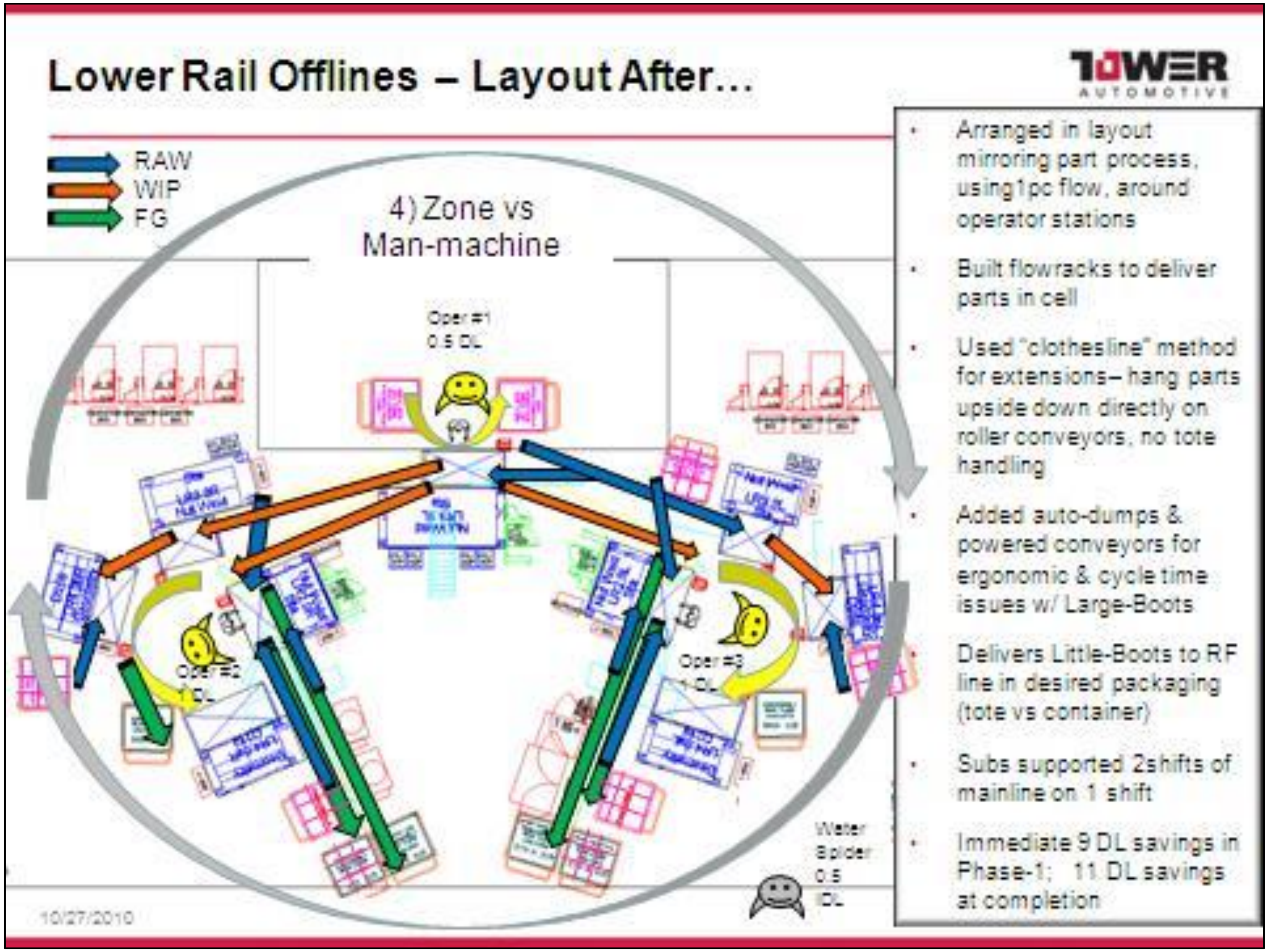
Appendix P – Layout change example (Tower Automotive)



