UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

DIGITAL KAIZEN

LEAN MANUFACTURING, KAIZEN AND NEW TECHNOLOGIES TO INCREASE BUSINESS PRODUCTIVITY

Second Edition

FROM LEAN MANAGEMENT
TO DIGITAL KAIZEN

GUIDELINES

DIGITAL KAIZEN

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Vienna, Austria
July 2022

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ACKNOWLEDGEMENTS

This publication has been developed by **UNIDO's Digital Transformation and AI Strategies Division, Directorate of Technical Cooperation and Sustainable Industrialization**. It is the second edition of the "*UNIDO Shop Floor Assistance Guidelines*" handbook, which was published in October 2019. A large number of colleagues have contributed to this work. Our gratitude goes to the team that developed the first edition, under the coordination of **Olga Memedovic**, with the support of **Oliver Authried, Eduard Khrypko, Victor Nadolski, Yuri Pallahoshka, Andre Shulha, Tim Scurlock, Anatoly Balonev, Julia Kniga** and **Iana Rössl**. Special mention should be made to **Jochen Schreiber** and **Christian Salvinetti** of EFS Consulting, who designed the basic framework for implementing Digital Kaizen.

This second edition was developed by **Marco Kamiya**'s team, with the support of **Oliver Authried, Jinfeng Mu, Yi Zhang, Alexis Yong and Anatoly Balonev**. Excelcis SARL assisted with editing.

This publication was produced within the framework of UNIDO project 'Institutional Strengthening and Institutional strengthening and policy support to upgrade the component manufacturers in the automotive sector in the Republic of Belarus', funded by the Russian Federation.

Content

1

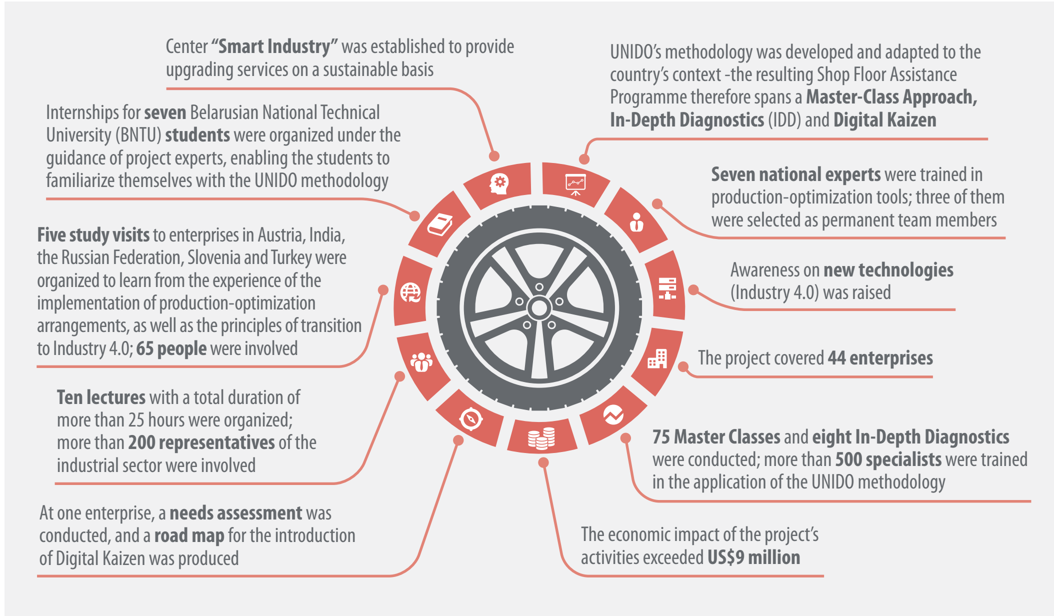
Introduction

In order to compete in a global marketplace, small and medium-sized enterprises (SMEs) in emerging economies, and countries in transition, need to make significant improvements in their approach to manufacturing. The need to ensure that improvements not only focus on efficiency gains, but also align with the greater focus on corporate social responsibility requires a wholesale review of manufacturing in many of these countries. Important factors include keeping production costs low, enhancing productivity and developing linkages to sustainable supplier networks. In this respect, UNIDO provides services that aim to improve the competitiveness of enterprises through clustering and networking, cost reduction and increased productivity, while developing sustainable supplier networks and seeking new markets.

A number of external and internal factors play a critical role in the performance and competitiveness of companies. Factors related to business environment and support institutions are as important as the internal factors that influence the production and growth of companies. UNIDO has focused its technical assistance on two interrelated levels: (a) a direct shop floor assistance programme for pilot companies to showcase practical examples of upgrading services; and (b) capacity-building of support and advisory institutions to deliver enterprise-upgrading services on a sustainable basis.

These guidelines outline UNIDO's approach to the Shop Floor Assistance Programme on Lean, implemented within the UNIDO project, Institutional Strengthening and Policy Support to Upgrade the Component Manufacturers in the Automotive Sector in the Republic of Belarus, which was funded by a voluntary contribution from the Russian Federation to the UNIDO Industrial Development Fund. The approach is based on the tools and instruments of Lean methods and has been implemented successfully in other UNIDO projects around the globe. Lean tools are widely known, and many publications and manuals have been produced about them. The current guidelines summarize UNIDO's experience on the Belarus project, using open sources.

The project obtained a number of significant results, as illustrated below.



Lean manufacturing is a worldwide proven approach for the improvement of production processes through the optimization of production and elimination of waste. The goals are better quality, lower costs and shorter lead times. Lean methods are still successfully exploited in industry and although they originated in the 1950s, they still are very relevant to business improvement. The requirement for companies to react rapidly to changes in demand and the relative simplicity of the approach mean that Lean implementation remains of significant benefit to any manufacturing or non-manufacturing business.

The Concept of Lean

The management concept of Lean is a series of tools and principles that can minimize waste (and thereby maximize value) in any business process and enable businesses to become more fit or resilient when addressing the changes in the business context. It includes some basic principles and outlines a series of logical steps to analyse and improve both manufacturing and non-manufacturing businesses. One of the core elements is that Lean engages the workforce to visualize, discuss and solve problems in the business in order to increase productivity, improve quality, reduce lead times and make better use of resources.

The best applications of Lean though extend beyond these tangible benefits to promote a culture of continuous improvement where employees are empowered to challenge the status quo, work together to solve and prevent problems recurring, and implement quality and productivity improvements. Companies, such as Toyota, where Lean has been the way of life for decades, enjoy the benefits of a Lean culture that permeates from the leadership right through to the workforce, and enables them to stay ahead of competition. Companies frequently choose Lean because it offers many of, or all, the benefits outlined in Figure 1.

2.1 BENEFITS OF LEAN MANUFACTURING

Non Lean	Lean Organisation	Benefits
Unclear or proprietary processes	Transparent processes	Better cross-functional understanding and visibility
Individual problem solving	Collaborative problem solving	Higher-quality operational solutions
Reactive employees	Proactive employees raise issues and concerns as they occur	'No blame' environment means problems raised and fixed promptly
Management-directed changes	Employee-directed changes	Faster change, more responsive to customer needs, less time required from management

Figure 1 – The benefits of a Lean Culture. Source: Applied Lean Consulting

2.2 LEAN MANUFACTURING ORIGINS

In the 1950s, Toyota was struggling to compete with GM's and Ford's mass-production techniques, with which high volumes of similar products could drive cost per piece to an affordable level. However, Toyota simply could not afford to replicate Ford and GM's approach with the lower volume, mixed product lines required for its local market. Instead, Taiichi Ohno, a plant manager at Toyota, took some of the concepts from GM and Ford and adapted them around a series of practical and cultural initiatives to create the Toyota Production System (TPS). TPS has since formed the basis of Lean production globally, which has progressively been rolled out from its roots in car manufacturing into all manufacturing, warehousing and service businesses; from multinational businesses employing thousands of employees through to SMEs with less than 30. The same principles apply and the fundamental way to implement Lean remains the same.

3

Main Techniques and Tools

It is important to understand some of the main Lean techniques and tools, in order to know how and when to apply them. These include:

- TAKT TIME
- ONE-PIECE FLOW
- PULL SYSTEMS
- VALUE STREAM MAPPING
- KANBAN
- STANDARDIZATION
- VISUAL MANAGEMENT
- THE 8 WASTES
- 5 S
- SINGLE MINUTE EXCHANGE OF DIE
- TOTAL PRODUCTIVE MAINTENANCE

The goal is to reach a situation in a production or service environment in which every employee knows "WHAT do I work on next?", "WHERE do I get my work from?", "HOW LONG will it take me to do my work?", "WHERE will I send it?" and "WHEN do I send it?".

The employees should know all of this information without a schedule, without a dispatch or expedite list, and without a supervisor or manager needing to tell them what to do.

3.1 TAKT TIME

WHAT

- Rate at which customers require finished units
- Origins are the German word Taktzeit, meaning 'pace' of 'cycle time'

WHEN

- Used in production planning (and building service capacity in non-manufacturing)
- Precisely match production time with customer demand

WHY

- The pace of production is important: too slow will not meet customer demand and too fast will result in excess output
- Allows flexibility in the workforce based around customer demand

HOW

- Divide available work time per shift by customer demand per shift
- React by demand levelling, putting in additional resources or re-engineering the process to correct the issue

Takt Time is the pace of customer demand expressed as a unit of time. In manufacturing, you need to be able to match the pace of production to the customer demand, either by speeding up the process or by employing more people who work together to keep the output rate at the right level. In service businesses, for example an insurance company handling claims from customers, Takt Time is less critical as a rate-determining tool but helps ensure you have the capacity in place to meet customer demand. So, in the insurance claim example, and with a customer demand of 70 claims in 20 working days, you would design your process with a capacity to meet 3.5 claims a day, or about one claim every 2 hours.

3.2 ONE-PIECE FLOW

WHAT

- Making and moving once piece at a time in a continuous flow
- Providing the next process step only what is needed and when it is needed

WHEN

- When there are multiple steps and multiple work stations in any process (manufacturing or service)

WHY

- Reduces inventory (unnecessary work in process)
- Reduces waiting time
- The first product is completed sooner
- Takes up less space
- Focuses on quality versus quantity

HOW

- Link processes together
- Reduce batch sizes
- Re-arrange work stations in a sequential set up
- Minimise part flow, with the goal of moving one part at a time

One-piece flow (also known as continuous flow or single-piece flow) is ideal for Lean systems in manufacturing in order to achieve an uninterrupted flow of goods between workstations, something that results in reduced lead time and less work in progress (WIP). If you were to think of water flowing down a hill, any rocks in its way are going to slow it down and create diversions, and there is likely to be a build-up of water behind the rocks. By identifying and removing the problems (or rocks) and modifying the production layout, it is often possible to link processes together and remove steps (and hence reduce time and WIP).

One-piece flow can be difficult to achieve. It is often prevented by issues such as those listed in Table 1 below.

- Poor layout / Process reversals
- Shared resources – e.g. specific machines become a bottleneck
- Specialist skills – only certain people can do certain jobs
- Unbalanced process times: sequential machines working at different paces

Table 1 – Typical issues preventing one-piece flow achievement

One-piece flow promotes other benefits in your Lean system too. If batch sizes are reduced, to one piece at a time, a quality problem will be identified immediately and can be dealt with easily. By contrast, in batched production, a quality error will require the scrapping or reworking of the entire batch. Additionally, linking work steps together into cells, and reducing the WIP between steps, reduces the space needed in the production facility.

3.3 PULL SYSTEMS

WHAT
- Creates a link to customer demand
- Replenishes only what the next process has consumed

WHEN
- You want to reduce inventory, cycle time or lead time

WHY
- Improves flow of information and materials
- Minimises inventory
- Allows bottlenecks to become visible

HOW
- Implement small localized supply of materials (or 'supermarket') for batches
- Implement a Kanban (signalling) system

When you can not create one-piece flow, pull systems link customer demand directly back to your process. By implementing a supermarket of stock in your system and controlling the amount in it via a Kanban (clear signal to replenish), you can control in-system inventory and reduce lead times effectively.

3.4 VALUE STREAM MAPPING

Value stream mapping allows you to view the value and the waste in your process. Value stream maps (VSMs) log both the information and the product flows in your production process, from entering a customer's order into your scheduling system, to orders placed with major suppliers and the movement of goods through your facility—from receipt through to dispatch. There is a conventional order to how VSMs are drawn, as shown in Figure 2 below. An example of a VSM is presented in Figure 3, below.

