CHAPTER 09
ONE-PIECE FLOW AND CONTINUOUS FLOW

Annotation

One of the ways to achieve continuous and levelled flow is to abandon the batch model of production and reorganise it into a system of related One-Piece Flows – the products be made one by one and the operations be carried out one by one.

In Just-in-Time Production and Delivery System we create a continuous and levelled flow based on one-piece or similar flows that we manage by pulling and refilling.

We will look at the characteristics of the different types of production flows – sequential flow, tree flow (straight tree and inverse tree), and network flow.

We will analyse in the aspect of continuous flow, what are the pros and cons of the most widespread and still applied production organisation models – machine-shop organisation, technological organisation, and product organisation.

The many and different varieties of cellular (island) organisation will also be shown.

We will also see the organisational models for achieving a levelled production flow.

The production flow, even if it is continuous flow, will suffer internal losses if it does not flow smoothly, if it flows in thrusts of varying intensity over time.

We will find out what internal factors in the flow prevent its levelling. These are the unequal or non-multiple each other capacities of operations and processes. Also, these are the unequal or non-multiple each other times of operations and processes. Flow disruption may come from inadequate capacities and/or very long auxiliary operation times relative to their respective main operations. The flow is also disrupted also if the repeated and corrective operations are done in places where their respective main operations are also done. Disruption may also be due to the capacities of some group processing tools do not correspond to the length of the series – I am talking about a uneven or not multiple number of units in these resources, if there is more than one group processing along the flow. Levelling is influenced by the return of the product back against the flow. Poorly managed bottlenecks not only disrupt the flow but also limit the total throughput of the entire production.

09.01. A Quote by Teruyuki Minoura

Teruyuki Minoura, former general president of Toyota Motor Manufacturing Co, said verbatim:

"If some problem occurs in One-Piece-Flow manufacturing then the whole production line must stop immediately and wait. In this sense, it is a very bad manufacturing system. But when the whole production stops, everyone is forced to solve the problem immediately. So, the team members have to think, and through thinking, team members grow and become better team members and people".

We suppose that we produce one product in a series of one single number and that technology is a process with successive operations. It's not hard to imagine…

The first operation is cutting blanks of rod material. The second operation is turning of the blanks. The third operation is milling. The fourth operation is drilling holes. The fifth operation is grinding. Finally, the sixth operation is packing.

The product starts in a single number from one operation to the next operation. If there is a problem in any of the subsequent operations, production stops. This production can only continue when the problem is detected and resolved.

Let's imagine we're running a series, not a single unit. If there is a problem in one of the operations, nothing prevents the other operations from continuing.

They just accumulate unfinished product that cannot continue to move further.

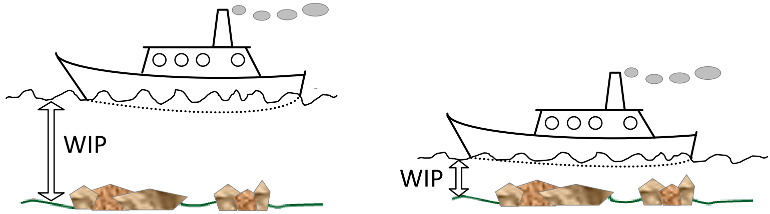
When we organise production as a flow of single items, and if somewhere in the flow there is a problem, production cannot continue until the problem is solved. What happens then? We're all going to the operation where the problem is. We think and try to solve the problem. It goes without saying, workers are polyvalent, everyone worker knows more or less the work of all others workers.

The idea of One-Piece Flow is an idea of fighting against the unfinished product.

In many cases, there is an unfinished product because some operations are in condition and others are not. Some operations have problems, others do not.

In operations without problems, production flows. In operations with problems, production stops and piles of unfinished products pile up in front of them.

09.02. We Need Either a Ship Pilot or a Dredging Machine



In some books about Lean, the effect of unfinished production is illustrated by an expressive picture. On the left picture, we see a ship sailing a river, and the water level in the river is high. At the river bottom, there are sharp edges of dangerous underwater rocks. But the water is deep, the ship is sailing high above the rocks and on the captain's bridge there is a sense of security and complete calm.

The water level is an allusion to unfinished production. When the water level falls, the rocks protrude above the surface or are directly below it. The ship needs an experienced ship pilot to guide the ship away from the dangerous cliffs.

Here, the ship pilot is an allusion to a need of a complicated management system.

Or the riverbed maintenance service has to blow up the cliffs... We see an allusion to preventive measure against a problem. If our ship has to sail in shallow water near underwater cliffs, we like it or not, we'll have to clear the bottom. Otherwise, someday, no matter how experienced the ship pilot is, our ship will be stranded.

Hence comes the idea that production must deliberately – let's say "artificially" – be brought to extreme regimes, and then, if in production system are potential problems, they will manifest, and this will force us to discuss and resolve them.

We have already spoken about squeezing technological cost limits. Here is the same idea. If we subject the production to extreme modes, every potential problem will be revealed. If the production is partially loaded, even if there are chronic problems, they will remain hidden, and we will most likely not notice them.

And so, we deliberately put production into artificially forced modes. Problems appear one after another. We remove them. What does removing them mean? We eradicate their root causes. We blow the underwater rocks up, there are no more rocks, the riverbed is flat and smooth, and the ship sails smoothly.

We realised that if the products go one by one and they end up in a problematic operation or process, the production should stop until the problem is eliminated.

If we run a series and part of it passes a problematic operation without us noticing that it is problematic, but the problem manifests itself subsequently, the products that supposedly passed the operation successfully move on their way.

The longer the series, the greater the effect on subsequent operations, which, although capable of working, have nothing to be fed with and they must wait.

In process is sequential, this effect is most pronounced and visible. If operations are independent, the effect will manifest itself differently – not as operations that are idle after the problematic operation because they remain unpowered but as operations working despite the problem, and thus they create scrap. If the operations are autonomous and one operation has a problem, this doesn't stop the other operations from working unless they remain under provisioned. Factually, all these operations are connected, because they together create the final product.

We produce a unit consisting of three components, and we have three parallel lines, each of which produces one of the three components. One of the lines has a problem, and at the same time, the other two lines have no problem. In this situation, the two lines without problems will produce unnecessary components.

These components have been made but stand immobilised because the final assembly operation lacks the third component and it is forced to stop and wait it.

09.03. Prototype "in Japanese"

One well-researched production does not pose the risks of nasty surprises. Let's try to understand the central idea of the so-called "Prototype in Japanese".

When the Japanese make a prototype of a new product (or a sample series, or trial series), they deliberately do so in a problematic production environment in which production factors are pushed almost to the limits of non-conformity.

Materials with very broad tolerance fields are deliberately used. These are suitable materials, but they're on the verge of non-conformity. They deliberately use machines that are about to undergo capital repairs. These are still working machines, but almost to the point of non-conformity. They deliberately use recently recruited workers. The workers have been trained but have not yet fully mastered their work and are therefore at risk of making mistakes.

Then, if despite using shoddy materials, worn machines and inexperienced workers, they obtain a suitable prototype of a new product, all the products of regular production will be better than the prototype. We do the opposite of the Japanese – we look for special materials, we use precision machines, we engage the most experienced technical and operative personnel. Then we are always unpleasantly surprised that in regular production we fail to obtain repeatability and reproducibility, compared to a "successful" prototype of the new product. The Prototype in Japanese is the forerunner of the idea of variable technology (aka Quasi-Exhaustive Technology), based on been well researched favourable and unfavourable variations and/or combinations of all production factors. From delivery to delivery, the characteristics of the materials change. The physical condition and the technological setting of the equipment change. Workers have different knowledge and skills. Atmospheric conditions change and affect the work environment. At a given moment, the production factors can combine in a different way, and for each combination, there is a technological variant that is appropriate for this combination. There could have been 30 or more variants of the technology. Today, the production factors are in combination № 16, and the applicable for today technology variant is № 16. So today we're going to use technology № 16. Here's a summary. If we have studied the production process in advance, we can develop solutions to possible problems in advance.

09.04. Make the Ditch More Permeable by Digging the Resistances

It is a good idea to deliberately put the production into forced regimes. The aim is to quickly and visibly reveal its weak points and to seek and find solutions to the obvious and potential problems of these weak points. Everyone has watered corn, or at least watched it being done. How is this done? You turn on the water. Water runs down the furrow. After a moment, something stops the water, it forms a puddle, and the water stays there and stops flowing. You dig with the hoe, you unblock the puddle, and the water flows again, something stops it again, again a hoe, again a puddle, again the water flows, again it stops, and again a hoe. That's how you help the water flow down the furrow. By digging over and over again with the hoe, the water goes down the furrow with a constant and even flow. You were able to level the flow. In time, the water will clear up, and then you will never need a hoe again.

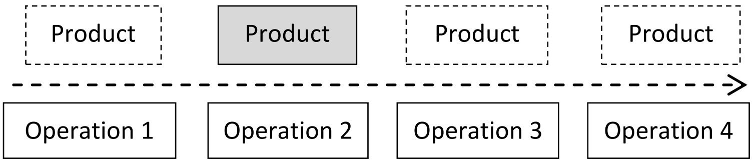
Accelerated product tests are tests under forced regimes of use of one new or renewed product, which are close to or even exceeding the admissible regimes.

The purpose of accelerated tests is not to wait for the normal use of the product to indicate whether there are some defects in its construction or workmanship but to detect and eliminate earlier possible the defects, if there is a risk of such.

The idea of intentionally forcing of the production loading or mode to uncover the obvious and hidden problems has almost the same logic as the idea of accelerated product tests. We force the production, it shows its teeth, and we cut them...

How long do we do this? We do it until we uncover and resolve all possible problems, both obvious and potential, and irrevocably eliminate their root causes.

09.05. One-Piece Flow



The two Lean terms "Single-Piece Flow" and "One-Piece Flow" are equivalent. What exactly is a One-Piece Flow, I will explain by describing its two features.

The first feature of these types of flows is that the products are made one by one. The second feature of these types of flows is that the product goes from operation to operation or from process to process without any detention between them.

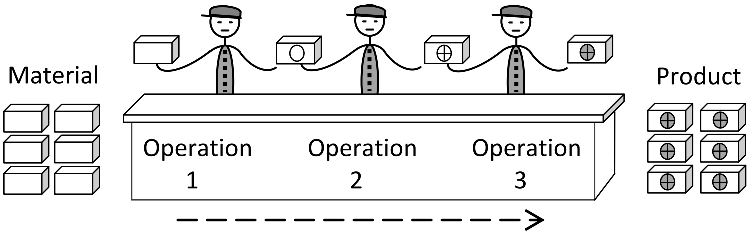
Regarding the above, we assume that the time for the product relocation between adjacent or even distant from each other operations or processes is equal to zero.

There are no intermediate stocks, no queues, no time is wasted in waiting, and no money is blocked. One-Piece Flow is the simplest form of continuous flow.

One-Piece Flow is a prerequisite for the next step – Pull managed production. With regard to the essence, mechanisms, and features of Pull Flow, see Chapter 10.

If it is of a sequential type, One-Piece Flow may suffer from a problem. If main operations and their respective auxiliary operations run one after the other, and if there are delays in some ancillary operations, they will eat up from the time of the main operations. This will not only disrupt the tact of the flow but also slow down its speed, lengthen Lead Times and worsen Cycle Time.

09.06. Continuous Flow



Let's look at the continuous flow. The picture shows how workers are making the products one by one and passing them on to each other. In this way, no inter-operation stocks are accumulated. Each worker does his work and passes the product on to the next, figuratively speaking, "from hand to hand".

With such an organisation, if there is a problem in any workplace, it will emerge and be visible to all team. I give you the product, but you can't accept it. Or you're waiting to take a product from me, and I'm not ready to give it to you in time.

Then we will realise that the workplaces capacities are not balanced, that the operation times are not synchronised, or that there is problem of another nature.

Otherwise, if we make the product in batches, this whether or not there are problems in production is unlikely to become apparent, or at least not so visible. Create a continuous flow in the process and see what problems come up!

09.07. The Ideal Flow Is a Chimera

There are two essential simple secrets of the ideal One-Piece Flow. Workplaces are equalised or mutually multiple capacities and synchronised operations times – they are also equalised or mutually multiple.

However, such an ideal condition of flow can only be obtained for a specific product and only for the corresponding production technology of this product.

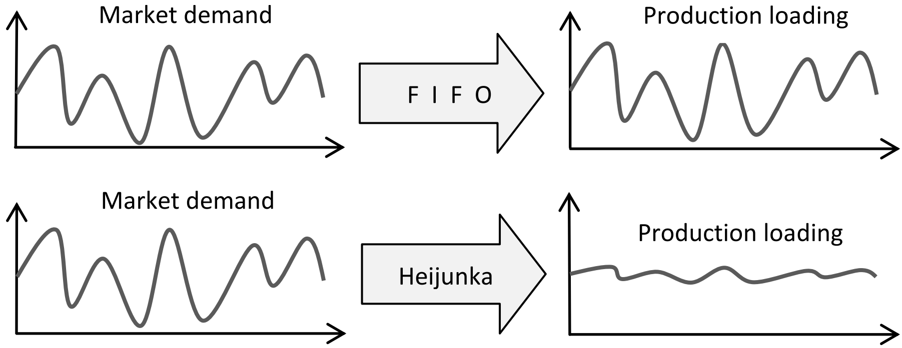
Behind every product is a technological mix of operations and their technological times. Even if the operations are the same, their technological times and, respectively the load of individual operations, will most likely not be the same.

We have a balanced flow for one product, but then we launch another product. There is another ratio of technological times, and the flow is unbalanced.

By balancing the capacities, we aim to balance the flow. Balanced capacities are the ideal state. Such luxury can be quite expensive in most cases. The input of production (orders for different products in different volumes) is constantly and unpredictably changing. The degrees of load on local capacities (these of individual operations) are subject to a number of unpredictable and capricious factors. It may be difficult, but it is best to try to balance the flow itself (even if the local capacities in it are not balanced). If we have a very long series, we can try and to achieve a good balance in the capacities of operations. If we work in short series, some products will have a balance. But others will not have a balance and will need buffers. It will not be so important whether we achieve balanced capacities of the operations and synchronised times of operations. It is much more important to achieve a state in which the flow flows without stopping and without wobbling.

09.08.01. Levelling (Heijunka)

Sometimes there is a big and very significant difference between a monthly schedule for taking and executing customer orders and a monthly schedule for putting into production and executing their respective production orders.



And so we get to Heijunka. On the left top and bottom of the chart is market demand, i.e., customer orders. They enter production in the form of production orders. If the sequence of production orders follows the sequence of customer orders (FIFO: first accepted, first introduced), like the customer orders flow varies, in the same way, the production flow will be subjected to widely variations.

Here are some very instructive considerations. Let us assume that in our industrial sector, the usual term for execution of a customer order is 30 days and that all the companies in the sector pursue such a deadline. The customer makes an inquiry, we give a decent price, we promise expected quality, and we offer a 30-day deadline.

The customer perceives this deadline of thirty days as normal, and the deal will be done. Let's imagine that we have learned, thanks to Lean tools, to execute the order not in thirty days but in ten. Then, even if market demand is unpredictable and highly fluctuating, we will not fulfill customer orders in the order of receipt, but in the order convenient for smoothing our production over time. We achieve a normal customer term of thirty days, but because we produce not in thirty but in ten days, we can smooth out the production flow. In Japanese, this is called "Heijunka". In other languages, it is called "Flow Levelling" or "Flow Smoothing".

09.08.02. Key Terms for Flow Levelling

One necessary prerequisite to achieve a levelled production flow is that the terms for fulfilment of production orders are much shorter than corresponding terms for fulfilment of customer orders usual accepted in the given industrial sector.

In the next Chapter 10, we will touch on another good prerequisite for the production flow levelling. The idea is to look for a wide variety in the product range offered to customers based on a small number of typified and/or modular constructive and/or technological solutions for production of this product range.

Let's go back to the idea that the term for execution of production order must be shorter than the term for execution of customer order. We will see two examples.

One of the examples is the automobile industry and its market. When buying a car on demand, the customer's term is between 45 and 60 days, and at the same time, the deadline for the production of a car from the metal sheets punching to the final assembly and the final test is in the range of one to two weeks (one of the consequences of the Covid-19 pandemic is that not only the deadlines for "on demand buying" but also the deadlines for "purchase from stock" flew all the way to the heights, and now we wait for a new car half a year or more).

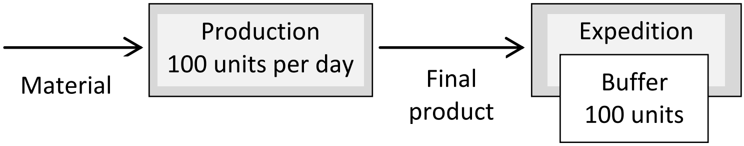
The other example is from a repair shop for amateur and professional power tools. Each day of the week, only certain groups of tools are repaired. On Monday, the shop repairs electric screwdrivers, nut drivers, drills, grinders, and mixers; on Tuesday, reciprocating saws, and jigsaws; on Wednesday, chainsaws; and so on. If you happen to bring in a chainsaw for repairs on Wednesday, you'll get it on Thursday, but if you bring it in on Friday, you won't get it until next Thursday.

There is a problem related to the differences between the production Lead Times and the customer deadlines. Traders see promotions as a means of boosting sales. Promotions can increase sales of both new and existing products only temporarily. At the same time, they can cause disruptions of the relevant production flows.