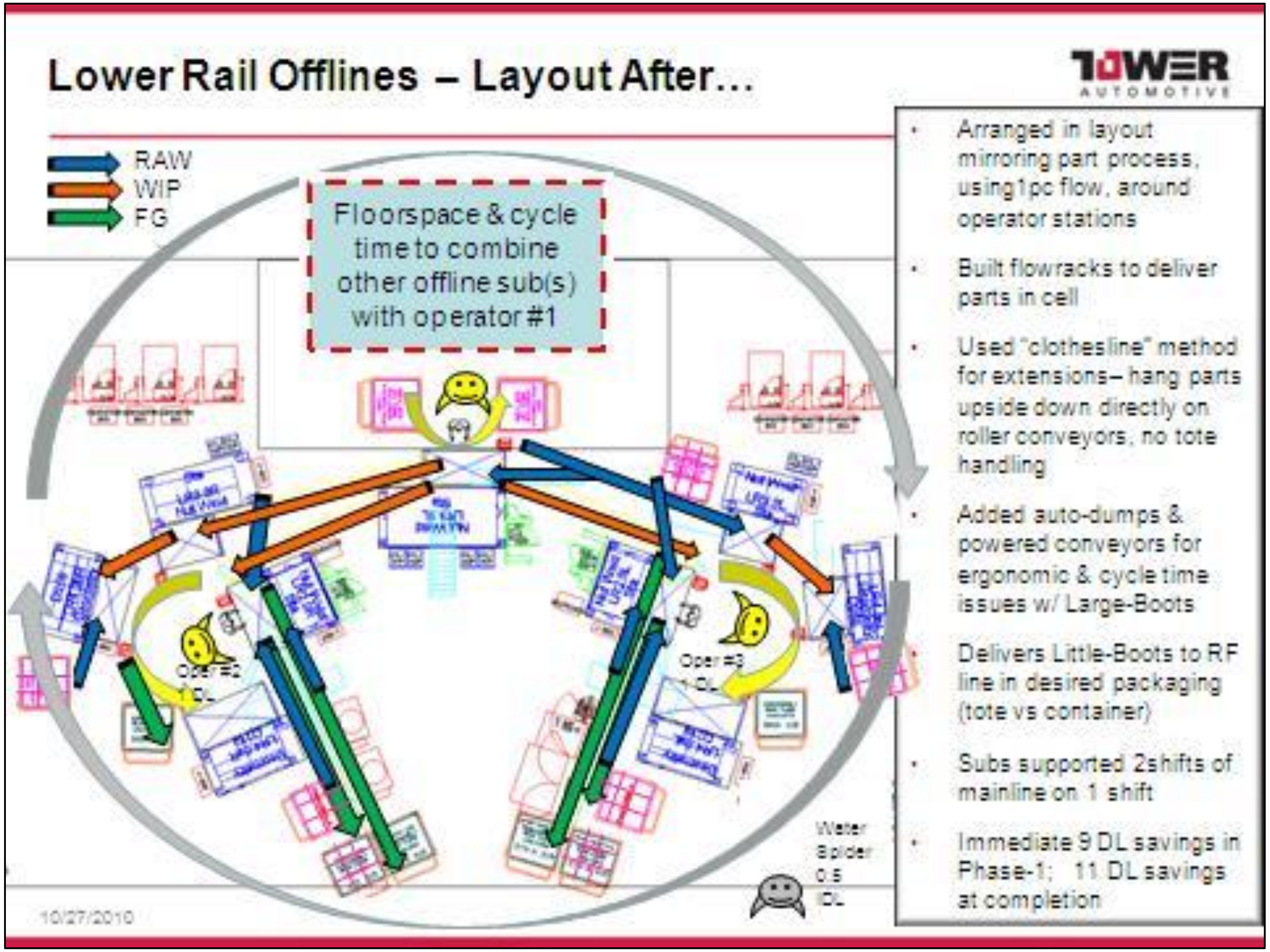
Appendix Q – Layout change example (Tower Automotive)



Appendix R – Layout change example (Tower Automotive)



Appendix S – Layout change example (Tower Automotive)



Appendix T – Layout change example (Tower Automotive)

Appendix U – Implementation Progress Tracking example (Tower Automotive)