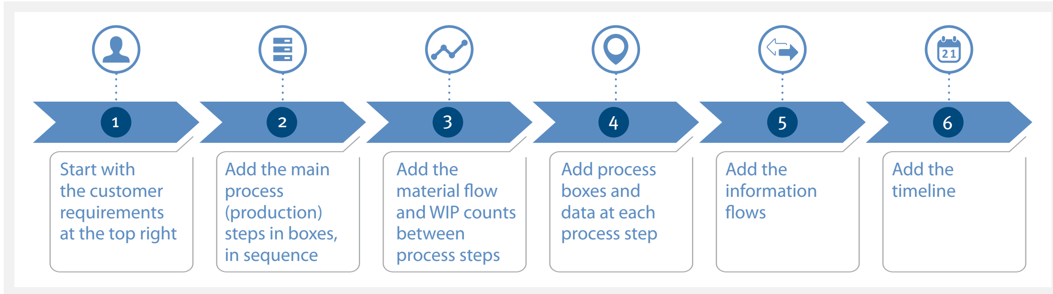


Figure 2 – Conventional order to how VSMs are drawn

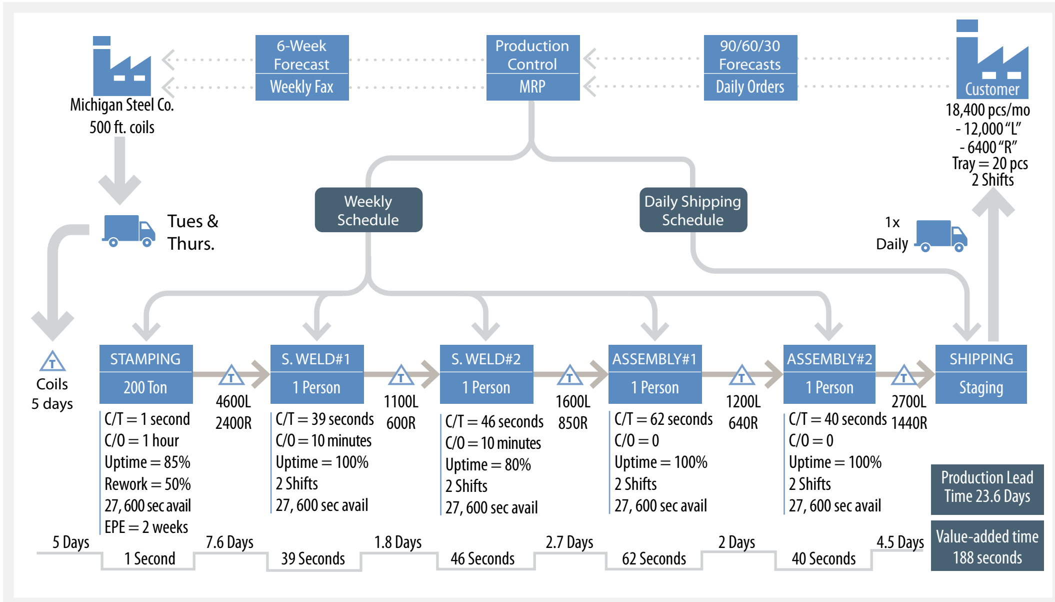


Figure 3 – Production Value Stream Map (from *Learning to See: Rother and Shook*)

The benefit of a VSM is that it maps both the information flow and the product flow through your business, identifying problems and waste, both at system and individual process levels. (For more information about waste, see Section 3.8). VSM simulation packages exist today to simulate productivity of various production process set-ups (vision of the future process, i.e improved process). But VSM should take into account the limitations in the production process, available infrastructure and ROI calculations within financial availabilities.

3.5 KANBAN

WHAT

- Japanese term for 'signal board'
- A signal that replenishment is required directly in response to a customer 'pull'

WHEN

- When we need to limit Work in Progress
- When replenishment of stock is required—especially in manufacturing

WHY

- Ensures the production line is adequately filled and line stoppage is prevented
- But also regulates the level of inventory (supermarkets) along the line

HOW

- Two-bin system (full and empty); level indicator; Kanban card exposed
- Signal indicates reorder quantities (and often supplier details), reorder quantities, etc.

Kanban systems are used extensively in production processes to limit WIP and provide a clear and unequivocal signal for replenishment. Some of the most commonly used signals are listed in Table 2 below.

- TWO-BIN SYSTEM (AN EMPTY BIN IS THE SIGNAL TO REPURCHASE WHILE THE FULL BIN IS BEING CONSUMED)
- A SPACE (WHICH SIGNALS THAT SOMETHING NEEDS TO FILL IT)
- A KANBAN CARD THAT GIVES SPECIFIC DETAILS OF THE PRODUCT, SUPPLIER DETAILS, REORDER QUANTITIES, AND SOMETIMES THE BIN LOCATION, PACKING TYPE, ETC. REQUIRED

Table 2 – Commonly used signals in Kanban systems

Most production plants rely on an Entreprise Resource Planning (ERP) or Materials Requirements Planning (MRP) system to predict what needs to be produced, based on historical demand and forecasts. A Kanban system, however, is linked directly to customer demand and can therefore give a more certain indication of market requirements.

A good place to start when considering introducing Kanban is 'consumables'. These tend to lie outside the 'bill of material' calculations and will enable you to build confidence in your system.

Kanbans can also work effectively in non-manufacturing environments, for example, indicating when more paper or office supplies are required: here, placing a Kanban reorder card between the last two boxes of paper will indicate when it is time to reorder.

3.6 STANDARDIZED WORK

WHAT

- List of detailed standard operating procedures required to conduct a task or series of tasks

WHEN

- When you want to create a standard baseline operation for improvement
- You want to help operators improve against their KPIs

WHY

- Ensures all workers are operating in the same way
- Reduces the chance of error and ensures consistent quality
- Allows planning of resources needed
- Provides a training document for new employees

HOW

- Work with each operator to record how work is currently managed in process steps with pictures and time allowed
- Some standard work documents can be very detailed, including number of steps taken, location of tools, etc.

The basis for Lean is standard work. If operators do things in a different way each time, then you can only manage by results and not by how effectively the work is done. Standard work demonstrates that there is a process in place for all operations and, in the event of a performance shortfall, puts the blame on the process not the operator.

Standardization helps to create consistency in quality and rate of production, and identifies where skill shortages are or training is required. If employees always work in the same way, they can develop improvements to the standard and create the basis for continuous improvement. One of the criticisms often levelled at standard work is 'we are not machines' and that standard work takes responsibility away from the operator. However, in practice, standard work empowers the operator by giving them the comfort of a stable state to work to and the opportunity to improve the process, with resulting gains in quality, reliability and throughput.

3.7 VISUAL MANAGEMENT

WHAT	WHEN
▪ Visual indicators to show 'at a glance' the status of work/delays and problems ▪ Check if we're ahead or behind target	▪ You want to check performance and see what is working and what needs attention
WHY	**HOW**
▪ Operators need to know if they are ahead of or behind target at any given time ▪ Encourages operators to raise probems preventing on-target performance ▪ Makes managers aware of problems and actions required	▪ Manufacturing: hourly counts, performance boards, Andon lights, line stop, inventory build up ▪ Service: performance boards with KPIs, progress metrics, etc. ▪ Computer systems tend to hide metrics and prevent real time reporting

Visual Management allows the status of work to be seen at a glance. In practice, this tends to be through 'hour-by-hour' charts, red/green performance indicators, progress against group KPIs and best practice examples which are displayed on charts close to the workplace.

Performance boards are recommended to record hourly or daily performance against target. Andon (signal) lights may be used on a production line to indicate the location and status of problem areas or bottlenecks, while a line stoppage and inventory build-up is a clear indication of a problem. In service businesses, computer systems might record real-time information but tend to aggregate information into daily or weekly reports that will tell you about performance last week or last month. Best practice in a service business is to record daily metrics and performance KPIs on a whiteboard, which is reviewed daily and used in addition to the aggregated metrics available from your ERP, MRP or CRM system.

3.8 THE 8 WASTES

Remembering that Lean is about maximizing value in a business by identifying and eliminating waste, the first step is to understand what we mean by waste. Value is something that you produce and that you can charge your customer for; waste is everything else. Of course, in a business there are some activities that are not directly attributable to this value/waste equation, but, through analysis, you can identify them and find ways to reduce them.

For example, packaging goods during production steps to prevent damage is a good thing but, by using the value/waste ideal, you know that the customer is not willing to pay for in-process packaging. So, if you can combine some process steps, create flow and eliminate the need for repackaging, then you can eliminate waste from your process.

Similarly, in an administrative process (for example, a purchasing process), by mapping the process, you can identify the number of handoffs between teams that add delay or raise questions, or the number of sign offs required, and therefore identify the waste associated with waiting. A simple acronym to remember the 8 wastes is TIM WOODS. They are listed in Table 3 below.

Acronym	Waste	Description
T	Transport waste	Moving goods/products around the site or from place to place, double handling of goods and the costs of couriers. For example, multiple steps in receiving/putting goods away, storage of WIP, or the distances involved between goods in, storage and where products might be being used.
I	Inventory	Batch processing and inventory at any step in your process. All inventory is waste, and while you may need some inventory to work on for some steps in your process, having more of it will not lead to your customer paying more for your product.
M	Motion	Waste within a process step, including lifting, bending and reaching. It also includes searching for parts, tools, information or files. In service industries, consider the cutting/pasting of information between IT systems or the movement to/from office equipment (printers, offices, server rooms, coffee machine, water fountain, etc.).
W	Waiting	Waiting for information to proceed, waiting for goods or waiting for the previous person or operation to complete a cycle. In a service business, you could include waiting for information from clients or other departments, waiting for checking or for decisions and approval. Also includes computer system response times.
O	Overproduction	Creating more than is needed for the next stage in your process or creating it sooner than it is needed and completing activities before they are required or even picking too far in advance of shipment. In manufacturing, the waste of overproduction can cause other wastes, upsetting the steady pace and creating tension in your production line as downstream processes struggle to keep up.
O	Over processing	Unnecessary checks of goods, redundant inspections and repackaging of WIP. In a service industry, this could also include excessive sign offs, duplication of paperwork and work that is repeated later in the process.
D	Defects	Quality defects in the product, mistakes in production that require rework or scrap, pick errors in the dispatch processes, errors in the service provided, and ambiguous information that requires verification. Include anything that requires an operator to refer back to the previous step to perform a check, before proceeding to the next step.
S	Skills	Highly skilled (or highly paid) operators performing low-skilled work. Include people working with limited authority, excessive command and control management, or people with inadequate training or business tools to do the job required of them.

Table 3 – Acronym to remember the 8 wastes

The ‘acid test’ of waste is to look at a process in your business and ask yourself, “If we did more of this, or had more of this, could we charge the customer more for it?” If the answer is not an emphatic “Yes”, then you are considering something that is on the waste side of the equation and need to find ways to reduce it.

Other Lean tools you may become aware of as your Lean programme develops include: 5S, SMED and TPM.

3.9 5S

5S is a series of tools defining and encouraging Lean in the workplace. Usually applied to manufacturing (although Lean in the office works too), 5S should be applied towards the end of your Lean journey, as an element of perfecting the process.

The 5S terms are derived from the Japanese language and are described below.

1 SORT - *Seiri*

At a workplace level, sort the items you need from the items you do not. This decluttering of your workplace can help to create a more orderly space—one where it is easier to see the status of work and easier for operators to work. A tool that can help in this is the Red Tag methodology.

2 SET IN ORDER - *Seitori*

Ensure that your operators have everything they need available at their workstation and make space for these things accordingly. A good analogy is to think of a surgeon in an operating theatre. They want to stand by their patient and have all the instruments they will need for an operation, in easy reach, in a logical order—without needing to move or search for them.

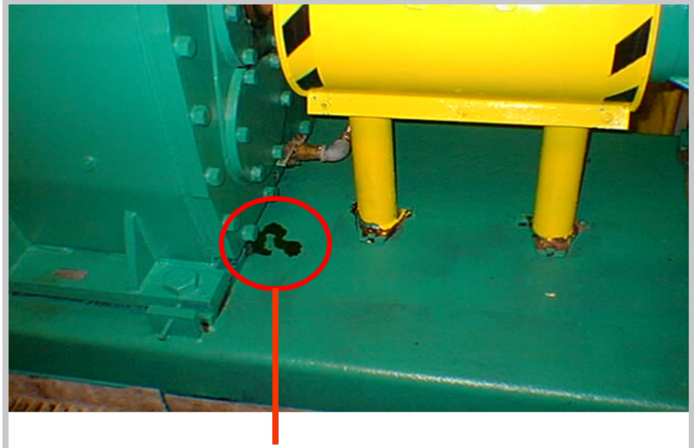
It is often useful to think of the things you need every day and make space for them at the workstation. Items needed only once a week can be stored in a common area between workers, and those needed once a month should be stored nearby and labelled accordingly.

The ideal is ‘everything in its place and a place for everything’. Shadow boards are good examples of a means to ensure that all items are in place at the workstation.

Figure 4 – Shadow board showing one pair of pliers is missing. *Source: www.Plasteel.az*

3 SHINE - *Seiso*

The concept of Shine is less about polishing and more about ensuring that your workplace, equipment and tools are clean and tidy. For example, while an operator is cleaning a drill or wiping down a pump, they will be able to assess whether there is wear that could cause the operation to fail later or if the pump is leaking. These potential concerns can then be escalated to the maintenance or engineering team to ensure no breakdowns occur.



Source of oil leak is only detected because pump housing had been cleaned during 5S shine. *Source: TXM.com*

Figure 5 – Example of *Shine* benefits

4 STANDARDIZE - *Seiketsu*

Once the workplace is at the level of order you require, capture it as the ‘standard’ for the area. Photographic standards, with a number of bullet points to define what ‘good’ looks like, should be displayed at the workstation.