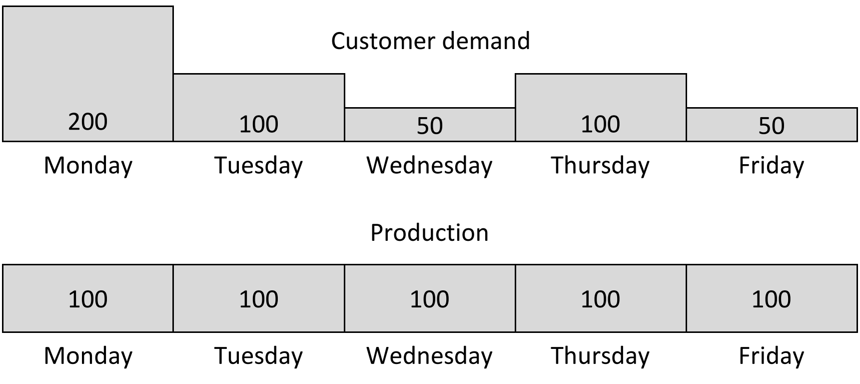
09.08.03. Flow Levelling "By Quantity"

A regular weekly order of 500 units, with daily orders of 50, 100 or 200 units on the five days of the week, for example

Monday	Tuesday	Wednesday	Thursday	Friday
200	100	50	100	50



There are two types of flow levelling: levelling by quantities (by series lengths) and levelling by product nomenclature. Here is an example of levelling by quantity. A factory performs regular weekly orders for 500 units. The daily orders within one week are different: 50 units, 100 units, and 200 units. On Monday there is order for 200 units, on Tuesday for 100 units, on Wednesday for 50 units, etc. Instead of each day producing a different number (the smallest number of 50 units is four times less than the largest number of 200 units), the factory can smooth the production flow by quantity, if it produces 100 units every day while at the same time maintaining a buffer of 100 units in an expedition warehouse.

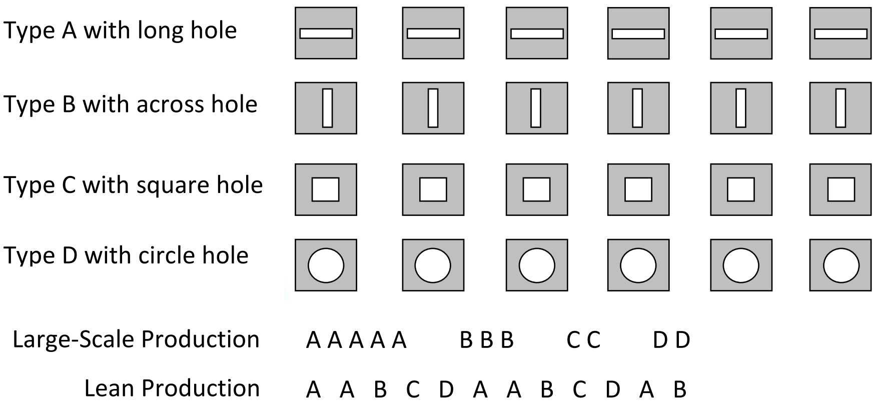


What is shown in the previous picture is now depicted in the form of bar charts. It is clear how the uneven demand (from 200 to 50 units per day, see above) has been transformed into levelled production (100 units every day, see below).

09.08.04. Flow Levelling "By Product Nomenclature"

The task of flow levelling "by nomenclature" arises when, instead of producing a small number of long series of different products, we break up the small number of long series into a large number of shorter series.

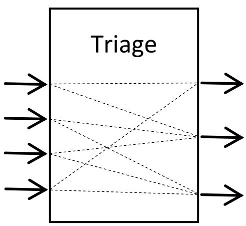
Weekly customer demand for four types of rectangular metal plates



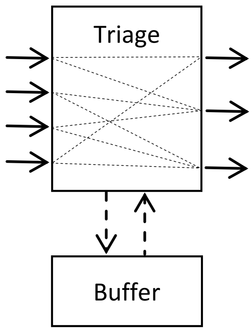
Now I will show how to achieve flow levelling "by nomenclature". Here are four types of metal plates – A, B, C, and D. Type A has a horizontal hole. Type B has a vertical hole. Type C has a square hole. Type D has a round hole. In a large-scale production, we first produce the entirety of plates type A, then the entirety of type B plates, then the entirety of type C plates, then the entirety of type D plates.

In a Lean Production, we break up the entire quantity of the types A, B, C, and D plates into short sub-series and run them in the order shown in the picture.

09.08.05. Flow Levelling in Triage Zones



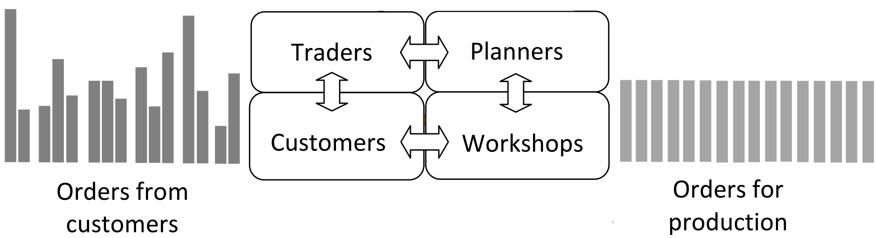
We see a triage zone. For example, it is a triage warehouse of a retail chain, in which goods from the suppliers arrive and are distributed to stores. Or it is a triage zone in a sensor factory, where many types of parts come from several production lines and are completed in kits and then distributed to several other assembly lines.



The problem with triage zones is that the intensities of incoming and outgoing goods in and out of them change over time. This leads to risks of surpluses and deficits. We solve the problem with small buffer zones to the triage zone, sized according to the differences between minimum supply and maximum consumption. We remove goods from the buffers in the case of deficit, or we put goods in the buffers in the case of surpluses. This solution works if the average supply and consumption intensities are equalised, or at least approximately equalised.

09.08.06. Heijunka Dialogues

In the following reflections, I will reveal another aspect of turning uneven market demand into an even production flow. Market demand is almost always uneven, as it is twice random. First, the sizes of customer orders are a random value, most often subordinated to the Gaussian distribution or Boltzmann distribution law. Secondly, the times between the moments of receipt of the customer orders also is a random value, most often subordinated to the Poisson distribution law.



At the top left, we have customer orders, random in size and times of receipt. And on the right, we have production orders – regular in size and in time of acceptance. This can be achieved through the so-called Heijunka Dialogues. They are conducted between four partners. Traders talk to customers and promise discounts according to the delivery term. For a normal term, the price is normal. For pre-order and longer delivery term, the price is lower. Express order – a higher price. In two words: Price according to the delivery term. Apart from these three types of prices, traders convince customers that if they receive indicative forecast orders from them, even without committing, if they give forecasts about what they will order over time, there will still be price discounts.

If we say that the indicative forecast is misleading, we are mistaken. Lots of customers – lots of predictions… One of them is optimistically overvalued up, and the other is pessimistically undervalued down. The average estimate is correct because the Law of Large Numbers goes into effect. Traders talk to production planners. In this way, they know what spare capacities they have now and in the future, and traders can inform planners early about what customer orders they expect or have accepted. The production planners talk to the production managers about when and which capacities to release for orders. The production managers, through the planners, ask the traders to provide such and such products for a given month, because then the capacity will be free or less loaded.

It is interesting to know that there are Bulgarian companies in which the Sales and Production Planning units are not separated from each other but are a common unit. Sellers and planners are always face-to-face. How is such an idea born? If the need for dialogue is not realised, there also is not realised the need to unite units. If the need for dialogue is realised, there also is realised the need to unite units.

Let's go back to the basics of levelling out. An important basis of levelling is to be able to execute a production order in a time much shorter than the usual accepted time in this industrial sector to execute a customer order. We saw it in the case of automotive production – 60 days for the fulfilment of customer orders, 14 days for the fulfilment of production orders. They've got so much time to play with. From 60 days to 14 days – that's a 4-fold difference. Thus, the final assembly plant can afford to plan the sequence for the assembly of the cars in the most efficient way for itself. Is this convenient for the previous links in the chain? The first sectors, which produce the details, components, and units, they're under real pressure. Next, I will explain why. When we speak of Lean Production, we should remember from time to time that this otherwise very good production system was born for the needs of the automotive and similar assembly industries.

It is applicable directly to any industry of this type, where a multistage chain of collection of parts and components in units, systems, and aggregates all the way to the assembly of end products. The actions of all the previous units in this long chain are subject to commands from the final assembly unit. We'll come back to Heijunka many times, but let's get it over with one conclusion: We can't have a perfect Just-in-Time Production and Delivery System without a perfect Heijunka.

When we start implementing Heijunka, we have to take into account whether we are dealing with Make-to-Stock production, Make-to-Order production, or Make-to-Catalogue production. It is easiest to level out Make-to-Stock production, but at the expense of a large volume of blocked unshipped product. The most difficult is to level Make-to-Order production, especially if we execute the customer orders in the sequence they are accepted and not in the sequence of the expedition. The levelling of Make-to-Catalogue production is easier if customer orders are predictable in terms of product types and product quantities. This suggests that Make-to-Catalogue production should create and maintain an active sales marketing and long-term relationships with regular customers.

When it comes to flow levelling, the role of the mix of series lengths is significant. In order to prevent the disadvantages of long and of short series, we need to learn to work in short series mode, artificially divide the long series into shorter ones, as well as run short series in the "windows" of or between the longer series.

09.09. Rethinking the Role of the Market

Our beloved customers, with their manner of when, what, how much and how they buy from us, they make it easier or harder for us to produce efficiently.

In marketing textbooks, we read that the customer is always right, that demand determines supply, that the market commands production and other humorous fabrications like that. Steve Jobs said the opposite in his own acerbic language.

The cynical truth is that one strong company knows how to deceive or force the customers to buy products that the company can produce in an efficient way.

That the customer is always right,
was probably said by some customer.

Steve Jobs, Apple

Without efficient production
there are no satisfied customers.

Lee Iacocca, Chrysler

Sparing the customer’s self-esteem, company gives him illusion that he has made the choice, but really is the company that has made the choice of whom, what, and how much to sell, and thus enjoys the comfort of high internal efficiency.

Such unholy customer treatment is especially true for three types of products for consumer use. Some of them are products with artificially forced market demand.

A typical example is the businesses of the deliberately neglected prevention – you make people sick and then sell pills and medical care, you violate road building technology, and then repair the roads, and other similar fraudulent schemes.

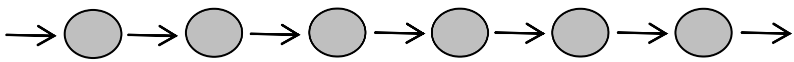
Another example is the industries of provoked fear – you scare people with theft and other crimes and sell locks, video cameras, and insurances for "free business".

There are also products with a challenged market (there is no existential need for them, but they satisfy egocentric or exhibitionist attitudes). Typical examples are products for machos (jeeps, eros stimulants) and girls (top fashion, beauty cosmetics, and surgical plastic corrections of bodily beauty), for divan idlers (reality TV, tabloid press), for hypochondriacs (organic foods and drinks, vital additives), for nouveau riche and snobs (limousines, yachts, aeroplanes) and other time wasters whose lives are not meaningful and filled with constructive labour.

With and without Lean, the products of these three types of searches are always efficient because of their inflated prices. The bad thing is that their high prices exert inflationary pressure on the prices of products for normal human needs.

Regardless of what the products are and whether the producer influences the market demand or is dominated by it, the wise Lee Iacocca will always be right. Lee Iacocca tells us that customer satisfaction, without the company losing from it, cannot be achieved if the company work with high internally inefficiency.

09.10.01. Sequential Production Flow



We will look at different types of production flows and their branch peculiarities.

Sequential production flow is simple to organising and maintain but it is typical only for the processing industries and for most of the manufacturing industries.

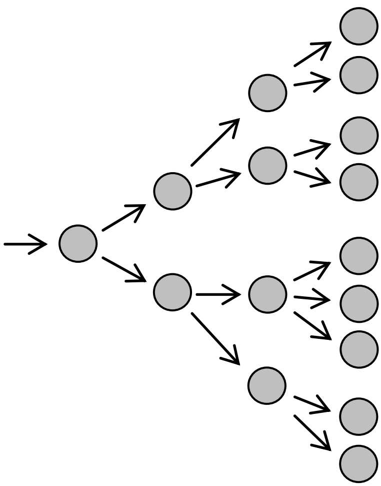
The production of optical components is carried out by successive operations of blank cutting, milling, grinding, polishing, coating, and varnishing. In mechanical processing of metal and plastic parts, work pieces are made with successive operations of cutting, turning, milling, drilling, grinding, polishing, and painting. I already explained this in Chapter 04 but I repeat it as it is more than important.

In sequential flow, it is somehow easier to look for synchronisation of operations and processes. In such a stream, "synchronisation" means equals or multiples to each other execution times of all the operations and processes in the flow.

In sequential organised production flow, if there are or if we want there to be reserves in the times of operations and processes, we must create them in the initial operations or processes, not in the final operations or processes.

In the case of a sequential organised production flow, whether we produce Make-to-Stock or Make-to-Order, for the purpose to obtain a shortened production cycle and a low level of uncompleted work, given the time limit within which we need to complete the last operation or process, we must have started the previous operations or processes as late as possible but respecting that deadline. This may be unclear at first glance. It seems illogic and absurd. The truth is that we deliberately squeeze the reserves along the entire production chain and make sure that all operations/processes are carried out correctly and on time, so that the last operation/process is loaded on time and that it is completed correctly and on time.

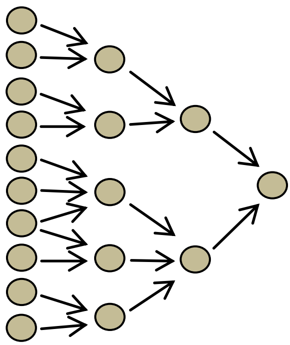
09.10.02. Tree-Like Production Flow



Tree-Like Production Flow is typical for most of the processing industries. In these industries, only one or a small number of materials are used to produce similar but diverse products. Examples for such type of industries are the primary processing of mining materials, the chemical, cosmetic, pharmaceutical, and petrol industries, the food and drinks industry, the building materials industry, as well as the printing and publishing industries. A similar nature has some industries for metalworking, plastic products making, and paper products making. See on pp. 99-102 many and different examples of such type of industries.

No matter if the production is Make-to-Stock, Make-to-Order or Make-to-Catalog, if there is a need to wait for a product to pass from one operation to another operation, the wait is at the beginning rather than at the end of the process.

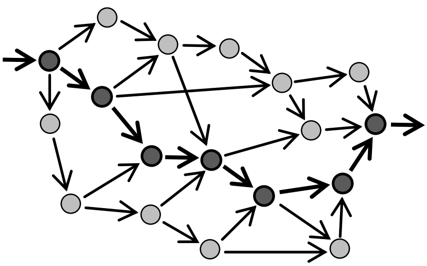
09.10.03. Inverse Tree-Like Production Flow



Inverse Tree-Like Flow is typical of assembly industries. There is a multistage flow of processing and manufacturing operations, as well as interim and final assemblies. A wide variety of materials, parts, elements, and components go into the production of systems and aggregates before reaching one or a range of final products. In an ideal case, all the times of the operations should be synchronised across all multistage flows. A pipe dream that we can't make happen…

If there is a waiting product, it is not in the warehouses of the intermediate or final assembly. It is not waiting in the last phases of the chain. The product waits at the beginning of the chain, in the suppliers of parts and components. It is difficult to organise such a flow. In the end of the chain is used Just-in-Time in purest form. The product is delivered as much as you want, when you as want, where you want, and with whatever quality you want. If you are not capable of working in this way, you must maintain stock of finished product, ready for shipment.

09.10.04. Network Production Flow

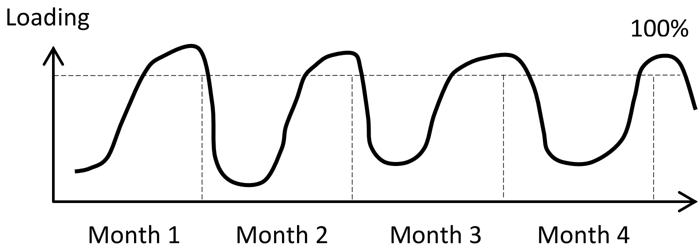


Network flow is typical for shipbuilding, construction, heavy machinery building industry, and other project-organised sectors. The so-called Critical Path is of key importance. The Critical Path is that continuous sequence of operations in which all the operations are without reserves of time and/or work resources.

Then it is done like this – we try to shift resources from non-critical operations, in which there are some reserves, to other operations lying on the Critical Path, in which there are no reserves. In this way, we can resolve the following task, that is always difficult. On the Critical Path lie operations without reserves, they cannot be performed in a shorter time. However, by shifting resources from non-critical to critical operations, we shorten the times of critical operations and even manage to implement the whole project earlier than the set deadline.

09.10.05. Cyclic Irregular Flow

Here is a cyclically uneven production flow due to month by month planning. Many factories work with such a cycle of planning and loading the production.



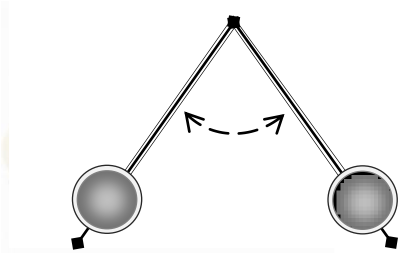
The first days of the month are very tense because we have to resolve countless number of unresolved problems from the previous month. Then follows a period of self-calming and the work pace slows down. At the end of the month, we have to force the work again because we are behind the production plan again. Production fluctuates every month in a wide range. This is not so much due to uneven customer demand but mostly because of a poorly thought-out anti-production system for planning and reporting the current production costs. We disrupt the production flow ourselves, often damaging our own interests due to the otherwise good idea of simplifying the planning and reporting procedures. By simplifying planning and accounting so wisely, we give birth to cyclically uneven production. We have forgotten that planning and reporting (they do not exist on their own) should help production to flow evenly and be manageable.

09.10.06. In Summary for All Forms of Production Flows

The sequential production flow can be easily transformed into One-Piece Flow. It is more difficult with tree-like production flows. The most difficult to achieve, and in practice it is almost impossible, is to do this in network production flow.