5 SUSTAIN - *Shitsuke*

The hardest part of 5S is keeping the first 4S elements relevant and ensuring that the old, bad habits do not return. Turning best practices into habits takes time and effort, but a commonly used method is a weekly or twice weekly audit of the workplace. Permanent results may however be best achieved when all employees are clearly understanding the benefit of new arrangements and can adopt the changes when seeing advantages also to themselves and not only for the business. Operators are marked according to the displayed standard and audit scores for each area, and improvement ideas and performance are recorded at a central location and reviewed regularly. Key to this is the concept that management re-enforce the standards, lending their support wherever possible.

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5 S AUDIT SHEET - **SHOP FLOOR**

S.N.	1S Sorting Out	Score	0	5	10	15	20
			LEVELS				
1	Floor cleanliness - free from dust, oil, mud etc.	20					
2	General cleanliness inside factory - walls, pillars, pipelines are clean without scaling, paint peeling marks, strains etc.	20					
3	Cleanliness of containers/pallets - free from dust, oil. Container/pallet in painted condition and free from damages.	20					
4	Cleanliness of parts - free from dust, oil (dry condition).	20					
5	Cleanliness of jigs, fixtures - free from dust, oil.	20					
6	Unused/excess material removed to separate place, away from work area.	20					
7	No mix up of parts in pallets, containers, trays etc.	20					
	TOTAL FOR 1S	140					
	1S SCORE = (TOTAL score X 100 /140)						
S.N.	**2S Systematic Arrangement**	**Out of**	**0**	**5**	**10**	**15**	**20**
1	Gangway - Marking is clear and no material in the gangway.	20					
2	Use of right pallet/container, trays, etc.	20					
3	Right pallets, containers, trays etc in right location.	20					
4	Right component in right containers/pallets etc.	20					
5	Only calibrated jigs/fixtures are used.	20					
6	Fire extinguishers are in fixed location.	20					
7	Proper shadow board for tools.	20					
8	Proper storage of housekeeping tools (broom, brush, small shovel, tool for cleaning at heights).	20					
	TOTAL FOR 2S	160					
	2S SCORE = (TOTAL score X 100 /160)						
S.N.	**3S Shine Everything**	**Out of**	**0**	**5**	**10**	**15**	**20**
1	Component parts not touching each other in containers, trays, etc.	20					
2	Containers, trolleys are OK and clean.	20					
3	Material movement facilities are neat and clean.	20					
4	Plant and equipment available in clean condition - all sides.	20					
5	Preventive maintenance schedule available and effective.	20					
6	Chip/swarf collection and disposable system available.	20					
	TOTAL FOR 3S	120					
	3S SCORE = (TOTAL score X 100 /120)						
S.N.	**4S Standardization**	**Out of**	**0**	**5**	**10**	**15**	**20**
1	Retrieval of tools, document is easy (ask for documents, related tools).	20					
2	Andon lights on machines are available and effective.	20					
3	Localized shadow boards, tools available for cleaning and maintenance and effective.	20					
4	Easy to see and inspect facility available on machines and equipment.	20					
5	Pre-fixed quantity per container/pallets is in practice.	20					
	TOTAL FOR 4S	100					
	4S SCORE = (TOTAL score X 100 /160)						
S.N.	**5S Self Discipline**	**Out of**	**0**	**5**	**10**	**15**	**20**
1	People are aware for "5S" requirement and their doing their role (ask 2-3 people).	20					
2	Availability of operating standards (operation sheet, work instructions) and are effective.	20					
3	Activities are done as per schedule (audit, action on NC products etc.).	20					
4	Appropriate legible visual control system in practice (area names, displays).	20					
	TOTAL FOR 5S	80					
	5S SCORE = (TOTAL score X 100 /80)						

Figure 6 – 5S audits should be completed for each area, and the team score displayed on a performance board. *Source: Previous write up*

3.10 SMED

SMED (Single Minute Exchange of Die) is a technique that aims to drastically cut the time taken to changeover production line equipment. Its overarching principle is to maximise the number of "external" steps, i.e. those that can be carried out while the production line is running, and to make any equipment changeover that cannot be done in this way simpler and more efficient. The term Single Minute Exchange of Dies originated in the automotive sector, where the objective was to achieve "single-digit" changeover times (i.e. times of less than ten minutes) in car manufacturing press shops, something that had previously taken hours. The process is described below.

STEP 1 – **OBSERVE AND MEASURE THE CURRENT SITUATION**
This includes recording the time taken, the tools required at each step; ideally, it also involves video footage that can be reviewed with the operator and discussed.

STEP 2 – **SEPARATE INTERNAL AND EXTERNAL ISSUES**
Define the process steps that are external and those that are internal.

STEP 3 – **CONVERT INTERNALS TO EXTERNALS**
Maximize the opportunity to prepare all the stages required for changeover while the equipment is still running. This could include ensuring all tools required are close at hand, and selecting the new press tools dies, and all settings for the new operation, while the previous run is still taking place.

STEP 4 – **STREAMLINE THE PROCESS**
Look for improvements and develop a target time for each step, as well as an action plan to implement it.

STEP 5 – **STANDARDIZE THE PROCESS**
Try it out, look for opportunities to improve, and create a standard, written operating procedure around the new best practice.

Figure 7 – SMED process

PRESS CHANGEOVER PROCESS - PRESS #1

PROCESS STEP	REMOVE GUARDS	LOWERING TOOL ONTO LOWER PLATE	UNDO TOOL FIXINGS	REMOVE TOOL + COLLECT NEW TOOL	ADJUST STROKE	FIT & ADJUST TOP TOOL	COLLECT + FIT BOTTOM TOOL	OIL PINS + FIT PRESSURE PLATE	CHECK FIT OF TOP + BOTTOM TOOLS	PREPARE FOR FIRST OFFs	LUBRICATE + PRESS FIRST 2 BLANKS
TIME TAKEN	2'30	4'50	3'0	7'30	9'30	4'40	8'40	6'45	3'15	12'	2'
		7'20	10'20	17'50	27'20	32'	40'40	47'25	50'40	62'40	64'40
INTERNAL OR EXTERNAL	I	I	I	I/E	I	I	I	I	I	E	I
POTENTIAL IMPROVEMENTS + OBSERVATIONS	QUICK RELEASE FIXING (PANEL KEY)	KEEP PLATE * NEXT TO TOOL INTERRUPTIONS!		TROLLEY + * TOOLS CLOSE TO PRESS	POSITION + * OF STEPS INTERRUPTION	PNENUMATIC JACK SOLUTIONS (PRESS CUSHION)	TOOL * LOCA-TION NEW * CLAMPS RATCHET SPANNER	LOCATION OF PRESSURE PLATE NEED 4 ALLEN KEYS		PRE-PREPARE ON TROLLEY 'SLUSH PUPPIE' OR OTHER AGITATOR 3'	
TIME SAVED	1'	2'40		2'	4'	3'30	3'	1'15		9'	
		3'40		5'40	9'40	13'10	16'10	17'25		26'25	

CHECK FIT OF TOP + BOTTOM TOOLS	PREPARE FOR FIRST OFFs	LUBRICATE + PRESS FIRST 2 BLANKS	CHECK QUALITY MEASURE & ADJUST	PRESS ANOTHER 2 BLANKS + CHECK QUALITY	MEASURE & CHECK + ADJUST	PRESS ANOTHER BODY (FINAL CHECK)	RE-FIT GUARDS & DEADENING	PREPARE FOR PRODUC-TION RUN
3'15	12'	2'	2'40	0'50	2'00	0'40	4'50	0'30
50'40	62'40	64'40	67'20	68'10	70'10	70'50	75'40	76'10
I	E	I	I	I	I	I	I	I
	PRE-PREPARE ON TROLLEY 'SLUSH PUPPIE' OR OTHER AGITATOR 3'		JIG TO HOLD BODIES TOGETHER FOR MEASURING 1'		JIG TO HOLD BODIES TOGETHER WHEN MEASURING		INTERRPU-TIONS! 3' QUICK REALESE FIXING (PANEL KEY)	
	9'		1'		1'		4'	
	26'25		27'25		28'25		32'25	

Figure 8 – SMED record chart. *Source: Applied Lean Consulting*

Once implemented, the benefits of SMED will include:

- REDUCED BATCH SIZES (moving towards the ideal of single-piece flow);
- IMPROVED RESPONSIVENESS TO CUSTOMER DEMAND (smaller lot sizes enabling more flexible scheduling);
- LOWER INVENTORY LEVELS (smaller batch sizes resulting in lower inventory levels).

3.11 TOTAL PRODUCTIVE MAINTENANCE

TPM (Total Productive Maintenance) is the mechanism by which a company manages its production facility to pre-empt and prevent breakdowns - and therefore maximize the potential operation of machinery and production lines.

Analysis of machine failures over time demonstrates a standard 'bathtub' curve: failures at start-up (infant mortality failures due to poor specification or engineering), failures during operation (so-called random failures of components), and failures due to wear out.

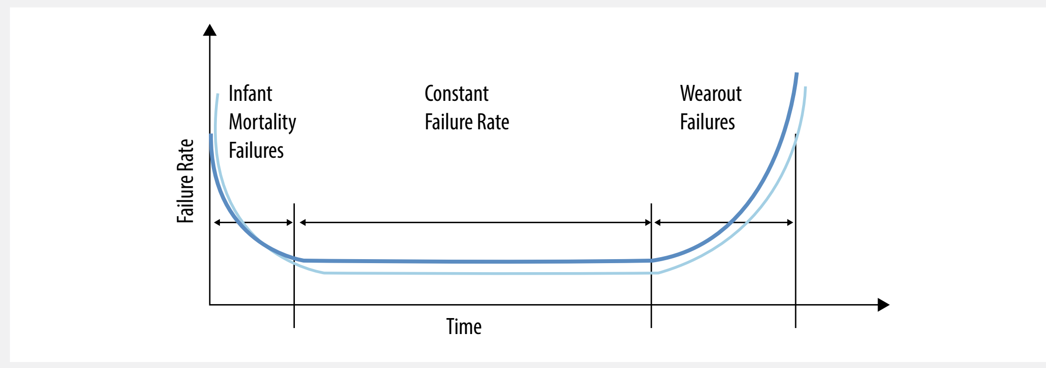

Figure 9 – Bathtub failure curve. *Source: Applied Lean Consulting*

TPM falls into two main types, as listed below:

1. PLANNED MAINTENANCE, which takes place before a breakdown and could be preventative, predictive or improvements; and
2. UNPLANNED MAINTENANCE, which reacts to breakdowns.

By studying where failures occur, and under what conditions, you can pre-empt breakdowns and proactively check for signs of problems while the line is running.

Type of maintenance	Action required	Ownership	Production line example
PREVENTATIVE CHECKS BY OPERATOR	Hourly/daily/weekly as part of 5S initiative	Operator (Autonomous Maintenance)	Cleaning, check for damage and checking lubrication
PREVENTATIVE CHECKS BY MAINTENANCE DEPARTMENT	According to maintenance schedule	Maintenance department	Service checks or replacement of bearings at standard intervals
PREDICTIVE	Follow-up of abnormal noise, temperature or vibration	Reported by Operator at Daily Stand Up. Owned by Maintenance	Premature wear or noise giving indication of future bearing wear-out
IMPROVEMENTS	Improve running	Engineering Department	Upgrade to bearings to give longer life
CORRECTIVE	Repair after breakdown	Maintenance Department	Bearing failure on machine

Figure 10 – Total Productive Maintenance is owned by many parts of the company – hence the name Total Productive Maintenance. *Source: Applied Lean Consulting*

In a Lean operation, operators, and the Maintenance and Engineering Departments need to work together as a team to monitor the situation and share responsibility for raising and fixing problems. Lean supports TPM via the two routes listed in Figure 11 below.