Thus, we come to the conclusion that, when designing complex flows, these three rules must be observed. The first rule is to avoid branching and merging their constituent flows. The second rule is that intersections and reversals against the direction of the main flow are absolutely taboo. The third rule is that the principle of One-Piece Flow is not a dogma and that, if there is no way to achieve such a flow, we must either put up with it or look for other technological solutions that bring production logic closer to that of the industries of a sequential type.

09.10.07. The Pendulum Effect



The cyclical Pendulum effect is painfully notorious to some of more experienced managers... There is a high readiness to produce, but there are not enough orders. That's why the managers get on their high white horses to look for orders with all their energy. They find orders, the orders rain down on us in full buckets but in the meantime we have completely forgotten how to produce. Once again, our managers make haste to restore the neglected readiness for production. While they are busy restoring readiness for production, we again do not have enough orders for production. And this meaningless dance never stops.

Why is this happening?! This is because managers feel unsure if they really hold the reins of the company. They want to have their finger in every pie, and as a result, the contact between production planning and commercial activities is lost.

This type of production in waves is four times as harmful.

First, it is harmful to our image in front of customers – on the one hand, we bow to them, and on the other hand, we do not always manage to perform the orders with quality and on time.

Second, it hurts our image in front of suppliers because we are unreliable buyers.

Thirdly, it damages the attitude of the personnel towards the company, which either cannot provide work or, on other occasions, overwork them.

Fourthly, it is harmful to management both because its time is spent inefficiently and because it loses authority both in front to customers and suppliers and in front to personnel.

09.11.01. Goldratt's Fat Boy

You must have read and loved Eliyahu Goldratt's book, The Goal. It is a fascinating read with a figurative and clear description of the Theory of Constraints.

There is an edifying story in the book. It is about a group of boy scouts hiking a mountain route with a few adults, their fathers, and the scout instructors.

From the beginning, the column begins to stretch out because some children are stronger and agile, while others are feeble and clumsy. So, the column stretches.

When the column is stretched out, the children who are out in front stop and wait for these at the back. These at the back catch up with their tongues hanging out. The ones at the front break away again, and the column is stretched again.

The adults wonder how to achieve an equal pace. They come up with a brilliant idea: To tie the left legs of the children to each other with a rope so that they walk in the same rhythm. A truly brilliant idea! This idea is an illustration of how Muri can spring up one after the other due to one ultra-smart management system.

At some point, they see the smiling and panting face of the fat boy in the line. Not only is he fat, but he's carrying a huge backpack stuffed with cakes, slowing down the entire column. His backpack is heavy, and the fat boy stops frequently to eat.

So, the adult sages put the fat boy out at the front to set the pace. The fat boy sets a perfect pace, as a result of which the whole column barely moves forward.

After some time for deliberation the adult sages decided to remove the cakes from the fat boy's backpack and moving them into other children's backpacks or simply eat them. The fat boy is now moving at a faster pace, but the other children are now moving more slowly because their backpacks have become heavier.

So, they decided to redistribute the luggage so that the stronger ones carry more luggage, the leaner ones less luggage, and so everyone walks in an even rhythm.

In the case of the boy scouts, we transferred resources from one operation to other operations. At the beginning of the hike, the children started out with different loaded backpacks, and at the end, they had equally loaded backpacks.

We put more load in the backpacks of the stronger agile children and lightened the backpacks of the feeble clumsy children. We evened out the work capacities, so we evened out the operation's times, and we create a flow with even rhythm.

Fat boy is the slowest operation who sets the pace of the entire production flow.

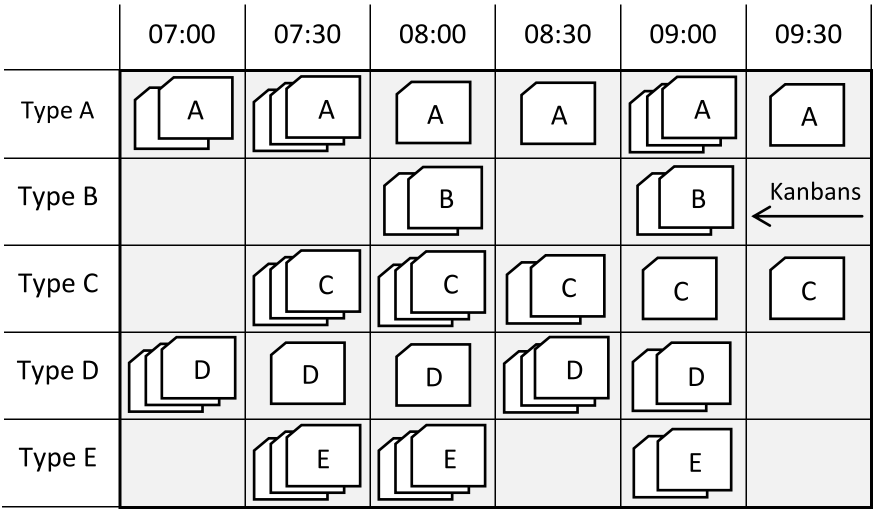
09.11.02. The Slowest Operation Predetermines the Flow Tact

What do we have to do? There are slow operations and fast operations. We have to try to equal up the times of the operations. How do we equal up these times? We'll equal up them by transferring resources from the fast operations to the slow operations. We'll put more highly skilled personnel on the slowest operations.

At the slowest operations, we will avoid unnecessarily wasting time, for example, in keeping records or training new workers. We will shorten the times for changes and readjustments, and we will ensure the equipment is always in good condition. We will supply them with suitable materials in a timely manner. That's the idea...

09.12. Heijunka Box

(Levelling Board)



For the purposes of levelling the flow, a Heijunka Box (Levelling Board) is used. Since the 1950s, the Heijunka Box has been something of a box file with nests.

Each column of nests in the box manages a certain time interval – from 7 o'clock to 30 minutes past 7, from 8 o'clock to 30 minutes past 8, and so on.

Each row of nests uses Kanban cards to manage the start and stop moments of production of several types of products – type A, type B, type C, type D, and type E.

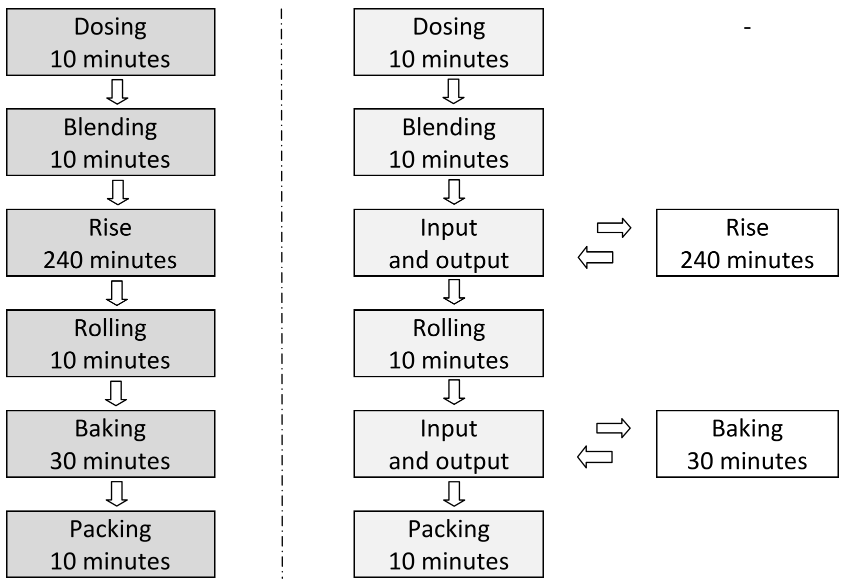
Kanban card is something like a production order for a single operation to produce a given quantity of the product or to relocate a given quantity of the product from the site of that operation to the site of some other operation.

If the flow permeates into different production units, and especially if they are territorially and/or organisationally very different, these Kanban cards are issued by the production's planning centre or production dispatching department. When the flow or a separate part of it is executed within a single unit, the Kanbans are issued (and released) by a designated person for this unit.

Today, the Heijunka Box is most often created in the form of a spreadsheet. However, the Heijunka Box with nests has not been discarded to oblivion because it gives a much clearer visualisation of the order of the sub-series.

We have seen Heijunka Box being used in the factories Liebherr-Hausgeräte Maritsa in Plovdiv City, Festo Production in Sofia City, and Tesy Boilers in the town of Shumen, and in several more factories, mostly these of an assembly type.

09.13. Flow with Technological "Pockets"



This is particularly the case for processes with large differences in timing of operations. This is a clear illustration of such a process in the food industry.

The sequence of operations is as follows. Dosing and mixing of ingredients – 10 minutes, rising – 240 minutes, rolling – 10 minutes, baking – 30 minutes, packaging – 10 minutes. The total time for the whole process is 310 minutes.

Two operations disrupt the flow: rising for 240 minutes and baking for 30 minutes. All other operations have equal and much shorter times – 10 minutes.

There is a way to balance the flow, and it is with so-called Technological Pockets.

Let's imagine that the production flow moves in a straight line, but where there are long-lasting operations, we "move" them to the side of this straight line.

The flow is still a consistent FIFO flow. But it is flowing in a new way – dosing, mixing, introduction of dough for rising, rising of the dough, outputting the raised dough FIFO according to the order of introduction, rolling out, introduction of a product for baking, baking of the product, outputting the already baked product FIFO according to the order of introduction, and finally, is the packaging.

To the left of the diagramme on the previous page, we have the total time – 10, plus 10, plus 240, plus 10, plus 30, plus 10, a total of 310 min. for the entire process.

To the right part of the same diagramme, we have a total time for the entire production process of 60 minutes, all operations are with equal times, running in synchronised, and the entire production process is running with an even rhythm.

This is the magic of balancing the flow through technological pockets. In other industries, too, there may be operations with relatively longer times within a single process, especially when single and group treatments (such as sandblasting, cleaning, heat treatment, electroplating, varnishing, etc.) alternate in the process.

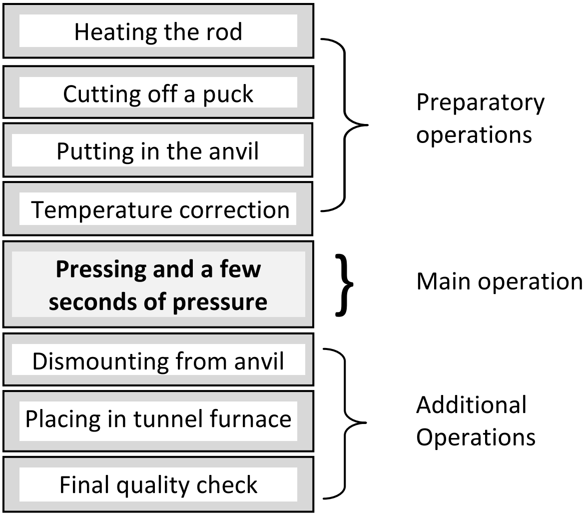
In some books on Lean, the above uniform flow of technology pockets is called Tsurube System – the idea comes from a well water pumping system in which the descending and the ascending full bucket are driven in parallel by the same reel.

The idea of smoothing the flow through technology pockets also has its place in the case of large differences in the times required to move a product from one operation to another, or if the operating or transport times are quite different.

A typical case is the removal of some operations outside the main production line.

The same idea applies to the case when some operations are subcontracted or carried out in buildings of the same factory but away from the site of the main line.

09.14. The Tact of the Flow Is Set by the Core Process



An example is the thermoplastic technology for forming optical lens. The raw material is a cylindrical rod of optical glass. The end of the rod is heated until it softens like French cheese. A guillotine cuts cylindrical blanks. Then they put the plasticized blank on the press anvil. But because the press has cooled down while he waited the temperature of the anvil must rise. All of the operations are preparatory operations. The drop hammer of the press presses the plasticized blank and holds the pressure for five seconds. Only pressing and holding are main operations. Only the main operations give a customer value – the lens geometry. After pressing, there is a rough edge which needs to be cut off with scissors. Then they put the lens in a preheated tunnel furnace. It has a certain temperature gradient along its length. The aim is to release the lens from internal stress. Most of the listed so far operations are auxiliary operations. The pressure of the pressing machine and the hold time together last only five seconds. The production could be arranged in such a way that the press is constantly working and every five seconds he produces a lens. The tunnel furnace has the capacity to take them. But due to irrationally planned preparatory operations, in practice, a rhythm of three minutes per lens is attained. In reality, the main operations take only five seconds, and the process in its entirety takes three minutes, sometimes more. What benefit is it that the equipment enables the main operations to last only five seconds when the Lead Time is three minutes.

We will insist and many times repeat in this book that, in quite a few situations, we do not use completely the capacity of the main operation due to insufficient capacities of any preparatory, finishing, additional or other auxiliary operations.

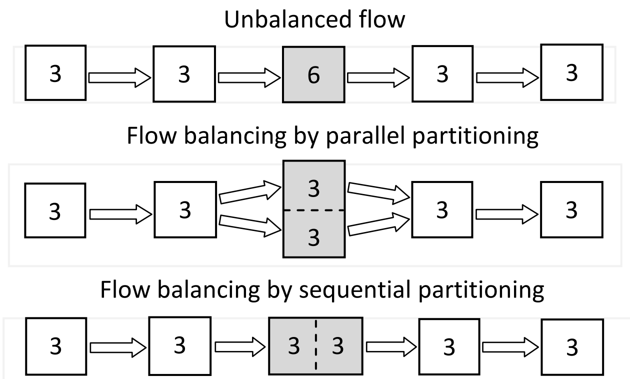
09.15. Flow Balancing with Considering the Bottleneck

Quite often, the capacities of different operations are not equal to each other.

The timing of the first operation in the production flow must be consistent with the capacity of the bottleneck. If the first operation produces more than the bottleneck can take, the waiting products pile up in front of the bottleneck.

When the rhythm of the first operation in the flow is consistent with the capacity of the bottleneck, there will be an even flow. Well done, congratulations to us! But then we may forget that we need to unclog the bottleneck too. Another trap we will fall into is the delusion that it no longer matters whether the production flow is push or pull, in both cases, the production throughput is the same. But we are connoisseurs dyed in the Lean idea, and these pseudo conclusions will not fool us. Let's formulate the principle backwards: If the first operation in the flow fails to fill the capacity of the bottleneck, then the incomplete capacity of the bottleneck will reduce the throughput of production in its entirety. This simple principle is more than important and should never be ignored...

09.16. Flow Balancing in Case of Unequal Operation Times



An unbalanced production flow with unequal operation times is seen on top of the scheme. The time of the first operation is three minutes; of the second operation is too three minutes; but of the third operation is six minutes, not three minutes.

A possible solution is seen in the middle part of the diagramme on the previous page.

This solution is to create two parallel workplaces for the third operation. He will still be carried out in six minutes, but it will be carried out simultaneously in two workplaces, and the resulting time for the operation is already three minutes.

This solution doubles the speed of the flow. There are already 20 items per hour.

Another possible and very interesting solution is to divide the long six-minute operation into two consecutive shorter operations of three minutes each of them.

And here, the rate doubles from 10 to 20 items per hour. The total time for the process is the same, but without the hold ups in the 6-minute operation.

If we leave the 6-minute operation as it is, without splitting it in either of the two ways that we have just shown, this 6-minute operation will create a queue in front of it. It cannot be compensated without buffering the next operations with pre-operational buffer stocks (they are redundant stocks, i.e., they are Muda).

Parallel workplaces for production flow balancing are more commonly applied in assembly industries. We also see parallel workplaces in manual operations in production flows where manual and machine operations alternate – for example, manual packaging operation and mechanised uploading on the rack operation.

Dividing a long time operation into two or more successive operations with shorter times is seen mostly in the manufacturing and processing industries.

In order to balance the production flow, we divide the slow executed operations down into a series of faster sub-operations, or we create parallel workplaces.

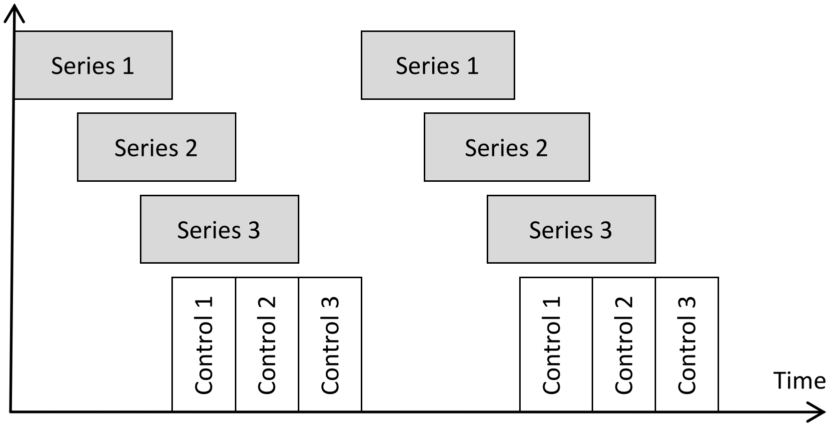
Instead of doing parallel workplaces, we can shorten the times of slow operations by increasing the workers number in them or introducing high-speed equipment.

How to do? It is another matter. The topic of flow separation is a broad topic for industrial engineering. This is because there are different types of flow separation – by products, by series, by types of equipment, by technologies, by customers...

All this must be carefully taken into account both in the design of the production layout and in the logic of operative management of the production schedules.

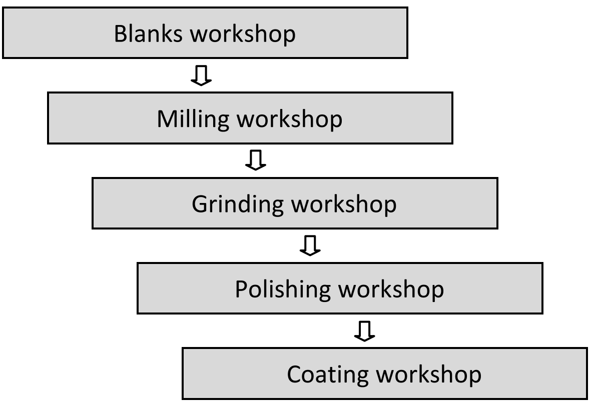
Here we consider the principle of balancing at different operating times. The solution is given by technologists, industrial engineers, and production organisers.