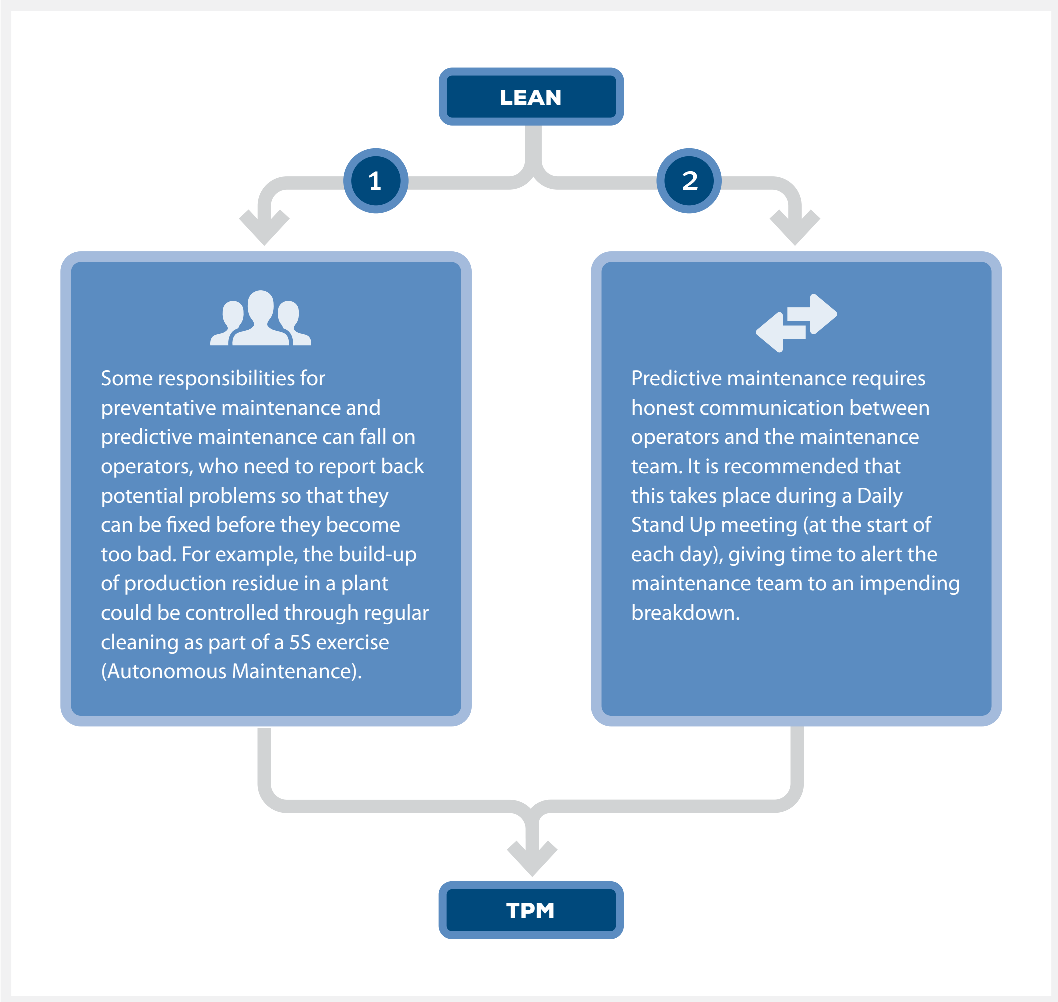

Figure 11 – TPM support through Lean

Total Productive Maintenance shares responsibility for keeping the production line running across a number of teams. Operators, through their 5S activities, conduct Autonomous Maintenance and report abnormal status as predictive maintenance at the Daily Stand Up meeting.

The Maintenance Department conducts service work and scheduled replacements according to service intervals, but their priority is repairing breakdowns. Engineering teams focus on improvements to either reduce breakdowns or increase line speed.

3.12 CREATING A LEAN CULTURE

Making Lean work effectively throughout your organization takes time and effort. Developing a Lean culture requires the building of relationships of trust and empowerment throughout the organization. Fundamental to this is the development of communication channels between the different levels in your business.

The diagram below shows how you need to analyse the processes to develop best practices. The management and methods involved need to become habits that form the basis of the behaviours you promote in the business. The behaviours across the organization are then distilled into the culture of the organization.

Figure 12 – Sustainable Lean model. *Source Applied Lean Consulting*

Leadership actions to promote Lean include: Formal and informal broadcasting of information throughout the company (including company vision), performance against targets, undertaking specific initiatives and identifying where support is required.

Shop floor actions of Lean companies include: At the shop floor level, a Daily Stand Up meeting (also known as a Daily Huddle) in teams to discuss performance against targets, gain feedback about issues preventing operators/teams from reaching their targets, resource planning for the day, problem solving, suggestion schemes, and reward and recognition programmes.

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4

4IR Solutions to Upgrade Lean Manufacturing

Among all the 4IR technologies, the following six solutions contribute significantly to lean manufacturing than the others. They have brought lean manufacturing to the next level, Lean 4.0, through facilitating connectivity, improving productivity, increasing transparency, ameliorating efficiency, reducing waste, and enhancing functionality. Now, let's look at these beautiful tools which transform global manufacturing.

4.1 IIoT, ENABLING AN INTERCONNECTED AND TRACEABLE GLOBAL SUPPLY CHAIN

The pandemic has been a wake-up call for the astonishingly fragile global value chains (GVCs), which are yet critical for global manufacturing. Among all, the greatest weakness of current GVCs is the lack of interconnectivity and traceability. Many works are still be implemented by workers manually, which results in unnecessary errors and unwanted inefficiency; every part of the GVCs remains a silo, where the information is not shared and the transparency is failed; the malfunctions throughout the value chain cannot be predicted nor found because there is no such monitoring system, which causes numerous loss of time and resources. All these heavily impede the development of lean manufacturing to fuel constant leapfrog in productivity and profitability inside most shop floors all over the world, particularly in developing countries.

The industrial internet of things (IIoT) is undoubtedly the biggest seeded player to change the game under this circumstance. IIoT refers to interconnected sensors, instruments, and other devices networked with computers' industrial applications, including manufacturing and energy management. This connectivity allows for data collection, exchange, and analysis, potentially facilitating improvements in productivity and efficiency as well as other economic benefits[1]. The IIoT brings together critical assets, advanced predictive and prescriptive analytics, and modern industrial workers[2] to introduce systems that can monitor, collect, exchange, analyze, and deliver valuable new insights like never before.

Figure 13 – IIoT allows for global data collection, exchange and analysis

1) The industrial internet of things (IIoT): An analysis framework, Boyes, Hugh; Hallaq, Bil; Cunningham, Joe; Watson, Tim (October 2018).

2) What is the Industrial Internet of Things (IIoT)?, Colin Parris, https://www.ge.com/digital/blog/what-industrial-internet-things-iiot

The sensors deployed in the IIoT play an essential role in forming this net of information flow. All elements in the value chain are seamlessly connected, which allows constant real-time information sharing, monitoring, and interaction. This characteristic significantly strengthens the value stream mapping of lean manufacturing with the information gleaned from connected devices, including user experiences with a variety of products to provide unprecedented possibilities to enhance manufacturing processes, reduce waste and generate traceability. Of all the technologies associated with lean manufacturing, IIoT stands to have the greatest impact, creating a pipeline of data that can be leveraged to fine-tune lean strategies and make adjustments on the fly[3]. The predictive tools enabled by connected and real-time data allow potential problems to be identified and cleared out at the first stage, which reduces waste of time and cost. With the endorsement of the IIoT, lean manufacturing remains the basic stage in a product life cycle yet exponentially wields its power to help businesses optimize decision-making, eliminate waste, and improve efficiency. Another considerable contribution of IIoT to lean manufacturing is that pull establishment becomes easier and more reliable. With the ambition of achieving a smooth workflow, a pull-based system with the tool of Kanban is to established to limit inventory and WIP items, which ensures JIC production and delivery. Compared to the previous Kanban in a pencil-board form, the IIoT creates a new pull-based system equipped with full inter-connectivity by sharing data instantaneously, which is operated without any human interference. The data captured by IIoT devices is leveraged to coordinate complex scenarios of multiple interconnected flows which can't be integrated any other way[4] to forecast demand, identify malfunctions, and reduce wastes.

3) Lean, the Internet of Things and Manufacturing, https://www.gray.com/insights/lean-the-internet-of-things-and-manufacturing /

4) Supercharging Lean with IoT, https://www.industryweek.com/operations/continuous-improvement/article/22006090/supercharg-ing-lean-with-iot

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A myriad of success stories speaks out loud for this magical combination of lean manufacturing and IIoT. The wait time can be measured by motion sensors, which will launch troubleshooting measures automatically if it is too long. Disney uses the same technology to reduce queue times at theme park attractions[5]. The inventory can be efficiently managed through sensors mounted on stock units using GPS coordinates, which simplifies cycle counting and increases inventory visibility across the supply chain. Similarly, the real-time sensors will prevent producers from overproduction by predicting the potential demand and keeping the stock levels always at acceptable thresholds. The defect resulting in a delay in quality improvement can be immediately identified by IIoT sensors once it deviates from the standard production process, which helps address problems more timely ameliorating customer satisfaction.

4.2 BIG DATA ANALYTICS, ENGENDERING INTELLIGENT AND TAILORED SOLUTIONS

Information is the new petrol at the twenty-first century. Whoever possesses the information is equipped with potent weapons to stand at the cusp of the development. However, with the inburst of numerous flows of petabytes of information every single second in today's world, information management has become overwhelming yet critical for every business. It is no longer the priority to access enough information but to seize adequate information efficiently among all information to provide visibility, analytics, and solutions. Therefore, to achieve a leapfrog for the global manufacturing sector, it is imperative to acquire information rapidly and sufficiently and manage, process, and visualize it efficiently and accurately.

Big data analytics emerged to usher global manufacturing to a new era of data processing. Big data is a field that treats ways to analyze, systematically extract information from, or otherwise, deal with data sets that are too large or complex to be dealt with by traditional data-processing application software. Data with many fields offer greater statistical power, while data with higher complexity may lead to a higher false discovery rate[6]. The three outstanding characteristics of big data are volume, velocity, and variety, also known as 3Vs. The amount of data matters, which can vary from several terabytes to hundreds of petabytes for different businesses.

Figure 14 – The three outstanding characteristics of big data ("3V")

5) Ibid.

6) Breur, Tom (July 2016), Statistical Power Analysis and the contemporary "crisis" in social sciences, Journal of Marketing Analytics, London, England: Palgrave Macmillan.

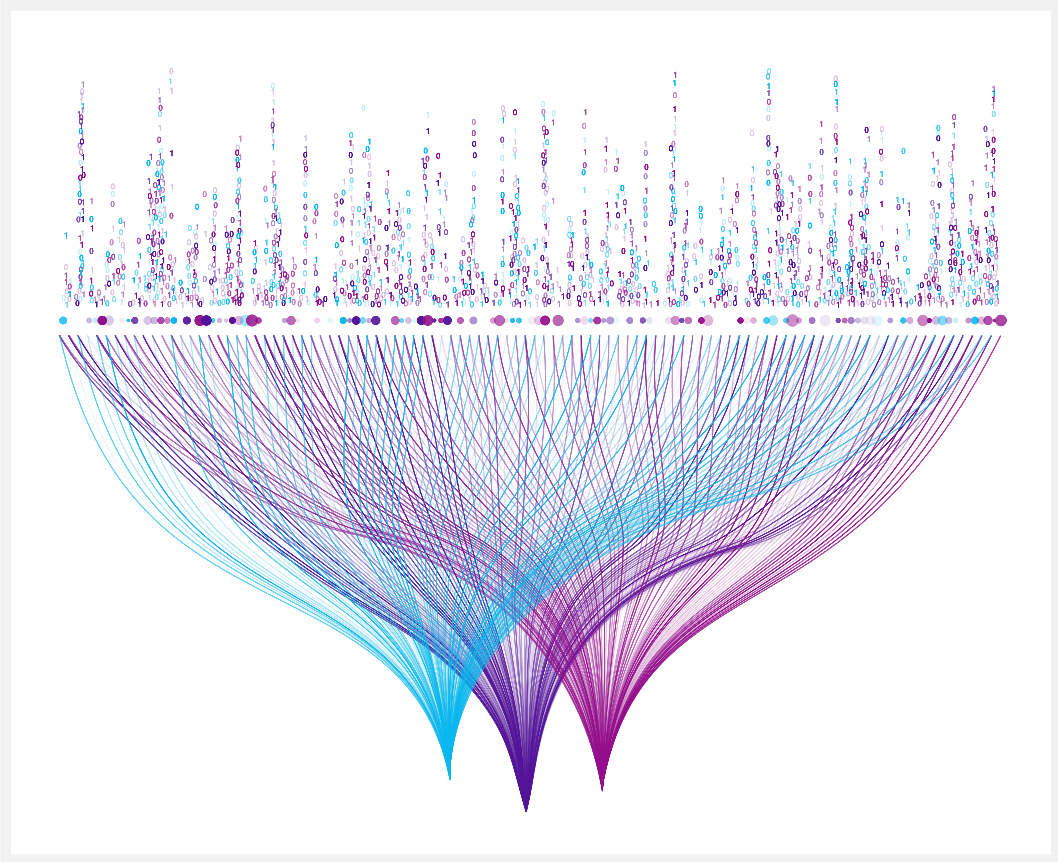

Figure 15 – Analytical visualization of big data

Velocity is the fast rate at which data is received and (perhaps) acted on. Usually, the highest velocity of data streams directly into memory versus being written to disk. Some internet-enabled smart products operate in real time or near real time and require real-time evaluation and action. Variety refers to the many types of data that are available. Traditional data types were structured and fit neatly in a relational database. With the rise of big data, data comes in new unstructured data types, such as text, audio, and video, which require additional preprocessing to derive meaning and support metadata[7]. The 3Vs of big data perfectly meet up with the needs and expectations of information management required by today's global manufacturing, which ensures real-time and efficient processing of abundant information from various resources to solve previously unsolvable (and even unknown) problems that undermine efficiency in complex manufacturing environments: hidden bottlenecks, operational rigidity, and areas of excessive variability[8].

7) Oracle, What is big data?, https://www.oracle.com/big-data/what-is-big-data/

8) McKinsey and Company, When big data goes lean, February 1, 2014, https://www.mckinsey.com/business-functions/operations/our-insights/when-big-data-goes-lean

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Through comprehensive and rapid data-driven analytics throughout the supply chain, even the slightest waste or mechanical malfunction can be identified and provided with intelligent solutions. Moreover, predictive tools and responsive systems empowered by big data analytics lead the whole supply chain to a higher level of efficiency and functionality in regard to better flexibility and agility to more frequent market changes and increasing customers requirements, which used to be boorish in manufacturing in the days of yore. Lean manufacturing is much more upgraded by dint of big data analytics through:

- Collecting, sorting, analyzing numerous data to determine the core needs of the final customers at a specific price, at a specific time, and for a specific product/service from customers' perspectives to better define value.
- Identifying the value stream and providing measurable actions to validate the process steps based on the aforementioned analytics to eliminate unnecessary waste at the expense of customers' benefits.
- Establishing an intelligent pull system to eliminate functional barriers and develop a product-focused organization through cycle time & inventory-related metrics engendered by big data analytics, which allows creating smooth flows.