09.17. Flow Unbalancing When Using a Shared Resource



This is a case of unbalancing the production flow due to the use of a shared resource. Here, the shared resource is the working time of the quality controllers to check several almost parallel produced series. Series of different products are running in the production. On the above diagramme they are variously labelled. When a series is completed, there is acceptance quality control. There are moments when the acceptance control is overloaded. There are other moments, and there are plenty of them, when acceptance quality control stands jobless. If we shift the moments of starting the production of the individual series, we will be able to evenly load the shared resource of acceptance quality control.

09.18. Flow Delay Due to Daily Reporting of Produced Quantities



On the diagramme of previous page, we can see five production workshops. The process runs in the order of workshops. Various operations are carried out in each of them – preforming, milling, grinding, polishing, and applying optical coatings.

Each workshop reports its daily production output at the end of the day and passes it on to the next workshop, which starts working on it at the beginning of the following day. Under this reporting system, the total time cannot be shorter than 5 days, although the total technological time is on order of hours. The rest of the time, the product sleeps sweetly, and intermediate stocks are accumulated.

Often, the duration of the production cycle is doomed and destined to be long, not because of anything else but because of the system of planning and reporting the produced quantities. This is absurd, but it is as absurd, as it is real, because in many Bulgarian factories and plants, this is exactly how it is done – a workshop or a technological organisation of the production with planning, reporting, and transfer of produced product from one unit to another unit in a one-day cycle.

09.18.01. Overlapping Inter-operation Batches

The problem of One-Piece Flow is that there will be downtime between operations, if the next operation does not have immediate readiness to accept the work from the upstream operation. We solve the problem like this. At least one of the two operations maintains a buffer of one or more units of the product.

Buffer compensates the waiting time due to the lack of readiness for acceptance.

I will illustrate this solution through an example of how we have worked on translating this book with Dr David Mossop. The 816-page text was we broken into portions of 30-40 pages each. As a result, I (upstream operation) do not clog David (next operation) with a product that is pending with him. If I submit the next portion barely after David has returned the translation of the previous portion, the process is delayed by the empty time between receipt by and sending to David. Empty times are these when I am not in front of the computer (having lunch, travelling, or something else). They would lead to an extension of the total time for translation of the book by 40-50 days or more. The delay was saved in a simple way. I not send David the portions one by one but two by two together.

So, I provide David with a high degree of readiness for acceptance. The One-Piece Flow ran uninterruptedly, and we shortened the Lead Time of the entire process.

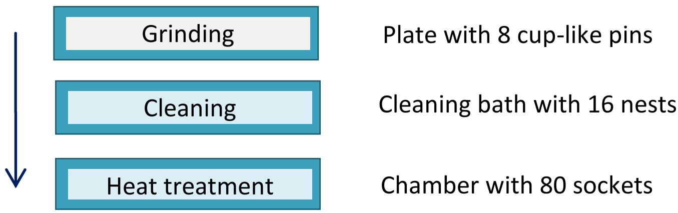
The conclusion here is that we should not perceive One-Piece Flow orthodoxly.

Products are processed one by one and operations are performed one by one, that's right. But it doesn't mean that products move from operation to operation one by one. And it does not mean that, before the next operation and/or after the previous one, there are no appropriately sized buffers that can compensate for any differences in delays and/or in the performance of individual operations.

09.19. Flow Imbalance Due to Expensive Operations or Weak Resources

If we want to balance capacities, sometimes it makes sense to proceed from considerations related to the high cost of one or another operation. This can be an operation performed on expensive and unladen equipment, which very slowly pays off. Or we have a group processing operation. Or an operation performed on equipment that cannot be stopped (in a glass factory, you cannot stop the melting furnace). Or an operation performed on equipment that requires particularly high qualification. There are great risks in such productions because only two or three specialists know the technology well, while all the other workers are illiterates. The specialists command the production (this is called "worker's autocracy"), and the production process becomes constantly dependent on "aristocratic workers".

09.19.01. Caution! Group Processing!



Here is an illustration for balancing the production flow by proportioning the capacities of the technological devices for group processing. There are three consecutive group operations – grinding, cleaning, and heat treatment. It is ground on a plate with 8 cup-like pins. The pins are fixtures through which the optical components are positioned and fixed. Cleaning is carried out in a bath for 16 components. Heat treatment is done in a chamber with 80 sockets, that is, for 80 components. The number 80 is divisible by the number 16, and the number 16 is divisible by the number 8, that is, each series is a multiple of 80 – a series of 80, 160, 240, 320, etc., goes through the three group processing without retention. There are 5 baths for cleaning and 10 grinding plates. They fully cover the volume of the heat treatment chamber. The entire process runs smoothly and quickly.

Grinding	Plate with 12 cup-like
Cleaning	Cleaning bath with 27 nests
Heat treatment	Chamber with 90 sockets

Here, I have deliberately unbalanced the flow. In the above illustration, the numbers of beds in the group processing devices are not proportioned. Whatever e do, we will have an incomplete load on the group processing devices, and along with this, we will have queues and we will have unfinished production. Here is the conclusion – when planning and designing technological devices for group processing, we must take them into account with the lengths of the series. We are supposedly saving money for the design and production of group processing devices, but we are condemning the production flow to be unbalanced, as we will have devices for grp processing with underloaded or with resized capacities. The operation, instead of doing it N times, we do it several N times.

At any length of production series, there will be parasitic wait times and parasitic stocks and queues between operations (on the one hand) and underloaded capacities of technological devices for group processing (on the other hand).

When we talk about the group processings, we need to be careful because it is not always true that they lead to economic or technical benefits. By the way, every textbook for industrial engineers says very clearly that when you are aiming for high-precision workmanship, you're running far away from group processings.

One of our clients makes products from pipe material, and his people have decided that it is too laborious to cut the pipes one by one, and that is why they package them in a bundle. The packs are of 12 pipes, fastened with an elastic belt for car rack, and fixed with an electric drop welding. They have to cut a six-metre pipe into one-metre pieces. If the pieces are longer than a metre, there is a solution, and it is additional filing. But if it's under a metre, it's discarded as technological remain. People there have come to the brainless decision to cut each work piece longer than the nominal length for the final product. As a result, the technological waste weighs almost as much as the blanks do.

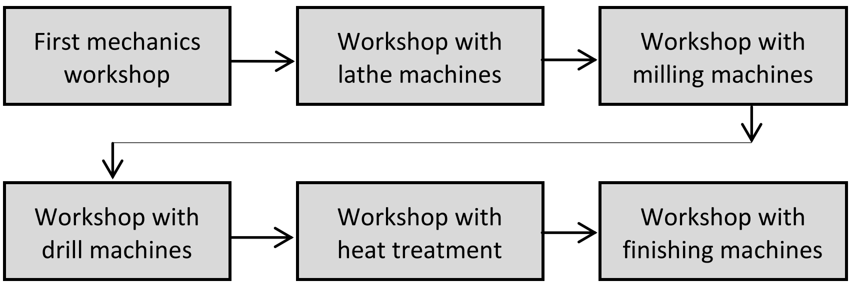
We need to be suspicious of group processings. They leads to a lot of Muda, requires to make additional devices, requires more space, reduces the yield of the material, prematurely wears tools and machines, and wastes technological consumables. In group processings, there may be a discrepancy between the number of items and the customer order. In this factory for pipe products, the pipes are cut into 6 pieces of 1 metre. The customer order is for 40 pieces. So, they are going to need seven pipes, which make 42. What do they do with the two left over? They put them somewhere and tell themselves that they will need them someday. But with poor identification, it's hard for them to find exactly where they have put them. From the point of view of Lean, group processing can provide an interesting simplification. They allow us to level and balance the flow in processes which alternate operations with long and short times and/or that alternate single with group processings. Let us look at three cases.

First case. In a fast-food restaurant the preparing of meatballs is a group process. The technological order is: kneading minced meat, forming meatballs, frying, reheating, and serving. We knead minced meat as much as the expected maximum daily consumption. We shape meatballs during the intervals when we have no or few customers. We fry as many meatballs as the empty volume of the reheating oven. We put as many meatballs in the pan as can fit. We put them in and take them out of the pan one by one. We put them in the heating oven. And we arrange them in as many plates and with as many meatballs in them as the current consumption. We serve them to customers. In this process, single operations (meatball after meatball) are shaping, placing, and removing (in and out of the pan, in and out of the reheating oven) and arranging them on the plates. Group operations (several uncooked meatballs or several fried meatballs) are kneading, frying, reheating, and serving. The second case is homemade production of 12 litres of juice from pears. Here the technological order. We cut 16 kg of pears into pieces (one by one, total 16 kg). We do the following twice. We blend 2 kg at a time. We pour the juice into jugs of 1.5 litres, remove the froth, pour 6 litres of juice into 8 bottles (one by one), and pasteurise them in a saucepan (group operation). While the pasteurisation is going on, we clean the blender. We blend again, pour into jugs, and remove froth. We remove the bottles (one at a time) from the pot, put on and screw caps (one at a time), and put the bottles to cool (two at a time). We repeat these operations four times. The process of production of the pear juice includes four overlapping sequences of group and single operations. The process goes on without stopping.

Third case. An optical production with such a technological sequence – blank cutting, blocking, milling, grinding, polishing, unblocking, cleaning, centring, then again cleaning, coating, varnishing and packing. The lenses are processed one by one during blocking, milling, unblocking, centring, varnishing, and packaging. Group operations are blank cutting, grinding, polishing, cleaning and coating. The process proceeds without stopping and without fluctuations if the productivities of all types of workplaces are equalised and if the capacities of all the group processing tools are equalised or are multiples of each other.

09.20. Classic Models of Production Organisation

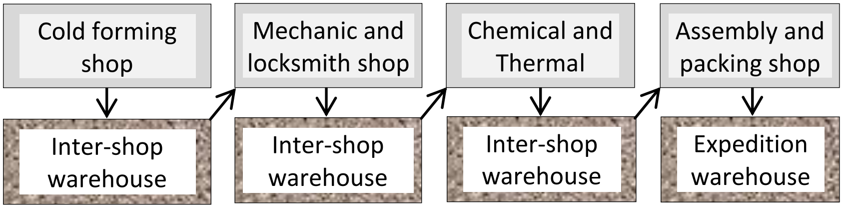
There are classic models for the organisation of production in the industry. These classic models for production organisation are not always suitable for Lean.



The scheme shows machine (workshop) organisation, in a factory for mechanic components. Given this type of organisation there are separate workshops, each specialised in the types of machines in them – a workshop for first machining, a workshop for lathe machines, a workshop for milling machines, a workshop for drilling machines, a workshop for heat treatment, and a workshop for finishing.

This is good solution for large scale production and small product nomenclature with relatively regular and proportional market demand for individual products.

If the product nomenclature is wider, if the technological mix is different for the different products, and if the series are short, this type of production organisation is unsuitable. There will be unevenly loaded workshops, unfinished product, and/or big volume of inter-shop stock and inter-shop transport. Traceability will be affected. Poor quality will be seen too late. The production cycle will be extended.



The technological organisation is similar to the workshop organisation. However, workshops are structured not by types of machines (or by types of operations) but by the order of the technological process. The scheme shows such an organisation in Odessos, a factory for metal-ceramic pots and pans in Varna City. This is a good scheme for cyclically repeating and proportional in volume, medium to long series of technologically similar products. This organisation can be applied to shorter series, but then it will be difficult to avoid inter-shop warehouses. They are needed to buffer the inevitable and often large differences between the throughputs of individual workshops. In medium and shorter series, these differences arise from the variable product and, respectively, technological mixes.

Products A – Chain hoists

Site A.1	Site A.2	Site A.3	Site A.4	Site A.5

Products B – Bridge cranes

Site B.1	Site B.2	Site B.3	Site B.4	Site B.5

Products C – Rack constructions

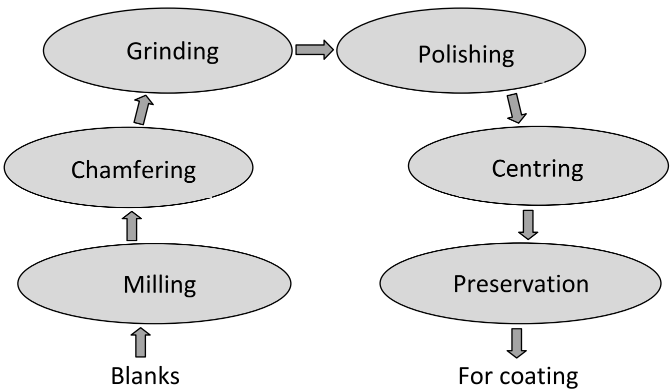
Site C.1	Site C.2	Site C.3	Site C.4	Site C.5

Product organisation (also called Divisional Model). This is Skladova Technika, a big factory in the town of Gorna Oryahovitsa. There are lines, specialised by type of products – chain hoists, bridge cranes, storage racks, cooking ovens, and fireplaces. These are few almost autonomous factories on a common ground. Some capacities are duplicated in most of the lines. For example, there are drilling machines in all lines. A disadvantage of the divisional model is that in some parts of the year, certain lines may be busting at the seams from work, in other part of the year, they may be out of work. If one line works and another stops, there is no way that the working line, that doesn't have the drilling capacity, to use the capacities of the line which has stopped. Despite the variable load of different lines, money always enters the company as a whole, which is a plus.

A similar model is used in the production of the same type of products with different dimensions or other significant differences in the constructive solutions and/or in the used technologies. For example, in an electric motor plant, there are separate lines for different diameters of rotors and stators. Another example – in a confectionery factory, there are separate lines for cakes, biscuits, and waffles. Third example – in a weapons plant, there are separate workshops for pistols, rifles, machine guns, grenade launchers, and the different ammunitions for them. One attribute of the divisional model is that individual product lines are served by units common to the entire factory (material warehouses, blanks workshops, instrumental warehouses, and pre-shipment warehouses) and by common departments (maintenance, personnel, financial, purchasing, sales, and others). A divisional model is used by some defence product plants, major food and chemicals producers, pharmacy and cosmetics plants, and other heavy-tonnage sectors. It is also used in general hospitals. A divisional model is mainly used in industries with conditionally continuous or continuous processes with relative constancy of product nomenclature and long or very long series. Therefore, in most cases, although the flow is of the type Push Flow, it is not subject to fluctuations.

The other two classic production organisation models (technological model and machine model) do not allow for or barely allow achievement a continuous flow.

Cellular Organisation (Island Organisation) in Optical-Mechanical Plant



Any model for the organisation of production has advantages and disadvantages. We will find out more about the cellular (island) organisation. It is one of the foundations of the Just-in-Time model. These are nearby located workplaces covering all or a separate group of related manufacturing or assembly operations.

Here we have milling, faceting, grinding, polishing, centring, and canning. All of these operations are connected with the production of optical elements.

In the optical industry, the centring process allows the optical axis of the lens to coincide with its geometrical axis because they may differ significantly due to the "wedge angle" defect (it is a violation of the parallelism of both sides of the lens).

In a cellular (island) organisation, it is important that the workplaces are close together. In the best case, the workplaces are arranged so that people, like on a picnic, are seated facing each other, and everyone can see and hear the others. The distances between workplaces are short, so with a normal voice, or slightly louder but still without a megaphone, the person next to you can hear you.

In some particular cases, the cellular organisation can be considered as a miniaturized variety of the product organisation. This organisational model is important from a Lean point of view, and we will address this in more detail later.

Let's imagine that we have a polyvalent worker whom we have taught to work equally well in all related workplaces. Demand is low. While demand is low, this polyvalent worker covers all workplaces. The demand rises, and at some point, the worker does not have the strength to cope. Then a second worker comes along. The demand continues to rise. Then along comes third and fourth workers.

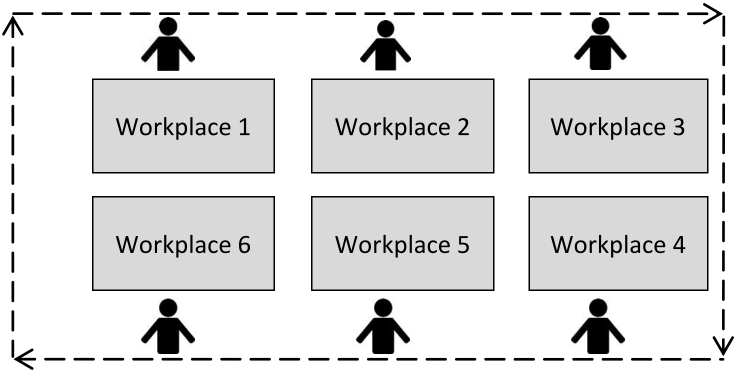
If, in some subsequent moment, the market demand rises further, then we transform the cell into a conveyor. However, this is not a conveyor belt with low-skilled and narrowly specialised workers attached to stationary workplaces.

I am talking about a conveyor in which the worker, along with the product, moves from one workplace to the next. They go around all the workplaces and perform all the operations involved in production the product, from the first to the last.

Let me say it again. Cellular organisation has two very important characteristics. One is that cellular organised workplaces cover all or several related operations for the production of one or a group of products. The second characteristic is that in the cellular organisation, the workplaces are located in such a way that from each workplace there is good visibility and good audibility, that is, good communication, to all other workplaces. The workplaces are arranged in the form of a circle, an ellipse, a horseshoe, or with the shape of the Cyrillic letter "П".

Workers form a team and perform a team production task or production order. They execute the task or the order as a team, each with their own personal contribution in the result. There are no individual planning assignments and there are no pay-per-piece. There is team assignment, team reporting, and team pay.

09.20.02. Workplaces Rotation Conveyor



This is what a conveyor with a workplaces rotation looks like in its simplest form. There is a difference from the classic conveyor. There, people are attached to the workplace, and the product moves along the conveyor, but people do not move. In a conveyor with a rotation of workplaces, workers are not profiled for a single operation, they are not "married" to it. They know how to do every operation of the entire process. They move together with the product in diverse workplaces.

I saw a conveyor with a workplace's rotation for the first time in 1986 in France in Delsey car seat plant. It was impressive. The worker walks with the seat from one workplace to another, from the bare chassis, through all operations to the final seat test. If everything is fine with the seat, the worker puts a label in a pocket under the chassis. The label bears the name of worker who assembled this seat. The training of a new worker is interesting. There are three types of operations – simple, complex, and most complex. They put the novice on a simple operation. He does it under the supervision of the entire team until they all sign in a notebook that he has mastered it. He goes to the next simple operation until he's done them all. Then he goes to the more complex ones. Finally, he's an equal member of the team, and he goes around the conveyor belt with everyone else.

09.20.03. Conveyor with Fixed Workplaces

Let's go back to the classic conveyor with fixed workplaces. The process is broken down into a large number of simplest to perform operations. Operations are so simple that a newly hired worker can absorb them in a matter of minutes. The worker does not need to be qualified or trained. The worker does not understand the role of the operation for the proper execution of the next operations, nor the significance of the operation for the function and quality of the final product.

It is no need for the worker to be motivated for high productivity – the conveyor speed commands the flow speed. There is no need for motivation for high quality – an army of inspectors and a foreman is breathing down the necks of the worker. The worker is paid by piece work (number of products, number of operations)

I said it in Chapter 01 that at the end of the nineteenth and the beginning of the twentieth century, this type of organisation of the production was in part a consequence of the labour market of that time – poor and illiterate wage earners.

The conveyor with fixed workplaces proved itself in the First World War. Then the strong young men were at the battle fronts, and the feeble women, children, and old people were working on the conveyors. The conveyor, born in the automotive and weapons industry, rapidly entered in all other assembly industries. It then enter in industries of a sequential type – mostly in the light and food industries.

It is not always a conveyor belt with a mechanised relocation of the product from one workplace to another. It could be a line, composed of close from each other workplaces with small buffers between them. The conveyor with fixed workplaces is a very strong means of increasing productivity, and no one would dispute that.

The problem is that this organisation model detaches the person from the fruits of his labour, which disrupts quality care, and there's not room left for motivation.

Here are two tragicomic examples of hyper-specialised labour. The first example is from the 1980s, and the place is a sewing conveyor in a factory for men's suits in Varna City. The cycle of physiological breaks is 55 minutes of work, 5 minutes of rest. Women on the conveyor are specialised in one or another operation. Most of them are older women, they need to go to the toilet sometimes often. Several more experienced women are able to perform all the operations, so they could temporarily replace women who are currently in the toilet. These women with universal skills were referred to as the "pee-pee girls", and they were affectionately addressed as follows, "Come, pee-pee, take my place for a while".

The other example was also from the 1980s. I visited a big factory for men's shirts in the town of Panagyurishte. We around and looked at the factory with the chief technologist, and she was explaining to me what was done, where, and how. In one room, I saw a mountain of shirts piled in the corner. To my inexperienced eye, these were ready-made shirts. I asked why they don't iron and pack them. It turned out that these were shirts without a left sleeve. The explanation was, "One of the women, specialised of the left sleeve attachment, is arranging her son's wedding and took two days off. She'll finish them off when she comes back".

A big psychological and social problem of the conveyor organisation of production is that it leads to deepening alienation between the individual workers themselves.

In the sewing factories, the work tables are arranged in a row, and before the eyes of each woman all day, there is the wonderful sight of the backs of other women.

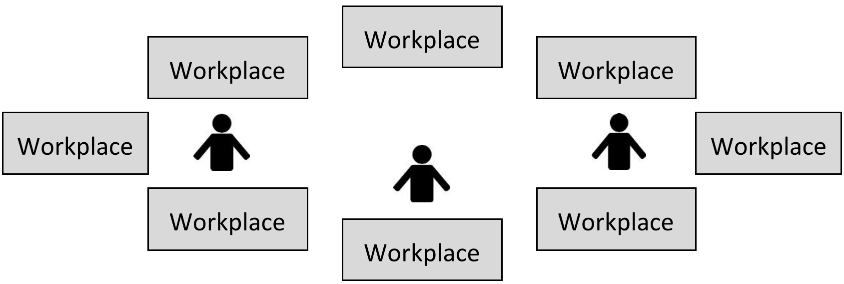
We did a very interesting experiment in one sewing factory in Plovdiv City. We rearranged the desks so that the women sat in groups of six, facing each other like a passengers in a railway compartment. In the early days, productivity plummeted because the women, face-to-face for the first time, competed to tell each other all the happy and sad incidents of life. After a while, the productivity reached its previous values, but the number of inattention errors sharply decreased.

We have to be careful with conveyors with fixed workplaces. People specialise in one operation, they do it for eight hours every day, every week, the whole year.

They don't like the work, they hate the boss, they hate the company, they hate the colleagues, they hate the whole world around them, they hate themselves.

I would like to tell Charles Darwin that it was not labour that turned monkeys into men but that the conveyor turned man into a monkey and robbed him of the proud name Homo sapiens. In reality here we see the complete fall of Homo sapiens!

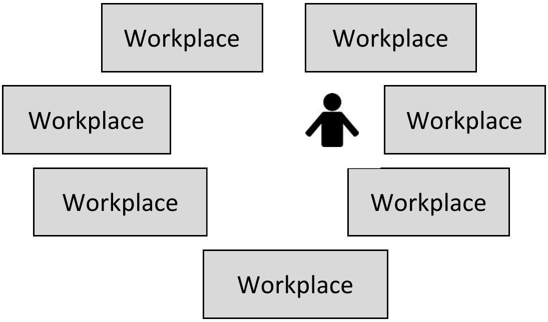
09.20.04. Island Organisation (Cellular Organisation)



We back on the islands with their plentifully equipped workplaces and with the polyvalent workers, few in number, who can serve any workplace. Usually there is no set sequence in which the product relocates from one workplace to another. The worker decides for himself which free workplace to go to in order to do his work. In most island organisation configurations, the adjacent zone, if common to all workplaces, may be located in the centre of the island or beside the island, or near the least loaded workplace. Or each workplace has its own adjacent zone.

Usually the workplaces number is greater than the workers number. This is the case if the cost of the machine time is lower than that of labour. However, the rise in the price of labour is a lasting trend which is inevitably catching up with us.

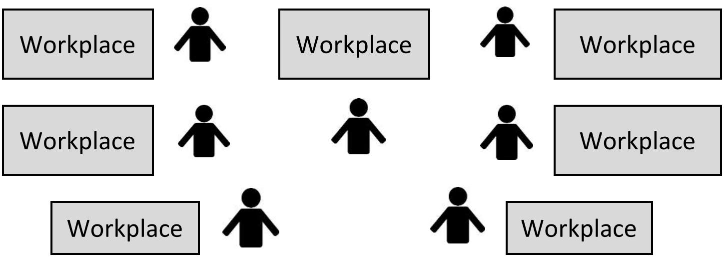
09.20.05. Sparsely Populated Island



A Sparsely Populated Island is a flexible solution for sudden changes in the lengths of the production series. We saw it on page 293 in this chapter. One polyvalent worker serves all workplaces. Even in some cases, a part of the workplaces are not active, if there is no technological need for them for the product currently under production. The unnecessary workplaces are covered with canvas covers, marked as temporarily unusable, or otherwise isolated from access. When the market demand rises, we add a second, or a third worker, etc., to the island. At a given moment, by overcrowding the sparsely populated island, we turn it into some kind of horseshoe, and then into a conveyor with workplaces rotation.

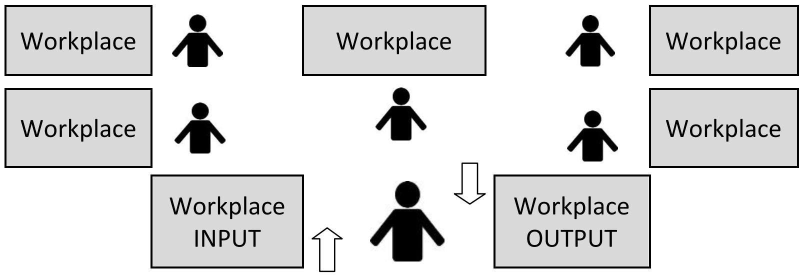
The interesting advantage of the sparsely populated island is that, given this type of production organisation, it is possible to work with a flexible working time.

09.20.06. Horseshoe



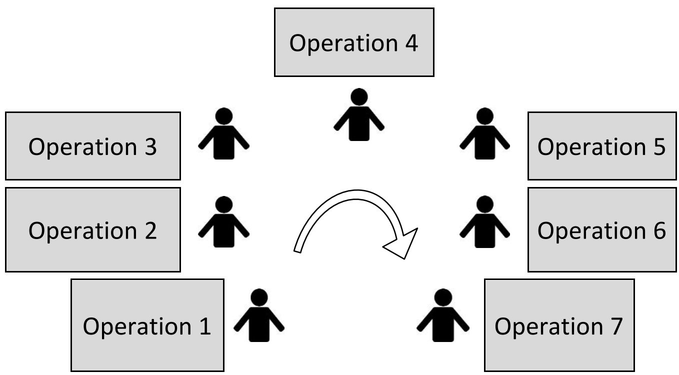
The Horseshoe model is a common form of Island Organisation. While in the classic island organisation does not have a specific direction or sequence for relocating the product, at the Horseshoe organisation are defined a direction and sequence in which the product is relocated from one workplace to another. In this and in the scheme below, the product relocates clockwise, assuming that all workers are left-handed. If they're right-handed, it'll be in the opposite direction.

09.20.07. Closed Horseshoe



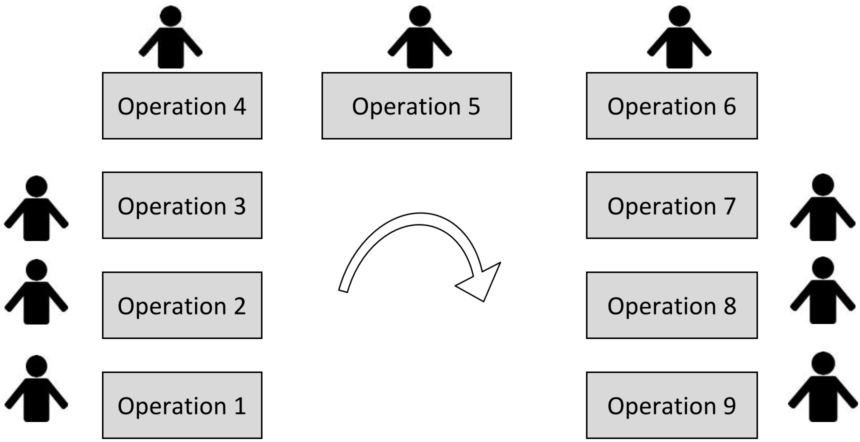
This is an interesting solution. The same worker is at the first and last operation. He fills and empties the horseshoe. This is how he "commands" the tact of the production flow. For example, at the input to the horseshoe, the worker checks the completeness of the assembly kits, and at the exit, he labels the products assembled in the horseshoe. By default, all operation times along the flow are well synchronised. This means that when producing different products in a short series, all products must have a similar technological mix.

09.20.08. Horseshoe with Workers Located INSIDE



The workers are close to each other "at arm's length". The product is passed from person to person. There is no need for inter-operation buffers. But there's a problem! Workers stand back-to-back and do not see each other. In this scheme and in the closed horseshoe, the product moves clockwise, assuming that workers are left-handed. If they're right-handed, it'll be in the opposite direction.

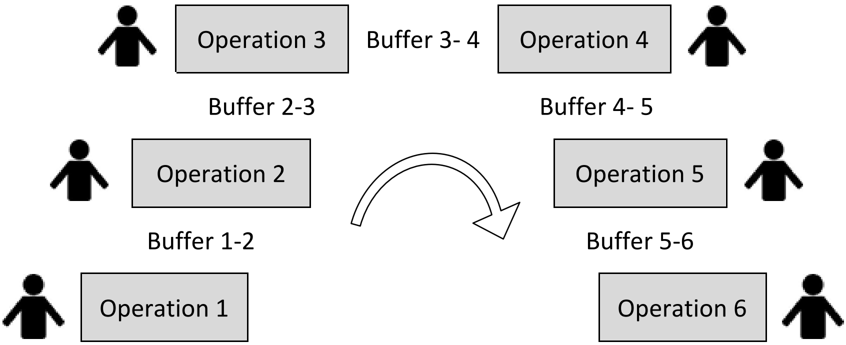
09.20.09. Common Workbench



Workers stand or sit side by side, their eyes meet. The product is passed from hand to hand. Buffers are required between operations if the operating times are not equalised. The buffers are located inside the common workbench. Not all workers need to be polyvalent. If rotation is done, it is on a daily basis. Where is located the adjacent area of the work workbench? The adjacent zone at a square or round workbench is at its centre. The adjacent zone of an elliptic or rectangular workbench is at one end, or there is more than one adjacent zone.

Here is an example. We were at the seaside with family of friends in two guest houses. We have lunch in the garden gazebos. One was a round gazebo with a round table. Other was rectangular with a long rectangular table. When we lunch in the round gazebo, everyone had easy access to the things for common use – bread, carafe, etc. You reach out and take them. When we lunch at the elongated table, access to the things for common use was difficult – you had to get up or have the other person hand them to you. These are unnecessary movements and moving. The conclusion of this example is that if the rectangular or elliptical workbench is very elongated, two, three, or more common adjacent zones may be needed.

09.20.10. Horseshoe with Workers Located OUTSIDE



The workers are positioned at some distance from each other. Everyone worker makes small lots at their workplace, and these lots are parts of the whole order. The product moves through appropriately sized buffers between the workplaces. If there is a common adjacent zone for all the workplaces, it is located differently depending on whether the workers have their backs or faces towards each other. If the workers have their backs to each other, the common adjacent zone is in the interior of the island. If they are face to face, the common adjacent zone is close to the entrance or exit of the island, where it is supplied with materials, or where the products are taken out. In this case, there may be more than one adjacent zone.

There is an interesting of economic point of view difference between a horseshoe with workers located inside it and a horseshoe with workers located outside it. This is that a horseshoe with workers inside it can be located on a smaller area.

There are two differences between the islands (or cells), on the one hand, and the horseshoes and shared work tables, on the other. One difference is that in sparsely populated islands, there is no defined sequence of movement of the product from one workplace to another. In the horseshoes and shared work tables, there is a sequence, and it is in the clockwise or anti-clockwise direction. The other important difference is in the number of workers. In the sparsely populated island, there is one worker, or two or three, but this is the limit at which the choice of the workplaces is no longer the choice of the worker but is defined by the direction and the sequence of relocating the product from one workplace to another. From four people upwards, the island can be transformed into a horseshoe. From six or seven people upwards, it is more appropriate to transform the horseshoe into a conveyor with a rotation of the workplaces.

Again About the Polyvalence of Personnel

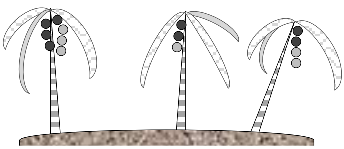
In all types of island organisation, it is important that personnel be polyvalent and therefore interchangeable – once to facilitate the moving and relocations of workers from one workplace to another workplace, and a second time to have good direct communication and cooperation in the course of production process.

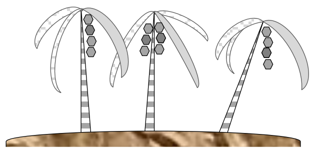
Thus, the island organisation and the polyvalence and interchangeability of people, taken individually and together, contribute to accelerating and smoothing the flow. Any company which is seriously committed to Lean Transformation should take action to continuously increase the polyvalence of its personnel.

Polyvalence should not be absolutised. It is limited by some specific skills. You can't look for interchangeability between a bass baritone and a coloratura soprano.

09.21. Isolated Islands

Isolated Islands is an allusion to an inefficient organisation of production and relocation of the product where workers are unable to assist each other or restricted from doing so since the workplaces or units in which they are located are isolated from each other (physically and/or communicatively isolated).





Typical examples are the workshop model of production, the technological model with intermediate warehouses, or the production at distant from each other work sites. Here, all Muda are large, regardless of the length of the series. In a workshop organised production, if working in medium and short series, there is a high volume of inter-workshop transport. There are also very large volumes of unfinished products. Here all the Muda are large, mostly the surplus of intermediate products. The technological organisation is applicable to different in length series, but it will be difficult to get away without intermediate warehouses. This is mainly due to the inevitable differences in the throughputs of individual workshops, which arise often due to the variable product and technological mix.

In production for a distribution warehouse, the producer has no control over its production schedule and quietly accepts any orders for any products in any series, and most often the orders do not take into account that some work resources are overloaded, and others are trembling with hope to be given any work.

09.22. Standardised Work

This is the establishment of strict procedures for operative activities in a single segment of the production process, which are focused at achieving the following:

1. The Cycle Time or interval of time for which the product must be able to be produced in order to meet the intensity of market demand.
2. The exact sequence and the exact time within which each operative activity must be carried out within the Takt Time for the entire process.
3. The exact quantities of the operative stocks before, at, and after workplaces, which ensure the flexibility and stability of the process.