Big data has been widely implemented in manufacturing in terms of supply management, customized product design, machine maintenance, and quality assurance. With the aid of real-time data analytics, big data features every part of the supply chain to provide accurate visualization and tailored solutions to specific problems concerning supply management. Also, these data-driven analytics allow businesses to have a clear image of customers' shopping habits, behaviors, and preferences to fine-tune the design strategies and production models to better predict and cater to customers' expectations. Big data can also help manufacturers keep track of how frequent and intense it is to maintain their machines by continually analyzing particular perimeters of the devices. Last but not least, better quality assurance has been harnessed through big data analytics by cutting down test time and focusing on specific tests, which significantly reduce the number of tests required for quality assurance. The result was a savings of $3 million in manufacturing costs for a single line of Intel Core processors. By expanding big data use in its chip manufacturing, the company expects to save an additional $30 million[9].

4.3 ADDITIVE MANUFACTURING, DEVELOPING CUSTOMIZED PRODUCTS AND SERVICES

For today's manufacturing industry, one thing always remains a puzzle: how to provide customers with the most personalized products/services to satisfy their increasing needs and expectations. Once upon a time, customized products/services were merely accessible to the noble and the rich, while most of the population could only lament over the available homogeneous ones with no personal characteristics attached. However, with the roaring economic development, more and more customers have raised their ambition to own more customized products/services at an affordable price, which has become today's top business competition. As a result, the prosperity of businesses is at stake, which entirely depends on if manufacturers can take the initiative to offer customized products/services at a reasonable price for mass production. It remained unimaginable until the prevalence of additive manufacturing (AM).

Additive manufacturing (AM), also known as 3D printing, is a transformative approach to industrial production that enables the creation of lighter, stronger parts and systems. Additive manufacturing uses data computer-aided-design (CAD) software or 3D object scanners to direct hardware to deposit material, layer upon layer, in precise geometric shapes[10]. Additive manufacturing techniques directly benefit from their fast and flexible way of realizing a small or medium number of parts in a cost-effective way.

9) 4 Big Data Use Cases in the Manufacturing Industry, September 15, 2017, https://imaginenext.ingrammicro.com/data-center/4-big-data-use-cases-in-the-manufacturing-industry-1

10) GE, What is additive manufacturing?, https://www.ge.com/additive/additive-manufacturing

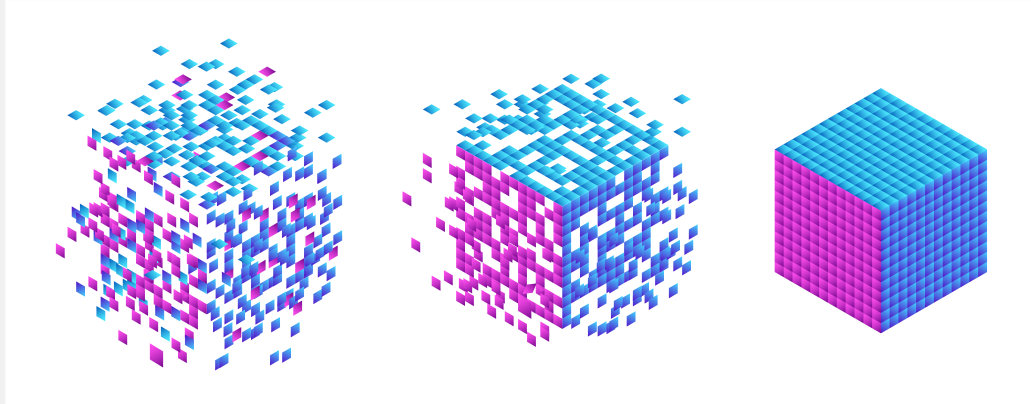


Figure 16 – Additive manufacturing allows to deposit material in precise geometric shapes

By dint of the AM, the traditional lean is upgraded to its smart version, which better serves customers' needs from their perspectives with personalized-designed products. The cost is significantly reduced and the efficiency is considerably increased since the products are designed initially to best suit customers' requirements with no redundant characteristics added. The AM unlocks new customizable possibilities due to the fact that it does not require expensive tooling changes based on individual specifications[11]. The AM helps define value and even create the customization value by taking into account customers' needs and expectations and implementing measures to achieve them. Functionally, more fit and tailored products with personalized features catering to customers' characteristics, preferences, and needs are delivered to improve the user experience faster. Aesthetically, more features such as colors, textures, forms, and logos can be tuned into an individual's preference to add more personal touch to the products and create their signature belongings. Technically, the supply chain becomes even safer as the AM rapidly prints unique codes containing comprehensive tracking information to ensure smooth fraud detection. Moreover, seek perfection procedure of lean manufacturing is supported by more substantial technical tools enabled by the AM. The philosophy of constant improvement is taking its solid strides by developing ideas and implementing them to reduce cost, increase efficiency, and enhance functionality, to which the AM has contributed.

According to McKinsey, research is showing that sales conversions increase by 22 to 30 percent when product customization is offered and consumers are willing to pay a nearly 20 percent higher price[12]. Customization empowered by the AM can be applied to many industries. In the apparel market, there will be sports shoes with the option of choosing different colors for different elements and suits/shirts fit to body measurements or scans.

11) Making product customization possible with additive manufacturing, https://www.fastradius.com/resources/making-mass-customization-of-products-possible-with-additive-manufacturing/

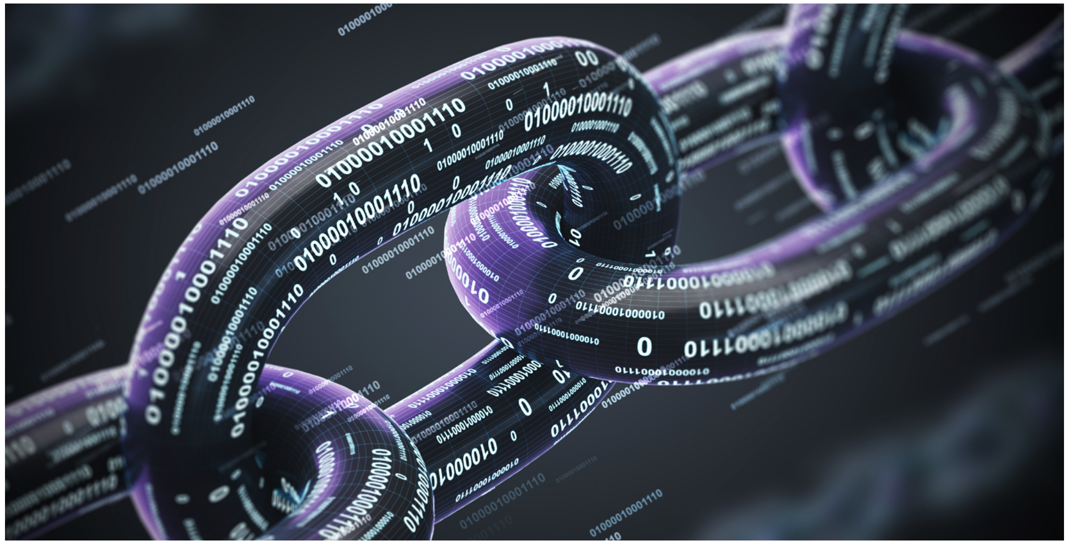
12) Ibid.

As to the food industry, more frozen yogurt with custom topping choices and personalized food and vitamins based on nutritional needs will be provided. When it comes to the automotive sector, vehicles are equipped with individualized choices for colors, seats, accessories, and body shapes[13]. The AM is fueling the next wave of mass customization by defining, creating, and implementing the customization values desired by manufacturers and consumers.

4.4 BLOCKCHAIN, SECURING THE SAFETY AND TRANSPARENCY THROUGHOUT THE SUPPLY CHAIN

One stubborn headache while implementing lean constantly repeats itself throughout the value chain: lack of transparency. Manufacturers are obliged to invest extra time and human efforts to guarantee transparency and secure the safety of the holistic supply chain. Yet, the gains are far from being satisfactory because of the occurrence of faults and unreliability due to human involvement. The manufacturing world has never stopped longing for an effective and efficient tech-based solution to address this rooting challenge until the birth of blockchain, which casts a new light of hope on the issue.

Blockchain is a specific type of database architecture based on the Distributed Ledger Technology (DLT)[14]. More precisely, it is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible (a house, car, cash, land) or intangible (intellectual property, patents, copyrights, branding). Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved. Blockchain is ideal for delivering that information because it provides immediate, shared, and completely transparent information stored on an immutable ledger that can be accessed only by permissioned network members[15]. Four key characteristics of blockchain are doing the magic[16]:



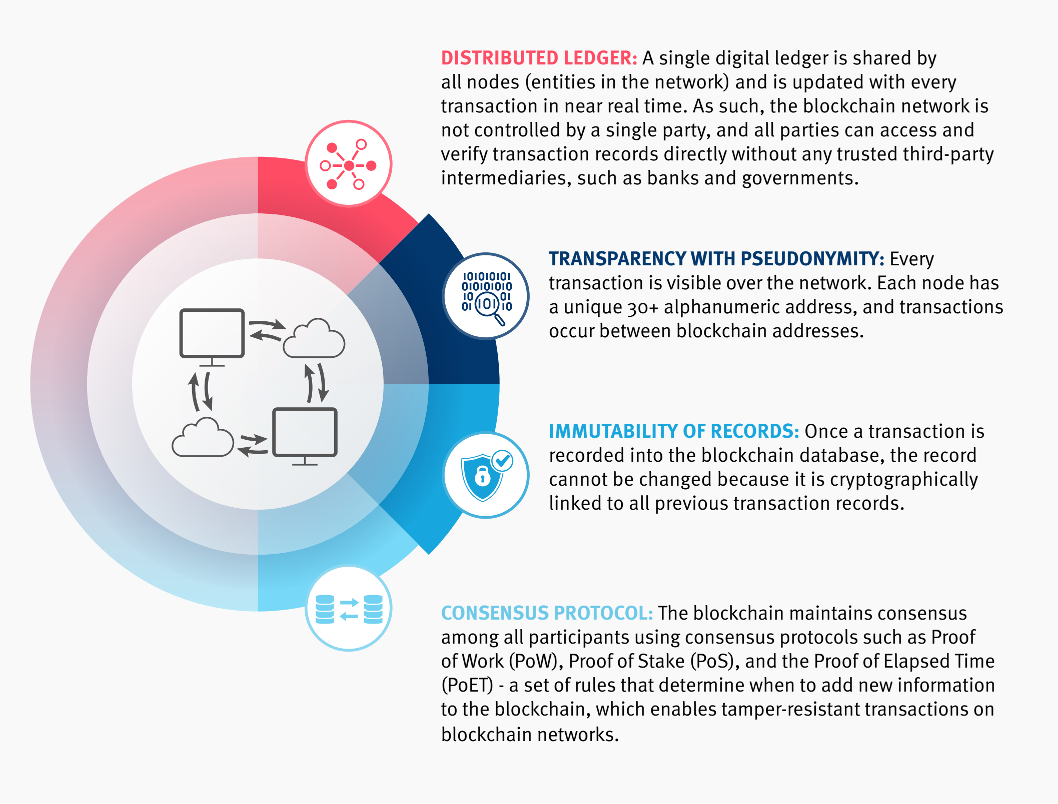


Figure 17 – Four key characteristics of blockchain

13) McKinsey and Company, How technology can drive the next wave of mass customization?, https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/bto/pdf/mobt32_02-09_masscustom_r4.ashx

14) Researchgate, Blockchain and supply chain relations: A transaction cost theory perspective, Schmidt and Wagner 2019, https://www.researchgate.net/publication/334433052_Blockchain_and_supply_chain_relations_A_transaction_cost_theory_perspective

15) IBM, What is blockchain technology?, https://www.ibm.com/topics/what-is-blockchain

16) The Fintech Center, A Study on Value Creation through Blockchain-based Supply Chain Networks in Lean Production System, https://fintech.morgan.edu/wp-content/uploads/A-Study-on-Value-Creation-through-Blockchain-based-Supply-Chain-Networks-in-Lean-Production-System.pdf

When it comes to enhancing lean manufacturing, the blockchain mostly contributes to reducing transaction settlement time and cost through a single decentralized ledger, shortening lead times and delays through peer-to-peer transactions and smart contracts, and mitigating the cost of opportunistic behavior through transparent and temper-evident records. Further, in the current global supply chain crisis such as the COVID-19 pandemic, blockchain networks are expected to serve as a more efficient business operations platform to implement lean management practices[17]. With the support of blockchain, the whole value chain is furnished with transparency, security, and immediacy. First, the supply chain is under close tech-based monitoring to ensure full transparency. Second, identity management of elements of the supply chain becomes easier, which determines materials provenance and counterfeit detection. Furthermore, effective and efficient quality control becomes much more feasible by applying Quality Defect Tolerance (QDT), which allows multiple inspections on a workpiece to be consolidated at a faster pace, effectively speeding up the entire quality control process[18]. Last but not least, full regulatory compliance is achieved thanks to the uniformity of blockchain consensus protocol and the reliability of secured and immutable data.

Blockchain has been imaginably prevalent since its incubation due to its substantial contribution to global manufacturing. 84% of executives across industries said their companies had had some involvement with blockchain, and 15% have live projects[19]. There is great potential for blockchain in manufacturing, which represents increasing visibility across all areas of the process from suppliers, strategic sourcing, procurement, and supplier quality to shop floor operations which include machine-level monitoring and service, blockchain can allow for an entirely new manufacturing business model[20].

4.5 ROBOTICS, NURTURING AUTOMATED AND COLLABORATIVE MANUFACTURING

Since always, the lack of a skilled human workforce has been a recurring problem for the manufacturing industry. As the aging population and the skillful workforce void keep scaling up, the global development has reached its bottleneck greatly refrained from the gap between the qualified workforce and the number actually needed by the market. The COVID-19 pandemic adds to the existing misfortune since a myriad of employees cannot continue to perform their work because of the illness. It is every manufacturer's dream to hire more "machine employees," who are immune to external influences such as diseases, injuries, accidents, etc., yet equally skilled as human workers to accomplish the tasks. This is where robotics came to the scene.

17) Ibid.

18) Blockchain in manufacturing quality control: A computer simulation study, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7920390/

19) PwC, PwC's Global Blockchain Survey 2018, https://www.pwc.com/jg/en/publications/blockchain-is-here-next-move.html

20) The role of blockchain in manufacturing, https://manufacturingglobal.com/smart-manufacturing/role-blockchain-manufacturing

Robotics is the intersection of science, engineering, and technology that produces machines, called robots, that substitute for (or replicate) human actions[21]. Robots can be used in many situations for many purposes, but today, many are used in dangerous environments (including inspection of radioactive materials, bomb detection, and deactivation), manufacturing processes, or where humans cannot survive (e.g., in space, underwater, in high heat, and clean up and containment of hazardous materials and radiation). Certain robots require user input to operate while other robots function autonomously[22]. So it doesn't mean that the robots will fully replace the human workforce but assist and collaborate with them.

21) Robotics, https://builtin.com/robotics.

22) Wikipedia, Robotics, https://en.wikipedia.org/wiki/Robotics

Robotics impresses global manufacturing in three dimensions: automation, accuracy, and reconfiguration. Instead of human workers, industrial robotic machines, which are much more immune to external factors, are deployed to shop floors by manufacturers. As such, full automation at any circumstance can be ensured, which is paramount for global manufacturing. In addition, fewer manual faults will be engendered, especially for repetitive tasks by industrial robotic machines compared to human workers, where the accuracy is considerably escalated. Finally, more human workforce will be liberated from mechanical work to more meaningful and creative responsibilities, which dramatically reduces the resource waste through workforce reconfiguration. Lean manufacturing has benefited from the comprehensively automated solutions generated by robotics since they reduce uncertainty, create versatility, increase efficiency, and diminish waste. More importantly, human workers are no longer confined to mechanical work but with time to learn and invest in value tasks, which directly contribute to the constant improvement of the products, processes, and culture.

Automation remains the kernel of the future smart factory, which is highly dependent on robotics technologies. Robotics technologies significantly promote innovative changes and create new production methods. Several robotic solutions are at the forefront of Industry 4.0, including mobile robotics for logistics by taking over the tasks of transporting and packing materials, and, in turn, freeing operators from repetitive and tedious tasks where efficiency and effectiveness can be lost and mobile manipulators, which are a very useful automated solution in smart factories because they permit manufacturers, above all, to save time and improve the efficiency of any given process[23]. Collaborative robots work hand-in-hand with humans in picking, packing, and palletizing, welding, assembling items, handling materials, and inspecting products for quality[24] to upgrade global manufacturing.

23) Smart factories: how robots are leading industry changes, https://robotnik.eu/smart-factories-robots/

24) Forbes, "5 Applications Of Collaborative Robots In Manufacturing", https://www.forbes.com/sites/cognitiveworld/2019/08/09/5-applications-of-collaborative-robots-in-manufacturing/?sh=437613086507

4.6 ARTIFICIAL INTELLIGENCE, EMPOWERING A SMART FACTORY THROUGH HUMAN-MIND SOLUTIONS

It is nice when robotics free the human workforce from tedious, repetitive work but isn't it nicer to have machines thinking like humans and developing their own solutions, which are bound to achieve even more? Manufacturers posed the question years ago, and until the advent of artificial intelligence (AI), they got the firm and positive answer.

AI, a term coined by emeritus Stanford Professor John McCarthy in 1955, was defined by him as "the science and engineering of making intelligent machines"[25]. It refers to the simulation of human intelligence in machines programmed to think like humans and mimic their actions[26]. AI possesses mainly the following characteristics: reasoning and problem solving, self-learning, facial recognition, natural language processing, knowledge representation, and perception.

Machines are expected to take greater responsibility in lean manufacturing under the auspices of Industry 4.0. It is the rise of AI, which endowed machines with more potential to achieve this bigger role. The different subsets of AI offer further insights into how to achieve lean manufacturing, which include:

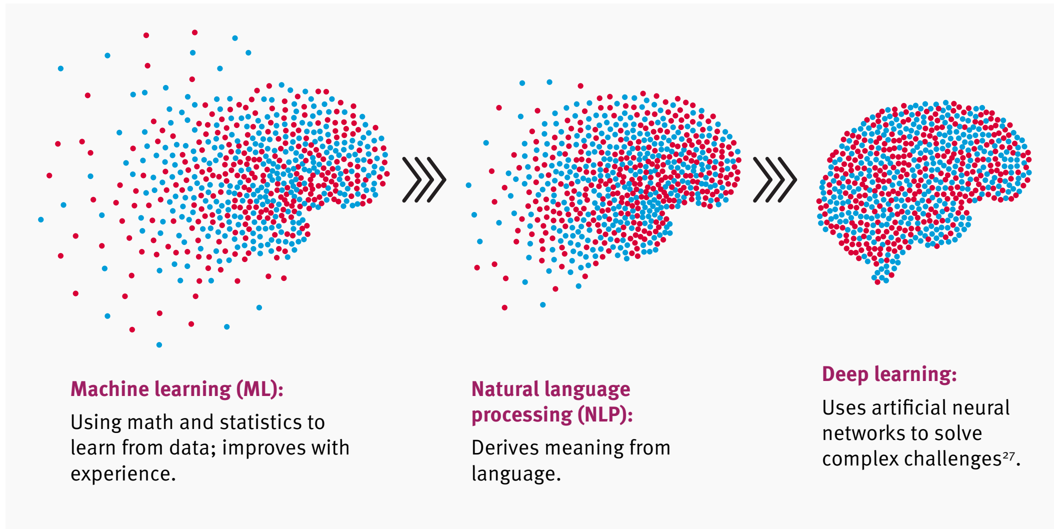


Figure 18 – Main artificial intelligence characteristics

25) Artificial Intelligence Definitions, Stanford University Human-Centered Artificial Intelligence, https://hai.stanford.edu/sites/default/files/2020-09/AI-Definitions-HAI.pdf

26) Golden Gate University, What Is Artificial Intelligence (A.I.)?, https://ggu.libguides.com/AI

27) The AI Approach to Lean Manufacturing, https://www.mastercontrol.com/gxp-lifeline/the-ai-approach-to-lean-manufacturing/

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Especially with machine learning, which is regarded as one of the strongest branches of AI to help forge a smart factory through

Virtual sourcing and developing a collaborative supply chain structure that rapidly advances e-tender virtual auctions with strategic and preferred supplier groups.

Advancing forecast demand modeling - predictive and directional market trending analysis to identify the manufacturing technology needed to meet current or future product designs and customer anticipated needs.

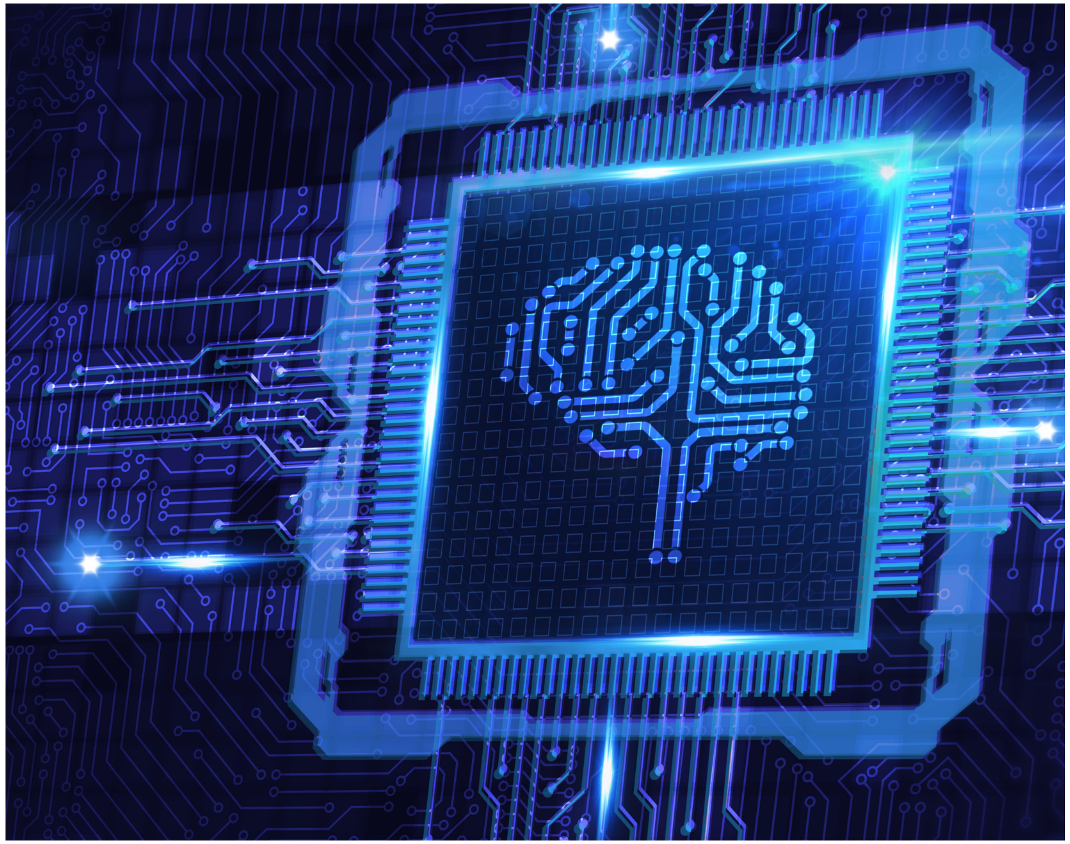
Blueprinting the digital factory by creating a very transparent view of operations, where minimal human involvement is needed or wanted in very fast and repetitive tasks and applying lean flow, pull, and optimized automation and robotic integration to run lights-out as needed.

Enhancing analytics capabilities that are perpetually working to predict and anticipate market trend conditions; modeling and simulating the perceived need in order to have the internal capability and manufacturing capacity within your existing digital factory or extended supply chain (third-party fulfillment) to meet market needs should this need be realized as per the predictive modeling applied[28].

28) Lean Enterprise Institute, Lean Management Meets Artificial intelligence, Machine Learning, the Internet of All Things, https://www.lean.org/the-lean-post/articles/lean-management-meets-artificial-intelligence-machine-learning-the-internet-of-all-things/

With the ability that machine learning has, of providing smart and predictive insights to users, it frees up process and quality engineers' time, which can now be focused on solving issues rather than investigating them[29].

92% of senior manufacturing executives believe that "Smart Factory" digital technologies like AI will help them increase their productivity levels and empower staff to work smarter, according to The Manufacturer's 2018 Annual Manufacturing Report[30]. One of the central promises of artificial intelligence for manufacturing operations of any scale is to achieve the fundamental lean process of observing, drawing conclusions, making decisions, and taking actions while all work is happening without any interventions, which perfectly fits into the idea of continuous improvement of lean manufacturing.



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5

Implementation Approaches

In response to the competitive pressure of modern industries to increase efficiency and effectiveness, UNIDO has launched an innovative approach that has proven to be successful in India, the Russian Federation, Serbia and South Africa. UNIDO, working in cooperation with its partners, has developed hands-on tools that help companies to become more competitive suppliers in global value chains by improving their performance in terms of quality-cost-delivery (Q-C-D). The programme features three tools: the Master Class Approach (MCA), In-Depth Diagnostics (IDD) and Digital Kaizen.

5.1 MASTER CLASS APPROACH

The Master Class Approach (MCA) uses a limited range of Lean tools (described in Section 3) to make rapid changes to small, targeted areas of a process. They focus on waste elimination and quality improvement. Master Classes can be used strategically, as part of a full implementation plan. However, they are more commonly used tactically to facilitate improvement to problem areas.