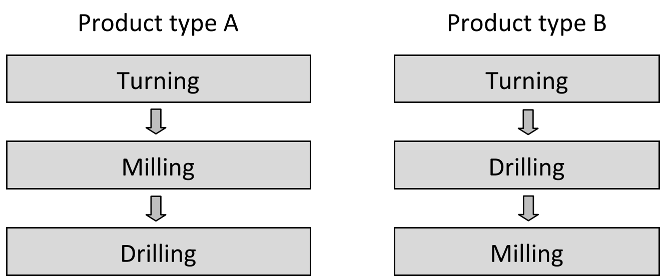
In this formulation of the term Standardised Work, two assumptions can be seen.

One assumption is that Cycle Time is adjustable to be in constant alignment with the variable intensity of market demand. The second assumption is that timelines for operative activities can always be set within the ever-changing value of the Takt Time. These two assumptions are not fully applicable to all possible situations.

There is also a broad interpretation of the nature of Standardised Work in terms of level of familiarity and degree of mastery of the conditions and requirements for proper performance of an operative activity. Standardisation is understood as a final step in a systematic sequence of steps in the study, analysis, optimisation, and stabilisation of operative activities. Whether it's industry or other sectors, the term "standardised work" makes sense mostly for routine executive operations.

The idea of standardisation of work can be extended to other company activities of a routine nature – standardisation of document circulation, standardisation of communications between different people and units, standardisation of operative analyses and solutions, even standardisation of the company language.

09.23. Variable Technological Sequence



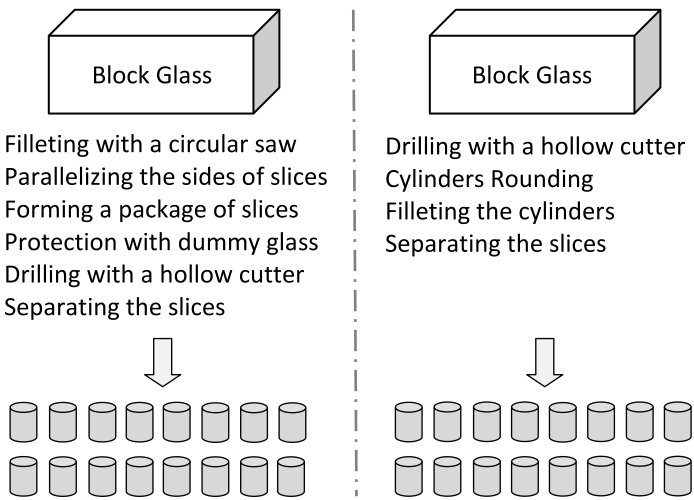
In the scheme above we look an example of mechanic operations. For product type A, the technological sequence is turning, milling, and drilling. For product type B, the technology starts from turning, but drilling and milling haves switched places.

The change of the technological sequence is not possible in every technology and every industry. It is not possible especially in continuous industries. For example, in the bio-industries, we cannot change the technological order of operations – we do not imagine baking dough before rising – when you bake the dough, then it cannot rise. But in the discrete industries, we have cases where the order of some operations can be changed, as long as the construction of the product allows it.

When the technologists select one or the other technologic sequence, they have different considerations – upload/download times, route of inter-operation transport and number of overloads, risk of damaging the product, level of unfinished production, and the like. There are cases where technological logic allows some changes in the sequence of operations within the overall process.

But we have to be careful. If when choosing one of the two technological sequences, shown above, we focus on the unfinished production, traceability may be impaired, or batch mixing may be allowed, or control costs may be increased.

Two Different Technological Sequences
When Making Blanks for Optical Lenses



If we compare the two different technological sequences, shown at the previous page, it turns out that there is a difference in the number of operations. In the right-hand technological scheme, some operations are superfluous and avoided. We have reduced the number of operations from six to only four operations. This shortens the total lead time and reduces the number of sources of errors.

09.24. Split Streams

Production of containers for auto parts	Production of wheels for storage platforms
Metal warehouse	Special sheet metal rack
Blanks workshop	Die cutting
Mechanic workshop	Locksmith correction
Units workshop	It is transiting here
Welding workshop	Spot welding
Painting workshop	Separated painting
Assembly workshop	Bearings and bandage packing
Expedition warehouse	Expedition warehouse

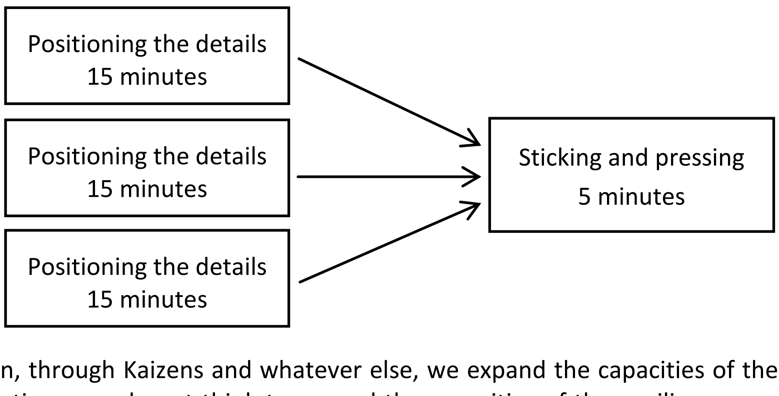
Here is a factory for containers for transport of auto parts. At the factory there's a metals warehouse. In the blanks section are machines for cutting sheets, profile rods, and tubes. These are followed by other sections – mechanical, assembly, welding (assemblies connect with welding), painting, and assembly (completing the container with various polymer and textile pads, dividers, and sealants).

So far, so good! Nothing much, and nothing to worry about... But in this factory, in parallel with the production of containers, another production process is taking place. To the right of the picture is the production of wheels for storage platforms. Because of the wheels in the metal warehouse, there is a separate vertical shelf, and there is stored special sheet metal with high-strength qualities. Then, in the blanks workshop, there is a punching machine. They only use it for the wheels. The blanks are the form of like deep plates for soup. In the mechanic workshop, locksmith corrections are made to the wonderful result of the blunted and not properly centred punch tool. In the section for pre-assembly, they weld two by two the soup plates with the bottoms inside. Then they are painted. The mode of painting the wheels is not like that of painting containers. They wait for five hundred wheels to be assembled to be worth to load the painting cell for them only. Then the rubber bandages are assembled and the roller bearings inserted. Next, they are packed in wooden crates. Finally, they are sent out.

This is a plant with a total area of six acres, of which over three acres are built-up area. The wheels travel, moving forward and backward through the huge factory, over 1,000 metres. There is also a huge accumulation of unfinished products, especially before the painting. You have to collect at least 500 wheels to paint them. This results in major downtime before shipping. No such customer that buys 500 wheels. This production chain (of the wheels) has become tangled, more precisely, entangled in the other chain (that of the containers). Yes, container production is basic, but wheel production is profitable. It makes them money...

The problem has a solution. Implementation on its solution is currently ongoing. The idea is to separate a work section with area much as half a basketball court. This work section has a vertical rack for metal sheets, occupying two square metres. There is a shelf for bearings and rubber bandages. It occupies one square metre. There is a press machine for punching, there is a locksmith's table to clean the whiskers from the punching, and there is an apparatus for drop welding with an air-ducted aspirator above it. There is an insulated paint chamber again with an aspirator above. There is a workplace with a bearing mounting bracket and another workplace with spark plug pliers for mounting bandages. And that's all. All the production is closed within 50 square metres of area. No one has calculated the route of relocation of the product, but it is not more than 40 or 45 metres.

A Striking Case in a Luxury Handbag Factory

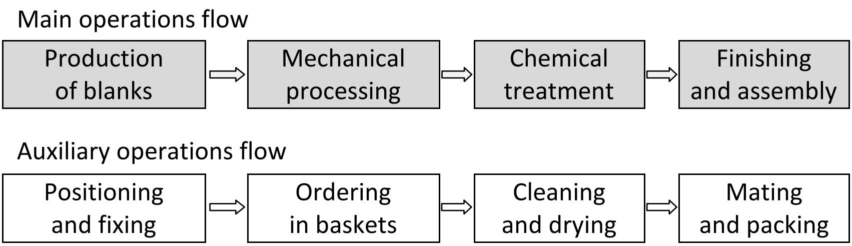


When, through Kaizens and whatever else, we expand the capacities of the main operations, we do not think to expand the capacities of the auxiliary operations.

We're going back in the luxury handbag factory. At the previous page we see three slow preparatory operations – positioning details in templates. A quick main operation follows – pressing of the positioned details. The positioned details are loaded into the pressing machine. The temperature of the anvil rises in ten seconds. This is followed by a short period of pressing at high temperature. Let's see what happens if the preparatory operations run in parallel for fifteen minutes each, and what happens if we run the preparatory operations consecutively every five minutes. If we run the three preparatory operations in parallel, we create an inter-operation stock that will have to wait to be taken over by the pressing machine – it is "swamped" with work, having previously waited for work. If there are no details ready for pressing in front of the press, the press waits. Let's imagine that we run the auxiliary operations not together but every five minutes. Then the press is constantly powered and works without stopping. Pressing is a core process, and its time must be squeezed out.

Lean Production is not a difficult job, he is easy job. But it requires people to brainstorm and come up with simple, intelligent solutions to make things more rational. In this 50-year-old plant, they had not thought to move apart the starting moments of preparatory operations. The solution is a piece of cake and does not cost money. Why had it not occurred to them for over 50 years? Because they were fast asleep in the production model to which they had grown accustomed.

09.25. Two Parallel Flows



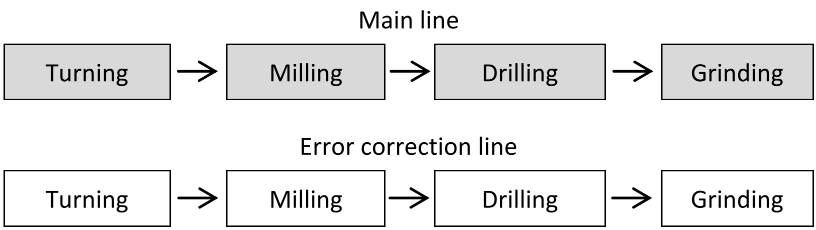
For many industries, we could say that they consist of two flows – a flow of main operations and a flow of auxiliary operations. Here are the main operations. We start from the production of blanks and go through mechanical processing, chemical processing, finishing, and mounting. Along with this, there is a flow of operations, auxiliary to the main ones – positioning and fixing (before mechanical processing), stacking in baskets (before chemical processing), cleaning and drying (after it), and finally mating and packing (after finishing and installation).

I have already mentioned this important rule, but let me emphasise it again. The capacities of the auxiliary operations must be sufficiently broader than the capacities of the served by them main operations. It is absurd that auxiliary operations should be the reason for holding back and delay the main operations.

When we set out to design a plant, we most seriously consider what the capacities of the main operations should be, balance them, etc. But we overlook the auxiliary operations. An ancillary operation with insufficient capacity relative to the underlying operations concerned becomes difficult to detect because of imbalances and disruptions throughout the flow. We are looking for bottlenecks in production to analyse and master them but it may be that they are below the surface and do not quite show. This is what happens to us because bottlenecks may not be in the main operations but to be hidden in the auxiliary operations.

Alexander Dumas father wrote three books called The Three Musketeers. The first book is called The Three Musketeers. The second is called The Three Musketeers Twenty Years After. The third is called The Vicomte de Bragelonne, sometimes called The Three Musketeers, Ten Years Later. Book three says that musketeer Porthos learned so quickly to fire the musket that three squires have not always been able to fill his muskets. Porthos performs the main operation – shooting with the muskets, and the squires carried out the auxiliary operations – filling the muskets with gunpowder and bullets and clogging them with cloth rags.

Two More Parallel Flows



We just looked at two parallel flows – these were the flows of main operations and the flow of auxiliary operations. We said that the capacities of the auxiliary operations should be equal to or wider than the capacities of the main operations.

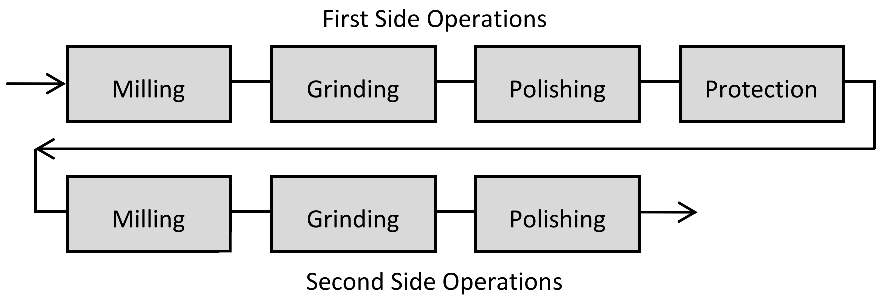
Now we will see two more parallel flows – of the main and correction operations. In other words, there are two lines: a main production line and a parallel line for rework and correction operations, with which errors in the product are eliminated.

In a number of industrial factories, main operations and rework and correction operations are carried out on the same line. This requires returning the product back against the flow. Identification is problematic. Traceability is deteriorating.

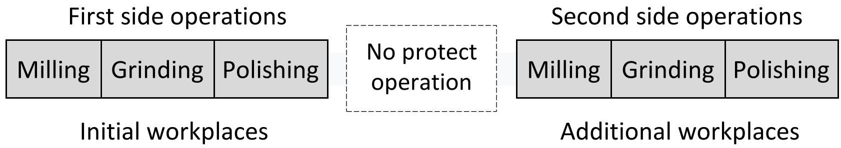
There is a big risk of mixing the series of good products and wrong products. In many cases, greater skills are required for the rework and correction operations. Sometimes rework and correction operations last longer than the corresponding main operations. Or when the wrong product goes to rework or correction, the workplace needed for the rework or correction operation is occupied in the execution of a main operation. Or vice versa, the main operation is delayed because the workplace is occupied by a rework or correction operation. This again breaks, disrupts, and slows the entire production flow. All of these are problems.

Some factories release the product for rework or correction with separate orders that are virtually or really different from the main orders. Sometimes the solution is to physically separate the rework and correction line from the main line. I am joking when I say that reworks and corrections are for these who have nothing else to do. If the market pressures us, we will try to produce only good products.

09.26. Return of the Product Back against the Flow



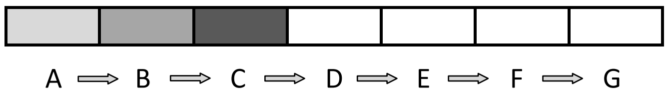
Optical lenses have two sides. One side may be convex, concave, or flat. The other side also may be concave, convex, or flat. Both sides of the lens have the same or different radii, diameters, and profiles. We processing the one side of the lens – milling, grinding, polishing, and applying a protective coating (the latter preserves the result of the previous processes). Then we take the lens back to the beginning of the production line and repeat the same operations, but on the other side. The two sides of the lens have different radii, diameters, and profiles and therefore we are readjusting all the machines and tools for milling, grinding, and polishing.



On the scheme of previous page, we worked with one milling machine, one grinding machine, and one polishing machine. We extended the initial line with additional workplaces – again for milling, grinding, and polishing. Now there are two milling machines, two grinding machines, and two polishing machines.

The lens goes from operation to operation first side and then goes from operation to operation second side. No protect operation. No return against the flow. Now the flow is fast, do not shake. The reader would say that all this is a lot of money on risky investments. Yes! The poor company is condemned to work expensively.

09.27.01. Chaku-Chaku



The ideal production line looks like a melodic, playful dance of the product with its operations and processes under the rhythmic chorus of the perfect organisation.

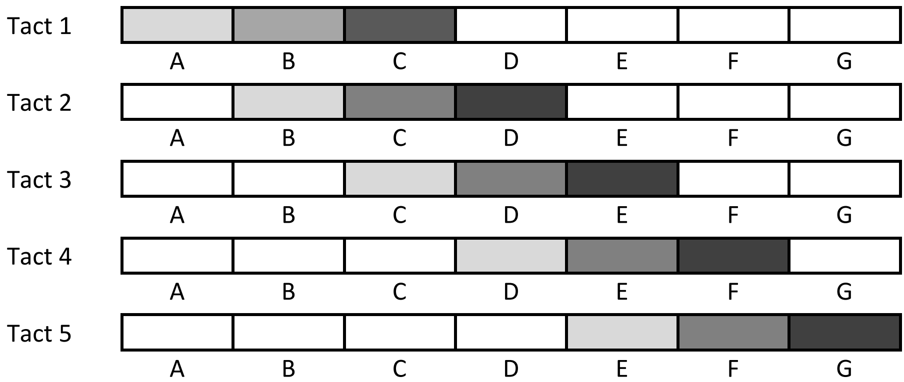
Workplaces have equal or multiples to each other capacities and their respective operations and processes have equal or multiples to each other execution times.

The product, figuratively imagined, slides from operation to operation with an even rhythm. No queues, stocks, or other Muda stopping his way through operations.

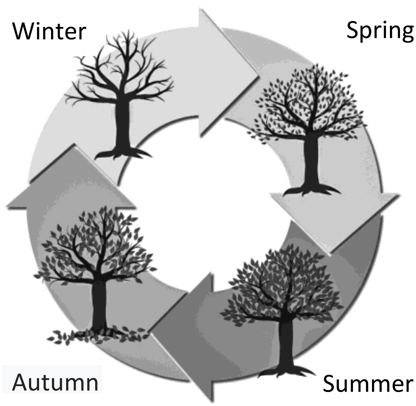
09.27.02. The Ideal Production Line

The process sounds like a symphony, as if a magical conductor's baton is beating.

There is no such process anywhere in the world. However, it is a goal worth constantly striving for. There can be such a production process, but only in very long series, when people have had years to think, invent, and fine-tune the line, technically and organisationally, in order to bring it into such an ideal rhythm. When in one future day the long series is gone, we have to throw "the ideal production line" into the trash because it will not be able to work with other products in the same way. So let's run away from very long series from now on.