Although it still uses front-line staff to engage in improvement activity, the MCA tends to be more focused on short-term outcomes rather than longer-term developmental issues. Therefore, UNIDO uses the MCA to demonstrate changes and improvements that can be introduced quickly. This approach is cited by line managers as favourable as it provides a more rapid return on effort, is more visible and does not challenge existing management control styles to the same extent as full adoption. Additionally, shop floor operators feel engaged in an improvement process that quickly demonstrates results to which they had some input. The MCA allows tangible improvements at shop floor level without significant investments, as well as training companies' staff through a learning-by-doing approach.

The key features of the MCA are the following:

- ENGINE CHANGES
- CREATING A FUTURE STATE IN STAGES
- ENGAGING THE OPERATIONAL TEAM
- CREATING CHANGE WITH THE HELP OF THE OPERATIONAL TEAM
- PROMOTING SUSTAINABLE IMPROVEMENTS TO THROUGHPUT
- ENCOURAGING A 'LEARNING-BY-DOING' APPROACH

Figure 19 – Key features of the MCA

The MCA is a demonstration tool that enables an enterprise to familiarize itself with basic Lean methodology and assess the effectiveness of improvements put in place. The MCA is a rapid improvement effort that emphasizes teamwork and innovation to increase employee ownership and productivity in both traditional batch build, and just-in-time, cellular flow processes. The process is best carried out by a cross-functional team of six to ten people, including suppliers, customers, and at least one person from outside the operational area, in order to encourage 'out of the box' thinking. The process includes freeing participants of any other responsibilities during the exercise. This is followed by:

- Recording current-state process performance;
- Evaluating the current-state process, as it is now, to identify problems;
- Developing a future state workflow;
- Implementing the new process flow;
- Re-measuring the new flow;
- Reviewing the results.

An MCA is normally designed for smaller production sites (up to ten machines, and up to 20 people). All the activities within an MCA are described, step-by-step, below.

STEP 1: Preliminary diagnostics

1.1 Establish a working group with the participation of senior and shop floor line management. The group should consist of the head of the working group and five to seven staff from the shop floor who are capable and authorized to make organizational and management decisions.

1.2 Organize an initial meeting to familiarize the participants with the Master-Class format.

1.3 Select the pilot area where the MCA will take place, with a clear indication of the existing problems and the metrics participants would like to improve. The most common requests for improvements are the following:

- Increased labour productivity, both in terms of reducing the time for a particular operation and increasing the number of manufactured products
- Reductions in times for equipment changeover
- Reduced downtime and increased equipment utilization
- Optimization of the production space
- Reduction of electricity consumption
- A reduction in the number of defective products
- Increased transparency in process management, etc.

1.4 Request the following information from the pilot area:

- The main product line on the site (the most popular or promising product/product group)
- Planned/actual production by site (broken down by months for the current year)
- Current layout of the site indicating the major pieces of equipment
- The matrix of personnel qualifications at the site
- The number of personnel on the site (actual and planned) for the current year
- Actual staff time spent on the site for the current year (report card indicating the amount of overtime/downtime)
- Production at the site for the current year (indicate the period if necessary)
- The capacity of the site (estimated/actual)
- The system of remuneration of workers in the areas (settlement list)
- Information on the quality of products manufactured at the site (statistics)
- Number of alterations/corrections per month (statistics) for the current year
- Established standard times for production operations at the site
- The number of unfinished products on the site
- Cost price (structure in percentage terms) of products (calculation)
- Description of the main problems and suggestions for improvements in the areas on the site (master/head of the site/head of the workshop, technologist, controller, worker).

1.5 Decide on the dates of the MCA interventions.

STEP 2: Diagnostics

The main task of the diagnostics phase is to collect all the data on the current status of the selected pilot zone and determine the potential for improvements. For this purpose, a map of the current state of the production process is constructed and quantitative indicators of QDC (quality, productivity, costs) are determined. The main tool for mapping is the timing of employee actions and product movements. After mapping the current state of the process, the potential for improvement and the necessary tools for Lean production are determined. At the same stage, a map of the future state of the process can be made. At the final stage of diagnostics, a second meeting with the management is carried out; its purpose is to discuss the potential for improvement, possible changes in the selected area, and preliminary coordination of methods for optimizing processes.

STEP 3: Day of verification

The main objective of this stage is to make sure that the organization is ready for the Master Class. It is important to ensure that the working group is ready for work, and to confirm the intention of the management to implement the planned changes. At the same stage, the programme and conditions of the Master Class are drawn up, agreed upon and approved.

STEP 4: Master Class

4.1 ANALYSIS OF THE CURRENT STATE

During the first day of the Master Class, the working group develops the diagnostic stage using the following tools:

- Timing (measurement of time) of all processes on the site
- Construction of load and Spaghetti diagrams (see Figure 14), which allow clear and objective depictions of the current state of the process
- Identification of all irregularities and overloads by dividing the actions performed into "useful work", "work of no value" and "loss"
- Analyse eight losses
- Conduct analysis according to 5S principles
- Alignment of the process to introduce single-piece flow.

All this makes it possible for the working group to show the current state of the process, explaining in detail the techniques, approaches and results, and agreeing on the choice of Lean production tools that will be implemented to make improvements. This is accompanied with an explanation of Lean theory and methods.

4.2 CREATING A PROTOTYPE OF THE FUTURE STATE

The goal is to create a future desired state of the pilot site, while ignoring the current state, starting from losses and problems in the area. In this process, it is important to take into account the opinion of people (workers) directly involved in production at the site as their buy-in and support is crucial to the efficient outcome of the initiative.

The future state of the site is presented in the form of diagrams (process maps/diagrams, etc.), and a new target (corresponding to the set goals for achieving key performance indicators) is plotted. Further, the working group identifies what is preventing the future state from being created right now. A list of activities that need to be implemented for the rapid transformation of the site into a future state is compiled. In the process of drawing up activities aimed at changing the pilot site, the working group may involve other specialists who are necessary for the immediate solution of the tasks (events).

It is important to carry out a preliminary report and coordinate the developed activities with the management of the enterprise; only then should you proceed to the implementation stage. The report is managed by the head of the working group. You should only consider the work on this stage to be complete after the implementation of layout changes.

4.3 STARTING THE PROCESS IN A NEW WAY, DEBUGGING

The next stage is to launch the new process in the pilot area, according to the approved plan. A working group conducts an experiment on the work/organization of the production process at the pilot site, analysing and comparing the theoretical scheme with how things work in practice. The working group determines the best way of working and reflects it in the standards, registers emerging issues and starts solving them. After debugging all the processes, the working group records the performance achieved. Problems that cannot be resolved are logged, and plans put in place to eliminate them in the future.

4.4 STANDARDIZATION. IMPLEMENTATION OF 5S TOOLS, STANDARD WORK AND VISUAL MANAGEMENT

At this stage, the new process is documented in order to develop a new standard. The operators are trained in the new principles of work organization, and the Takt Time is checked against target. The working group works on the development of 5S standards (the tools for this are described in Section 3). Visualization of all processes on the site is carried out and visual control of processes on the pilot site takes place.

4.5 CALCULATION OF INDICATORS AND THE FINAL PRESENTATION

The final stage of the Master-Class event is the work on calculating the expected economic effect from the implementation of improvements (eliminating the "bottlenecks" and losses identified). This is done jointly by the working group and a specialist(s) from the enterprise's economic department. The result of this work is a document showing calculations of the expected economic effect from the improvements implemented at the pilot site (targeted at previously recorded performance indicators). This is signed by the head of the company who provided the economic service specialist and the head of the working group.

In order to ensure the improvements implemented are sustainable, the expert, together with the working group, develops a stabilization plan. After receiving data on the results achieved, a final presentation is made to the management of the company.

This reflects the work carried out during the event (information is placed on posters/stands; employees reflect on the information daily; and the current state and future state performance and the new process are compared) including how the key performance indicators of the site's performance have changed (safety, quality, productivity, costs, personnel development). The presentation is conducted by the head of the working group and all participants in the Master-Class event.

A sample of schedule for Step 4 is shown on the next page.

Monday		
Data collection on the current state	1 h	11:00 - 12:00
Lunch	1 h	12:00 - 13:00
Mapping the current state	2 h	13:00 - 15:00
Analysis of the current state map	1,5 h	15:00 -16:30
Collection, summary of the day	10 m	
Tuesday		
Collection and schedule for the day	15 m	8:00 - 8:15
Mapping the future state	~ 2 h	8:15 - 10:00
Charting load	1 h	10:00 - 11:00
Plot improvement plan	1 h	11:00 - 12:00
Lunch	1 h	12:00 - 13:00
Drawing up a new site layout	1 h	13:00 - 14:00
Preparing to start the process "in a new way"	2,5 h	14:00 - 16:30
Summing up the day	10 m	
Wednesday		
Collection and schedule for the day	15 m	8:00 - 8:15
Starting the process "in a new way"	~ 4 h	8:15 - 12:00
Debugging identified problems of the new process		
Lunch	1 h	12:00 - 13:00
Make Production Management Stand (PCB)	1 h	13:00 - 14:00
Implement the first 3 "S" systems 5S on the site	1 h	14:00 - 15:00
Make a new standardized job (Stw)	1 h	15:00 - 16:30
Summing up the day	10 m	
Thursday		
Collection and schedule for the day	15 m	8:00 - 8:15
Debugging identified problems of the new process	~4h	8:15 - 12:00
Training site staff		
Lunch	1 h	12:00 - 13:00
Counting KPI Improvements	1 h	13:00 - 14:00
Calculation of the economic effect	1 h	14:00 - 15:00
Preparing for the final presentation	1 h	15:00 - 16:30
Summing up the day	10 m	
Friday		
Collection and schedule for the day	15 m	8:00 - 8:15
Preparing for the final presentation	~ 2 h	8:15 - 10:00
Preparing a stabilization plan	1 h	10:00 - 11:00
Final presentation	1 h	11:00 - 12:00

STEP 5: Stabilization

Stabilization is the final stage, when members of the working group check that all points of the stabilization plan have been implemented and the improvements are sustainable.

MCA'S STRENGTHS:	MCA'S WEAKNESSES:
▪ Can focus on tangible objectives ▪ Immediate benefits ▪ Less of a challenge to management style ▪ Intensive approach diminishes resistance to change ▪ Low investment in time and cost ▪ Immediate impact on service quality	▪ Does not affect all staff ▪ Partial involvement ▪ Lack of overall visibility ▪ Potential lack of sustainability ▪ Does not cover all improvement possibilities ▪ Shorter, simpler projects only ▪ May not help embed a culture of continuous improvement

5.2 IN-DEPTH DIAGNOSTICS

In-Depth Diagnostics (IDD) is an approach for the comprehensive analysis of a manufacturing process and the development of an improvement road map based on pre-set targets. IDD is normally provided at the level of a specific workshop or at the level of an entire production cycle for a specific product within the context of several manufacturing sites located in different workshops.

IDD includes an in-depth analysis of the manufacturing system based on the application of the UNIDO methodology approaches and tools, and the identification of the sites with the largest capacity for improvements, in order to ensure the maximum target effect. The most common indicators of this effect are economic efficiency, performance improvement, increased production cycle, resource saving, and rendering staff and/or production areas available. Before work begins, the customer defines the target indicators to be used in the diagnostics and road map development.

IDD is conducted on the basis of the business already having undergone one or more MCA cycles and having already set up a working group. If an MCA has not been conducted, the head of the working group and its specialists will need to be fully trained.

The key objectives of IDD are:

Analysis of the existing model of organization of the pilot zone;

Identification of bottlenecks and losses that directly affect the efficiency of work; and

Development of conceptual directions to eliminate bottlenecks and losses.

STEP 1: Preparation

1.1 Top management should decide on strategic priorities and goals, considering production type, order volume and demand quantity since these indicators are highly related to Lean implementation.

1.2 Based on company policy, management commitment and the future plan, IDD can be initiated by forming a working group on Lean. The working group should receive specialized training in Lean methods, philosophy, implementation road maps and other Lean theory and skills training, as necessary. The working group usually consists of experts and management personnel from different departments, and their main objective is to organize people and resources to implement Lean in the production process.

1.3 Selection and inspection of the pilot zone, including collection of the following information:

- The main product line on the site (the most popular or promising product/product group)
- Planned/actual production by site (broken down by months for the current year)
- Current layout of the site indicating the major pieces of equipment
- The matrix of personnel qualifications at the site
- The number of personnel on the site (actual and planned) for the current year
- Actual staff time spent on the site for the current year (report card indicating the amount of overtime/downtime)
- Production at the site for the current year (indicate the period if necessary)
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- The number of unfinished products on the site
- Cost price (structure in percentage terms) of products (calculation)
- Description of the main problems and suggestions for improvements in the areas on the site (master/head of the site/head of the workshop, technologist, controller, worker).

STEP 2: Analysis

The next step is to sketch the existing process status and interrelationships. Manufacturing processes are visualized, and the value streams of that process are identified using value stream mapping, visual control and time study methods. All key indicators for the selected pilot zone should be recorded. As a result, you can identify the bottlenecks and losses in the process of manufacturing the product that directly affect the efficiency of work.

All information collected is combined into a single document and laid out on the wall in order to visualize the process being analysed. Then, the financial benefits of the future state (with bottlenecks and problems removed) are calculated. The result of this work is a document, signed by the head of the enterprise, which compares the expected economic benefits with the previously recorded situation.