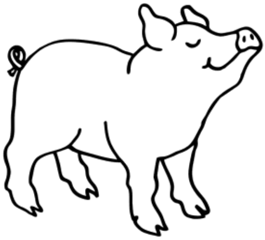
09.28. Levelling by Seasonal Stream Spreading



It's not exactly a Lean idea to level the flow by seasonally spreading products with a similar technological mix. But it is a very fresh idea and deserves to be added to the levelling tools arsenal.

Let us first examine three examples of agriculture. In different months of the year, a large number of different agro-enterprises take place in the orchard – plowing, fertilising, mulching, pruning, hoeing, watering, spraying, harvesting, and collect dead leaves. And we repeat: plowing, fertilising, pruning, hoeing, and so on. Plums, quinces, peaches, and apples are planted in the orchard. There are several types of fruit trees, and each type of fruit tree has several varieties. Why is this? Because, for individual types and varieties of fruit trees, agrotechnical events and activities are not simultaneous but spread over time. Harvesting is not done in just a week or two. It is spread out from June to October.

This levels out the intensity of all the fruit-growing activities. It levels out the stock of fertilisers and plant protection preparations, the loading of machines and people, as well as the currently necessary working capital to finance the business.



The second case is pig farming. Here's the cycle. The sows give birth to piglets. At first, the piglets suckle. They are weaned and fed with fodder for piglets. The piglets are gaining weight, and they are being fed other feed according to their weight. Eventually, they are fattened up. On their last days, they eat corn. At each stage, they eat different foods, and in different quantities, different volume of manure is accumulated, the risks of infection and the corresponding veterinary care are different.

A farm annually raises 12,000 pigs to a weight of 110-130 kg. We do not imagine that they will give birth to 12,000 piglets at once, that they will fatten 12,000 pigs at the same time, that in recent months the forage warehouse will bust at the seams and still will not match the needs of increasingly greedy pigs, that in these months the purification plant will overflow with faeces, and that in the end they will feed the already fattened 12,000 pigs with corn grain at the same time.

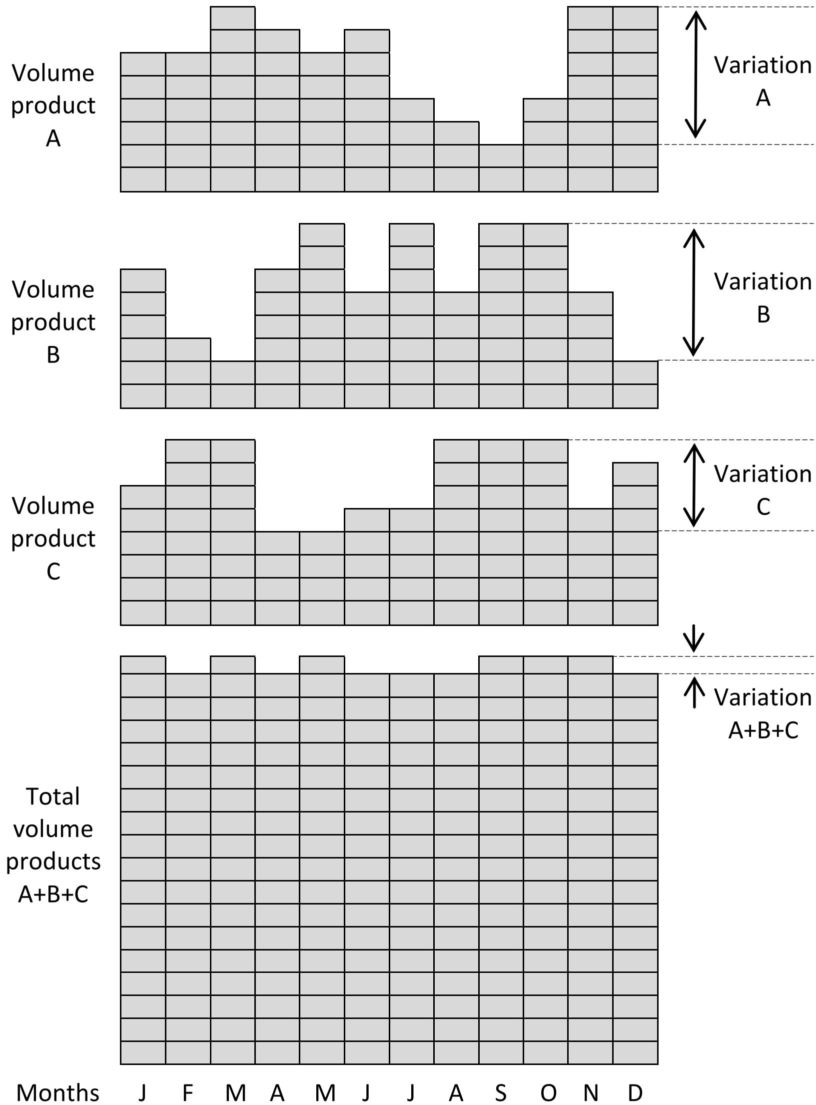
The solution is a planned pregnancy. Every month of the year, 1,000 piglets are born, and the rearing process goes through the stages of fattening. This levels the stocks of feed, preparations, and medicines, levels the intensity of pig-breeding and veterinary work, levels the consumption of water and electricity, levels the load on transport and on installations and energy facilities, levels the working rhythm, and levels, as well as, in the case of fruit-growing, the currently necessary working capital for the ongoing financing of the business.

The third case is quite similar to the second, but it concerns purebred dairy cows. The milk consumption is generally uniform throughout the year. If cows become pregnant in their natural annual cycle, there will be times of milk overproduction and times of milk shortage.

And here the farmers implement the so-called "planned annually pregnancy" – inseminating the cows artificially – each month, fertilising one-twelfth of all cows.

Thus, throughout the year there is almost levelled process of milk production and delivery – this is a good mechanism for balancing the milk production flow relative to the generally uniform market demand for milk during the year.

Similar to seasonal spread, flow smoothing can be sought through the phased production of two or more similar products, the demand for which is stable as average intensity over a longer period but fluctuates widely from month to month.



Let's look at the diagramme from the previous page. Here are three products: A, B, and C. As construction and technology, they are similar. Demand is different from month to month. We are able to produce equally efficiently, regardless of the length of the monthly series. If we take into account the different demand and put them on the same production line, we have a levelled production flow.

The levelling, in principle, should lead to even employment of key resources – be they equipment, personnel, production areas, or otherwise. This principle has various and quite interesting applications in most seasonal product businesses.

A hotel chain has hotels in ski resorts and on the sea. They achieve year-round load of the key resource – the management staff. In the spring, they prepare for the summer, and in the summer, they manage the seaside hotels. In the autumn, they prepare for the winter, and in the winter, they manage mountain hotels.

On the territory of the big company Microprocessorna Tehnika in the small town of Pravets, a Bulgarian-Chinese factory produced motor scooters in the autumn and winter months and air conditioners in the spring and summer months. By the way, motor scooters and air conditioners have a similar assembly process, and all components and kits for both types of products are purchased from suppliers.

Thus, this factory achieved almost year-round a high degree of employment of equipment and almost permanent year-round employment of its workers.

09.29. Variable Topology of Equipment

If we have in parallel constant long series and episodic medium or shorter series, it is feasible to perform them in separate and differently organised work areas.

If demand is with dynamic product nomenclature and mixing of series lengths, fixed workplaces are a difficult obstacle to achieving continuous and levelled flow.

In some factories, this is a common phenomenon – work is carried out in parallel on long, medium, and short series. This is not convenient because the appropriate organisation for long series mode is one, and in short series the mode is another.

The product mix is changing, and the technology mix is changing accordingly.

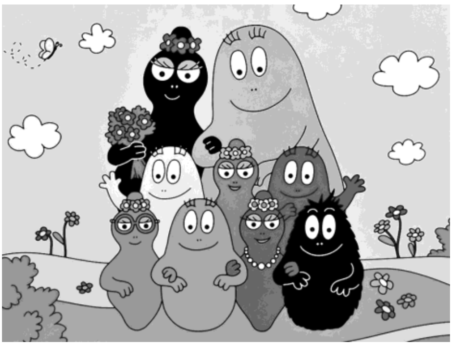
Therefore, more and more often, we need to reorganise the topological disposition of equipment (the layout). And we have just reorganised it very well, changes in product nomenclature and series lengths will again make it inadequate.

It is inevitably to think of the need not for a fixed layout but for a variable layout. There are a large number of various organisational and technical solutions here.

Here's a possible solution. We design the factory so that it has only bare floors, bearing walls, and anti-earthquake washer shims. There are separate zones for workplaces and pedestals for machines, and near them are the terminals for power supply with energy carriers – compressed air, electricity, water, and steam.

Then, according to what we are going to produce and in how long a series, we place the machines where it would be appropriate from the point of view of a good production organisation, we erect temporary intermediate walls, we trace temporary transport corridors between the work areas, and so on. After a month or a year, if the nature of the production mix (respectively, the technological mix) has changed, we stop the whole factory for a day or two and reorganise it again.

Barbaron Company



We remember the children's movies about Papa Barba and the Barbarons. They are kind creatures, able to rapidly change their bodies into new and bizarre forms to come to the aid of all their numerous dear friends. The truly modern factory is similar to the Barbaron's family. It can swiftly change its layout and takes a friendly stance against the challenges of the ever-changing customers demand.

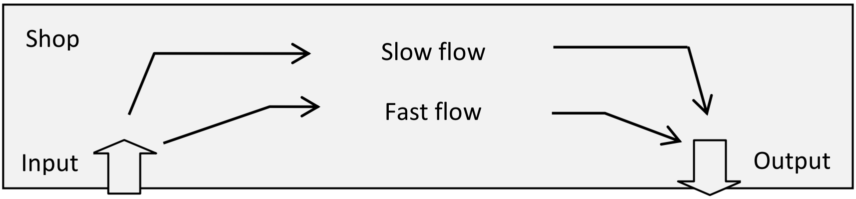
What is the guiding rule? We make the long series on conveyors with rotation of workplaces. Medium series we perform on islands, and short series and single products – on sparsely populated islands. The sparsely populated island is richly furnished and has a worker who has mastered all the steps of the process. The island will be reorganised into a conveyor with workplaces rotation when needed.

Again about the Layout

Certain companies are worried and hesitant to revise the layout, fearing that it will cost a lot of money, or that it will take a long time, or that the plant will not produce as long as the displacement of equipment is ongoing. There are many and always instructive examples of successful revision of the layout in companies with heavy and large equipment – for example, such are the factory Vaptech in Pleven City, and the factory Siemens Energy in the small town of Pravets.

There is a difference between a new layout and a revised layout, especially in terms of the data needed to prepare the project. In the case of a new layout, these are data on the introduction of new products or processes, and data for the creation of new units or a physical merger of existing units, and may even be data for the building of an entirely new plant. When revising the layout, we need data extracted from the Future Value Stream Map and/or by analysing the structure, the dimensions, and the root causes of the detected losses we want to deal with.

09.30. Fast and Slow Flow



There may be production of frequently and/or intensively sought-after products in parallel with production of rarely and/or non-intensively sought-after products.

Then it is appropriate to position the two types of products in two physically separate flows from each other – fast and slow flow. The production of frequently and/or intensively demanded products is accommodated in the fast flow, and flows in a short trajectory between the inlet and outlet of the workshop/factory.

The production of infrequently and/or non-intensively demanded products is accommodated in the slow flow. It is organised separately from the fast flow, does not intersect with it, and flows away from the workshop's inputs and outputs.

09.31. Industrial Engineering of Flow

Industrial Engineering has become a fashionable subject in technical universities around the world. It is close to technological specialties and the factory design.

What is specific about the mission of an industrial engineer? Production technology defines methods and means for performing basic operations and preparatory, finishing, and other auxiliary operations, and as well as the technological sequences of operations. Here are the tasks of the technologists. The topological disposition of equipment, corridors, and trajectories for inter-operation and inter-shop transport and, in general, the solutions in the field of internal factory logistics, are all industrial engineer tasks. Over the years, there has been a tendency to divide the tasks of technologists from these of industrial engineers. Increasingly it will be necessary to revise and reorganise existing layout in pursuit of five related goals. First goal is there should be no bottlenecks. Second goal is to equalise the throughputs of units. Third goal is to shorten the times of all the operations, both main and auxiliary. Fourth goal is to avoid any intertwining and intersections of flows. Fifth goal is no product return against the flows.

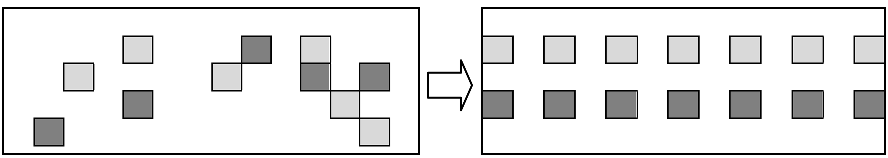
This latter in some highly regulated industries it is strictly prohibited. For example, in the food and pharmaceutical industries and the military ammunition industries, there can be no intersection of flows, crossing of flows, or going back into flows.

09.32. Redesigning Flow

Often, the actual production flow, as it is, is difficult or even impossible to change. It may be more rational to redesign and rebuild the entire flow. We like to dream of radical improvements, of drastic breakthroughs in constraints, but sometimes the really big constraint is in the lack of funds for bold endeavours. And that forces us to settle for more modest improvements, ones that are within our means. Sometimes the restrictions on improvements are fateful, and we may have to redesign the plant or build a new plant on green belt. Increasingly, there are cases, especially in continuous-type industries, where the flow, as it was designed, simply cannot provide good efficiency compared to richer competing companies, which initially paid for more efficient technical and organisational solutions.

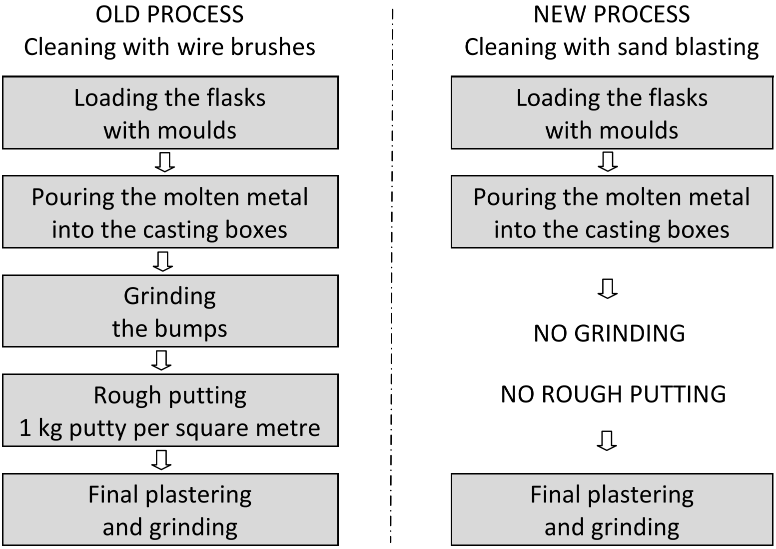
I will show cases in which without large investments, with only small changes in some process elements, we have a process with a radically different appearance.

Two Streams – Heavy Machinery and Light Machinery



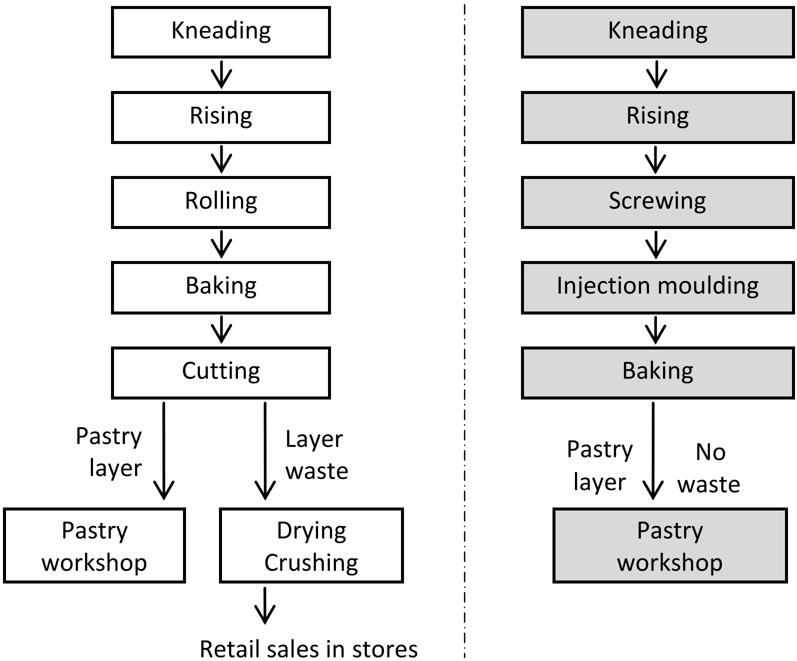
It is the big factory Vaptech in Pleven City. A huge machining shop with heavy and light machines, disorderly dispersed in it. They transformed the machining shop into two separate lines – one heavy machines line for big work pieces and another light machines line for the small work pieces. This radical transformation of the production layout reduces inter-operation transport and moving by 80%.

Without Three Redundant Processes



Here we see a casting process for corpus components of metal cutting machines. The operations are the following: cleaning the foundry crates with wire brooms, loading the crates with foundry moulds, casting the metal, and grinding the protrusions. You get an uneven surface, and you have to add filler – first is added the rough filler (with consumption of one kg and more rough whale per square metre), then there is added a fine filler, and finally there is grinding. The chief accountant exerts pressure to make savings. Strange manifestation of this pressure is the creation of a technological cost limit for the use of wire brooms. As a result of the poorly cleaned crates the protrusions increases. This is how the costs of grinding and rough filler increase. Therefore, it becomes necessary to raise the cost norm for coarse filler (expensive filler – Parrot, Lesonal…). So there is an abundance of "unused" filler that is sold at half price at repair shops around town. We make a simple and inexpensive change. We replace the crates cleaning with a wire broom with sandblasting apparatus cleaning. Subsequent operations (loading and casting) remain the same, but the need for grinding the protrusions and the coarse filler are eliminated. We see how by "gently touching" one operation we were able to perfect the entire process so that two operations were dropped. The lion has the task of creating a technology with a small number of operations. This is how this lion removed two out of six operations, there are only four left.

Improved Utilisation of Raw Materials

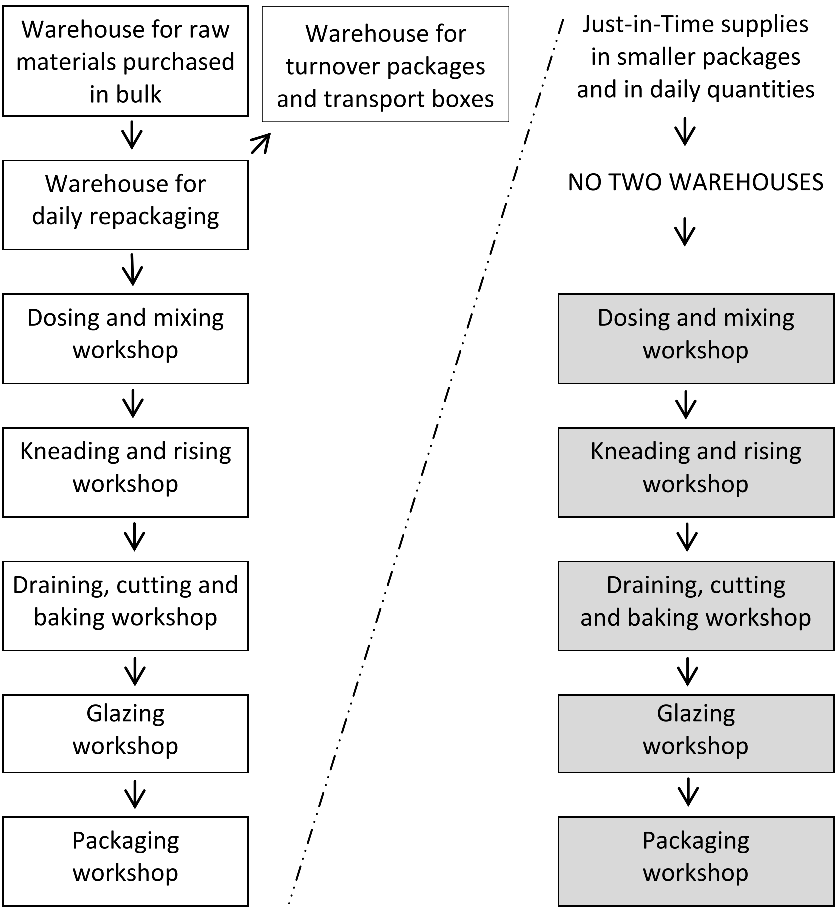


We go to a confectionery factory and produce a layer cake. We want to achieve a higher raw materials yield (flour, sugar, cocoa) in the production of the layer cake. The operations here are kneading, rising, rolling, baking, and cutting. The baked layer is a dough crust, one centimetre thick. They cut the baked layer into pieces, leaving waste between the pieces and along the edges of the layer. Waste is expensive. In confectionery industry, more than 80% of the direct production cost is formed from the raw materials, and they are expensive. Waste is not thrown in the trash. It is dried, crushed, packaged, and sold to small food shops. We buy packages with crushed layer cake, and so we prepare delicious homemade cakes.

We make a change. Look at the diagramme on the right. Again, it starts with kneading and rising, there is no rolling, and before firing there is augering. The layer is not cut. The auger loads a syringe. It fills the raw layer into metal pastry moulds with a removable bottom, and they, with the raw layer in them, go to baking. Not a crumb of layer scrap in this new and intelligently composed process!

By changing the nature of only two operations in the process, we achieve a great improvement. The scrap was over 11%. It wasn't really scrap but recoverable scrap, except that people, machines, and factory space were engaged in it.

Elimination of Large Warehouses for Raw Materials

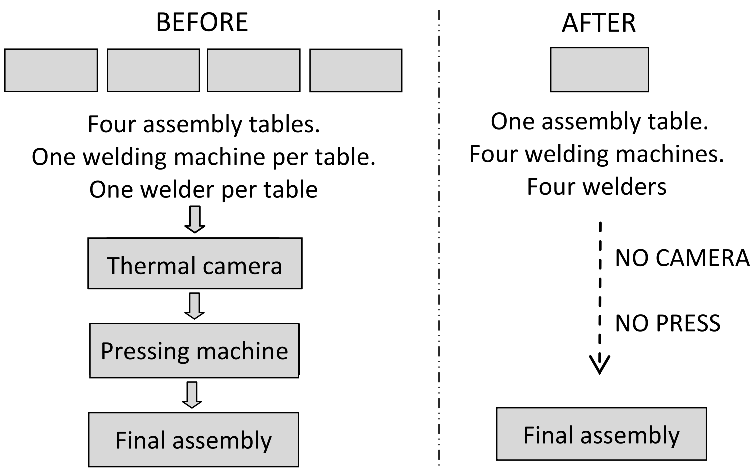


Here we are at another dry pastry factory. The production takes place through five separate workshops – a dosing and mixing workshop, a kneading and rising workshop, a pastry rolling, cutting, and firing workshop, a glazing workshop, and a packaging workshop. We see three warehouses before production workshops.

In the warehouse for raw materials, wholesale purchased, are stored large packages – big bags, containers, tanks, etc. In another warehouse, they repackage the big transport packages into technological packages for the needs of one shift or working day. In this warehouse are prepared raw materials and materials for the daily loading of production. It is easy to imagine with what amount of transport means and packages they operate. So, they need for an additional warehouse for unnecessary packages and turnover transport means and packages.

The plant decided to give up working with wholesalers and to work with suppliers who are not "one-to-one" clean Just-in-Time suppliers but agree to deliver day to day and in the quantities needed for each day. Thus, the three warehouses turned out to be completely superfluous, and within a relatively short time, it became possible to equip five new production work chops on the freed warehouse areas.

Two Difficult Operations Are Eliminated



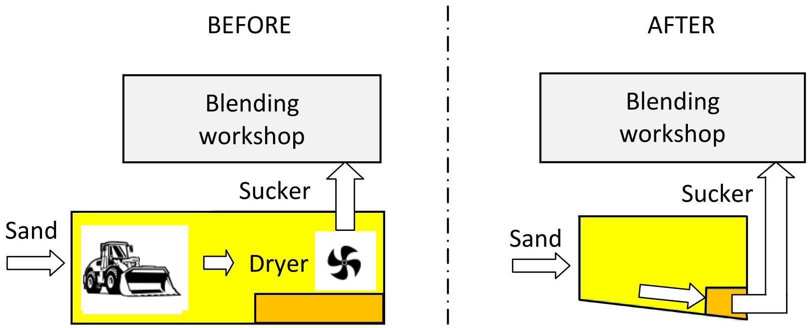
A truly high level of production and business efficiency is achieved with a bold and radical transformation of philosophy, organisation, technology, equipment, topological disposition of lines, conveyors, and islands, and other radical actions aimed at the complete Lean transformation in the overall picture of production.

Let's go back to the container’s plant. The bottom of a container is a rectangular frame, one metre by two, on which the walls and other assemblies are mounted by welding. But let's look at the production of the bottom of the container.

In the assembly shop, there are four mounting tables, one welding apparatus per table, and one welder per table. In order for there to be no deformations due to temperature differences, the welds should be make diagonally. It's too much to ask of the welder to waltz past the frame. Why should he bother to run diagonally from one end of the frame to the other? He welds the bottom "point by point" without getting tired to go around on the diagonals. Finally, the bottom of the container takes on a strangely crooked shape. The bottom is placed in an oven heated to a set degree. Then one end of the bottom of the container is clamped in a stationary vice. A noisy, smoking 30-year-old clamp forklift clamps the other end of the bottom in its jaws and starts twisting it here and there, in an attempt to straighten it. It can never be straightened completely. A very pointless process!

What is the good solution? The work should be done on a single assembly table. At the corners of this table, there are four welding apparatuses, and four welders making welds simultaneously along both diagonals. There are still distortions of some bottoms, but not so great that these comic circus tricks have to be played.

Don't Push the Sand, Pull it



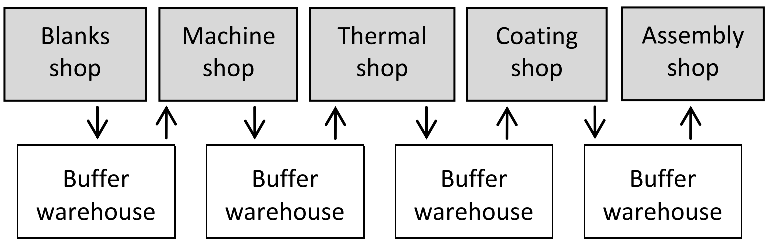
Horizontal concrete floor.
Bulldozer pushes the sand into dryer

Inclined slippery sheet metal floor.
No bulldozer, no dryer

We're in a glass factory now. We can see the sand warehouse. Dump trucks come and dump the sand. The bulldozer pushes it inward to the bottom of the warehouse. The sand is pushed for days from the entrance to the end of the warehouse. At the bottom of the warehouse, there is an installation for drying the sand. Then a sucker sucks the sand 8 metres height up to the mixing workshop, where mixing of the sand with the other components of the glass takes place.

Let's now see a simple and elegant solution to the problem! The sand warehouse had a horizontal, rough concrete floor. Now the floor has a slight slope in the direction from the entrance of the warehouse to the dryer. The sloped floor is covered with slippery steel sheets along the entire length from the entrance to the dryer. The dump trucks come to the front of the warehouse and pour the sand so that it falls on the beginning of the sheet metal floor. The sand slowly slides down to the bottom of the warehouse. Aided by the weight of the sand (gravity doesn't cost anything) and the low resistance of the slippery floor, the warehouse "pulls" in as much sand as the mixing section can take. There is still a drier, but it uses less power, which reduces electricity consumption. Electricity consumption is also low due to the fact that there was no time for the sand to get wet. You don't need a bulldozer anymore. Besides, there are no mixing of different batches of sand. This reduces the necessary analyses and adjustments when mixed with the other components of the glass and also in the smelting furnace.

Implement SMED First in the Blanks Workshops



A water pump factory makes four families of pumps. Technologically organised sequential production flow: blanks shop, machine shop, thermal shop, coating shop, and assembly shop. There are buffer warehouses between the workshops.

Slow readjustment of the sheet bending machines and the cutting and drilling machines in the blanks workshops. That is why the factory works like this – one month it produces one type of pumps, the next month another type of pumps, the third another type of pumps, and the fourth, yet another type of pumps.

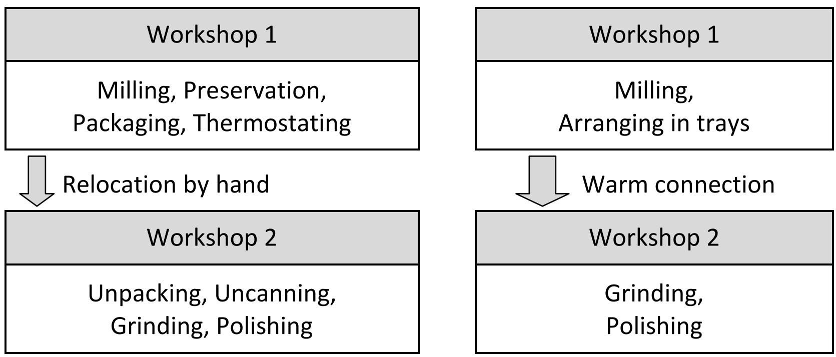
Market demand for pumps from the four families has no relation to the months in which pumps from the four families were produced. As a result, they have high levels of unfinished product. Although the warehouse for finished products overflows with ready for shipment products, there are frequent cases when customers are looking for such pumps that the factory currently does not have.

	Blanks shop	Machine shop	Thermal shop	Coating shop	Assembly shop
Family 1	Blanks	Cutting	Hardening	Coating	Assembly
Family 2	Blanks	Cutting	Hardening	Coating	Assembly
Family 3	Blanks	Cutting	Hardening	Coating	Assembly
Family 4	Blanks	Cutting	Hardening	Coating	Assembly

The factory went from successive production (one-month series of each of the four families) to parallel production in short series of all families (based on the current market demand). For this purpose, the factory implemented SMED first in the blank workshops and then in all its workshops. In parallel with the SMED implementation, the factory launched the four pump families in four separate lines. It took them nine months.

Before this transformation, the four families had been produced in successive months. Now all the families are produced in parallel according to demand. The level of unfinished product is quite low, the warehouse for finished products is almost empty, and the deadlines for executing orders are convenient for customers. Before transformation the customers was spoken like this: "You want these kinds of pumps, in two-three months, you will have them". And when the customer hears this, he goes to buy pumps from another producer.

Without Six Redundant Processes in an Optical Factory



In the picture of the previous page to the left side are workshop 1 for milling and workshop 2 for grinding and polishing of optical lenses. The two workshops are in separate buildings, about ten metres from each other. People carry the lenses between the buildings by hand. The temperature in the workshops is maintained at 22°C but the outside temperature in winter is below zero. To protect lenses against temperature shocks after milling in workshop 1, people can and package the lenses and placed them in portable thermostatic containers. After moving the lenses to workshop 2, they unpack and uncan them. We see at the picture on the right a warm connection built for 20,000 BGN (10,000 €). There are no more unnecessary processes: canning, packing, carrying, unpacking, and uncanning. Once there are no more redundant processes, the speed of the flow is higher. By the way, the eliminated five processes are the sources of a large number of errors.

09.33. Organisation Stems from Technology or Vice Versa

This is interesting question with multiple contradictory answers. Things depend not so much on technology as a set of production methods, as much as from the specialised technical equipment with which we apply these methods. In heavy industries, technology is often the leading factor, i.e., their inherent technological sequences and specialised equipment predetermine the production organisation. It's similar in agriculture – the cow tells you when to milk it, and the wheat tells you when to harvest it. In discreet industries, it's different. The more universal the equipment and the more susceptible it is to regulation in its operating modes, the less the production organisation is dependent on technology. Even the organisation can make choices about which technologies pose fewer organisational problems. No matter what the industry is, the organisation, and especially the series lenghts, can also predetermine the needs for this or that type of logistical equipment.

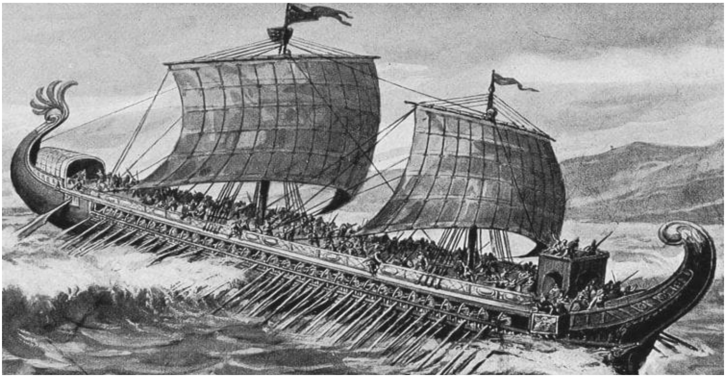
09.34. One-Piece-Flow – Labour Rationing, Reporting and Payment

In the case of One-Piece-Flow, we aim to balance the capacities of the workplaces and equalise or synchronise the times of the operations. This creates an even rhythm in the relocation of the product from one workplace to the next.

This rhythm "synchronises" the work pace. There is no longer any need for labour rationing. There is no longer any need for individual accounting of each worker.

This allows us to move from pay-per-piece to payment for time worked. And if production planning manages to fill the efficient working time of the production line, then we can move to a constant pay according staff position. This will save on organisational expenses required for labour rationing, reporting, and accounting.

The Greek Trireme



In the Greek trireme, two hundred oarsmen on three decks row to the beat of the drum. The rhythm increases when ram attacks. On a long-haul, the rhythm is moderate. In a manoeuvre, the drum indicates which oars to stop or paddle back. The strongest oarsmen are on top deck. There are reserve oarsmen in the hold. In the case of an attack, they take part as well. The oarsmen watch and listen to each other and feel the rhythm and strength of the rowing. The drum thunders loudly and creates in the drummer a sense of power over three hundred oarsmen.

Conclusion to Chapter 09
One-Piece Flow and Continuous Flow

The batch production flows in thrusts and waves. It is not possible to avoid stocks, queues, and long lead times. With the continuous flow, there are no or little stocks and queues, and in order to protect ourselves from unevenness, we need to identify and resolve the causes of queues, delays, downtime and thrusts. We need to build the continuous flow as a connected system from One-Piece Flows. This poses at least three challenges. The first challenge is for industrial engineers. They should optimise workshop and factory logistics – shorten the trajectories of moving and transportation, and set organisational and physical barriers to inter-operation and inter-plant stocks and queues. The second challenge is for the maintenance personnel to ensure high OEE (Overall Equipment Effectiveness) at least for the key workplaces and equipment that determine the constant availability and continuity of all operations and processes. The third challenge is for the training specialists and direct managers. They should create the conditions and attitude for development of a high and versatile qualification, full awareness, and an active communication environment for the company operative personnel.

Discussion questions, homework tasks, practical assignment, and exercises

Discussion questions

Under the conditions of your company, is it possible for some unbalanced production flows to be disaggregated and levelled as sets of One-Piece Flows?

Homework tasks

Determine if there are auxiliary operations in your company whose capacity is insufficient compared to that of the value add main operations they serve.

Practical assignment

Make observations and estimates and determine whether there are related work capacities that are not balanced. Think about how they can balance each other.

Discuss with colleagues what needs to be done to synchronise the operating times in a production process of your choice.

Exercises

See two practical exercises on page 742 and the answers on page 752