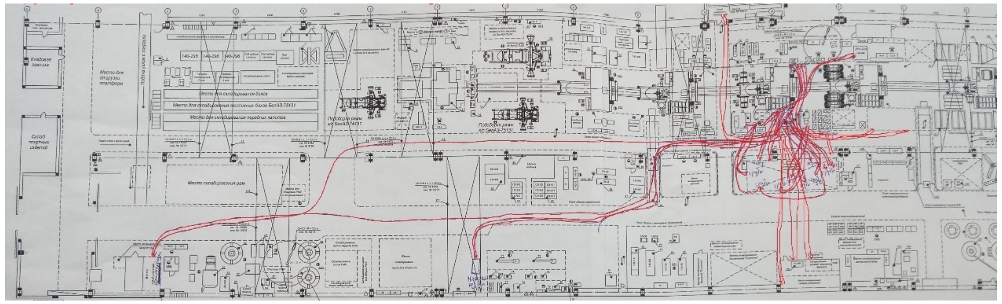


Figure 20 – Illustration: Spaghetti diagram

STEP 3: Preparation of the road map for the introduction of Lean

3.1 SELECTION OF APPROPRIATE LEAN TOOLS

Selecting and implementing new Lean tools and techniques is the next phase of the project. Waste minimization is the core objective in this phase. Various Lean strategies have been developed to reduce the non-value adding activities and promote a Lean manufacturing system. However, care must be taken to ensure that the Lean strategy selected does not increase other non-value adding activities elsewhere in the manufacturing process. Therefore, appropriate Lean strategies must be selected to eliminate wastes or improve the performance metrics of the manufacturing process. Moreover, it is preferable to select the Lean strategies that have the greatest overall impact on the wastes identified or performance metrics, depending on the manufacturer's priority. The selection and implementation of these tools depends strongly on the product volume and investment capability of the company.

3.2 FORMULATION OF THE LEAN ROAD MAP, INCLUDING IMPLEMENTATION PLAN

The road map is a long- or mid-term document outlining the stages of introduction of a Lean culture into the organization, strategic directions and vision, the main tasks and responsibilities and deadlines. The implementation of the IDD assumes that the road map prepared will subsequently be used for the introduction of Lean production tools in the pilot zone.

IDD'S STRENGTHS:

- Complete cultural shift
- Massive improvement potential
- Sustainability of changes
- Whole system change
- Can link changes with strategy

IDD'S WEAKNESSES:

- Considerable implementation challenges
- Longer project timescales
- Slower achievement of the main results
- Greater potential for resistance
- Less fit with existing management styles
- Potential to lose sight of where the process is going

5.3 DIGITAL KAIZEN

The Digital Kaizen method can be considered as a first step to a transition to Industry 4.0. The method is based on classical Lean techniques and supported by new digital technologies and solutions. To showcase Industry 4.0's benefits, UNIDO introduces practically oriented continuous improvement interventions on the shop floor level. This combination of classical proven Lean methods combined with Industry 4.0 technologies results in additional advantages for the production process without the need for significant investments.

Supply chain leaders in every sector recognize that Industry 4.0 offers myriad benefits, all of which impact an organization's bottom line. It confers unique advantages for the automotive industry, as listed in Table 4 below.

The Industry 4.0 concept concerns the relationships between digitalization and digital transformation and their implications for enhancing productivity in manufacturing. Industry 4.0 takes automation of manufacturing processes to a higher level, with the introduction of smart autonomous systems capable of self-cognition, self-optimization and self-customization. Tools such as cyber-physical systems (CPS), the industrial Internet of Things (IIoT), big data, industrial artificial intelligence (IAI), cloud computing, autonomous robots, blockchain and additive manufacturing complement a smart embedded system of machines able to communicate with each other and people and to perform autonomous tasks in both decision-making and production.

AGILE SUPPLY CHAIN
Both suppliers and OEMs in the automotive industry are subject to increasingly stringent fuel regulations. The result is a push for using light materials to decrease demand for fuel and for parts and components that are designed in such a way that they can be reused. Industry 4.0-readiness also gives OEMs and suppliers the agility to quickly adapt manufacturing specifications in response to changing technical and environmental standards as well as buyers' demands.

SELF-MONITORING CAPABILITIES
As production facilities increasingly move towards 24-hour production, equipment reliability becomes even more critical. Industry 4.0-enabled plants will have robust monitoring systems to identify potential maintenance issues before they result in downtime. This same technology can also be used in cars themselves to reduce the frequency of unexpected breakdowns.

CAPACITY FOR CUSTOMIZATION
Today's car drivers consistently express the desire to customize their vehicle configurations. The traditional automotive manufacturing process does not allow for such personalization. However, evolving towards Industry 4.0 would give auto manufacturers the ability not only to customize individual vehicles, but also to shorten delivery times for those vehicles.

NETWORK FLEXIBILITY
Automotive manufacturers have locations all over the world. Industry 4.0-ready manufacturers are also able to strategically connect all these locations. If production or demand fluctuates, operations can shift between facilities as needed.

Table 4 – Main benefits of Industry 4.0 for the automotive industry

The UNIDO methodology on Digital Kaizen or “Lean Manufacturing in the digital age” is adjusted to the Master Class Approach described in the previous sections and uses the classical continuous improvement methods, with a special focus on the information flows and the application of Industry 4.0 technologies, as follows:

- It analyses weaknesses in data utilization: the process and peculiarities of data capturing, processing and preparation, including customer, capacity, order, usage, production, quality, environmental, stock and inventory data
- It identifies potentials for process optimization by application of digital technologies

Digital Kaizen strives to integrate:

- Successful methods of Toyota Production System (TPS) adopted to new requirements
- Improvements through application of Industry 4.0 technologies supported by:
  - Data utilization analysis: identification of weaknesses and proposing measures for improvement
  - Integration of all participants in the process, from plant workers to production planners
  - Cooperation with successful technology suppliers

Digital Kaizen elements are the following:

- A focus on continuous improvement of already existing systems, processes and methods
- Industry 4.0 shop floor intervention
- Step-by-step transformations
- Low investments into technologies required

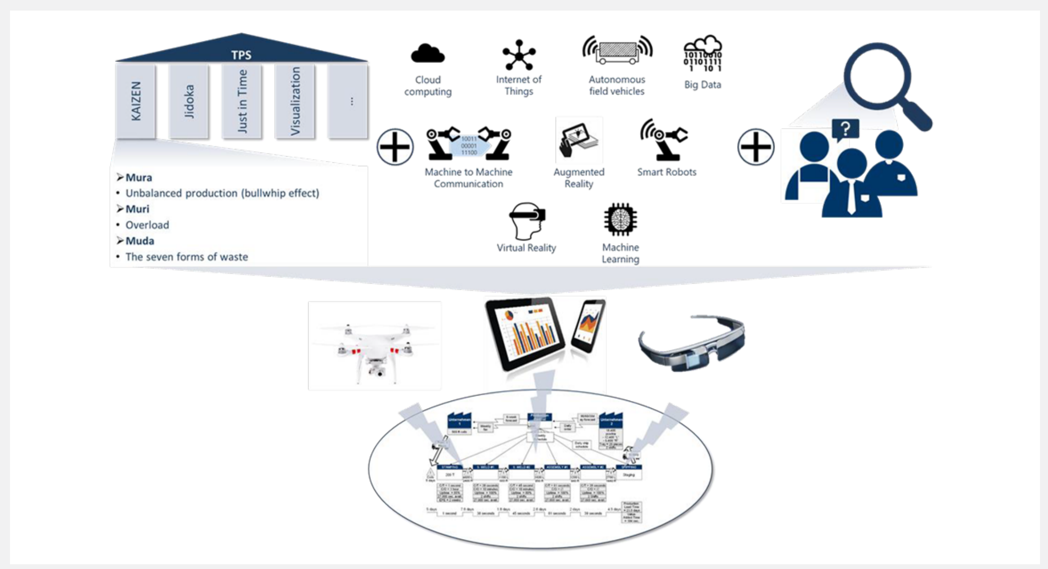


Figure 21 – Digital Kaizen

Based on the Digital Kaizen analysis, measures to streamline the production processes and the corresponding information flows are elaborated and technology-based improvements are proposed for specific use cases. The main focus is on realizing benefits such as win of working time, material based financial gain, and quality improvement.

The next step is verification of feasibility and acceptance of the specific use cases, defining KPIs for each of them and planning a roadmap for their implementation. To support the implementation, all necessary data, technologies and gadgets plus their interaction for each use case are described based on established framework.

The Digital Kaizen methodology should be applied to companies that are advanced in practising Lean methods and that define digitalization as one of the priorities for their future development.

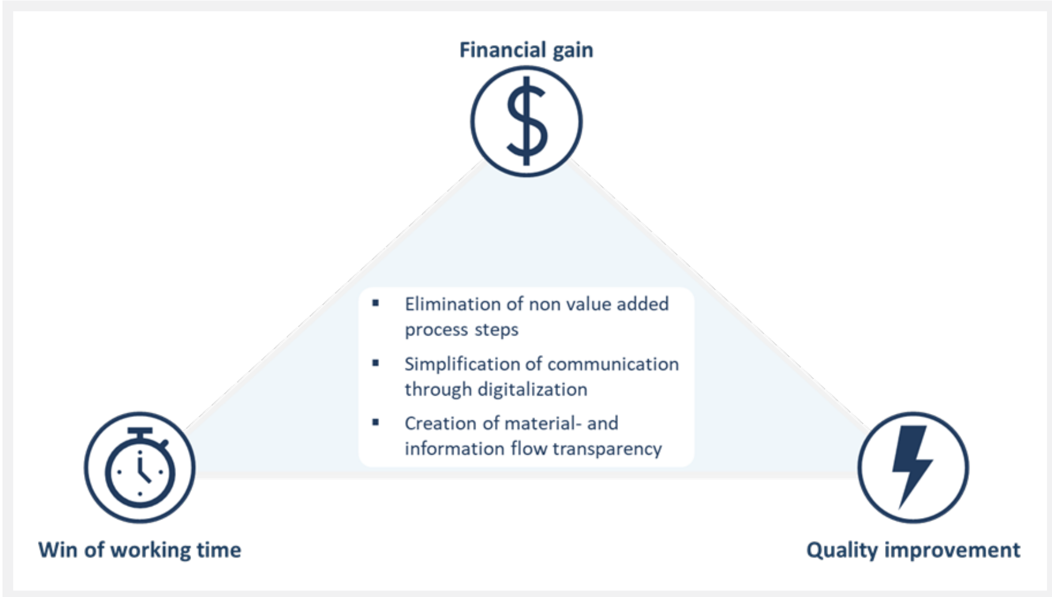


Figure 22 – Sustainable elimination of defect root causes

PROJECT RESULTS:

WIN OF WORKING TIME
- Up to **–30%** planning department
- Up to **–100%** of specific operative jobs

FINANCIAL GAIN
- Significant reduction of work in progress (WIP)

QUALITY IMPROVEMENT
- Sustainable elimination of defect root causes

The simplified structure of the Digital Kaizen Master Class is presented below:

1. Establishment of a working group within the company, defining the scope and goals of the future interventions as well as aligning expectations. Before starting interventions, the maturity of the company with respect to digital transformation needs to be analysed and adjustments made accordingly. The following need to be considered:
   a. Past, ongoing or planned initiatives to introduce digital solutions; strategies and priorities (if any);
   b. Awareness of the benefits and challenges associated with Industry 4.0 at all levels—from shop floor workers to senior management.
2. Analysis of the current situation by visiting the shop floor, interviewing employees and comparing process planning with shop floor actuals.
3. Evaluation of potential; preparation for interventions and feasibility check.
4. Analysis of the existent infrastructure and selection of potential suitable technology providers.
5. Implementation, control and stabilization.

EXAMPLE: The Digital Kaizen approach was tested in Belarus and eight potential areas of improvement were identified, as shown in Figure 17 below.

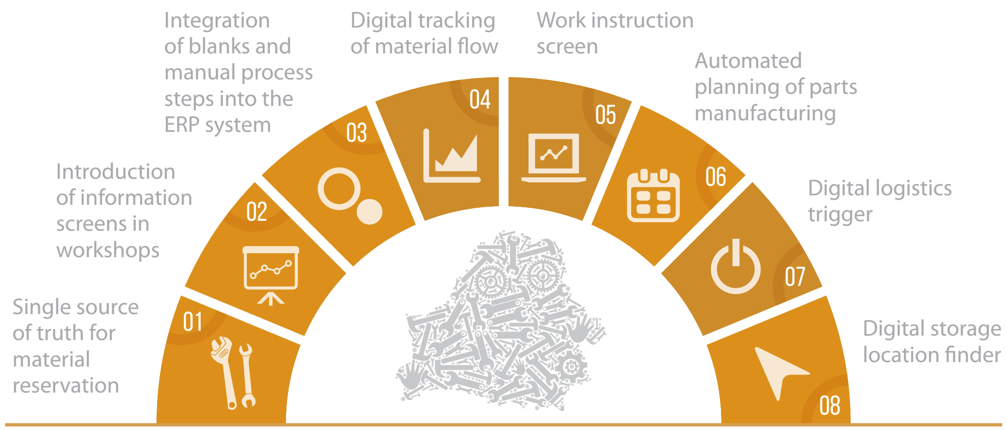
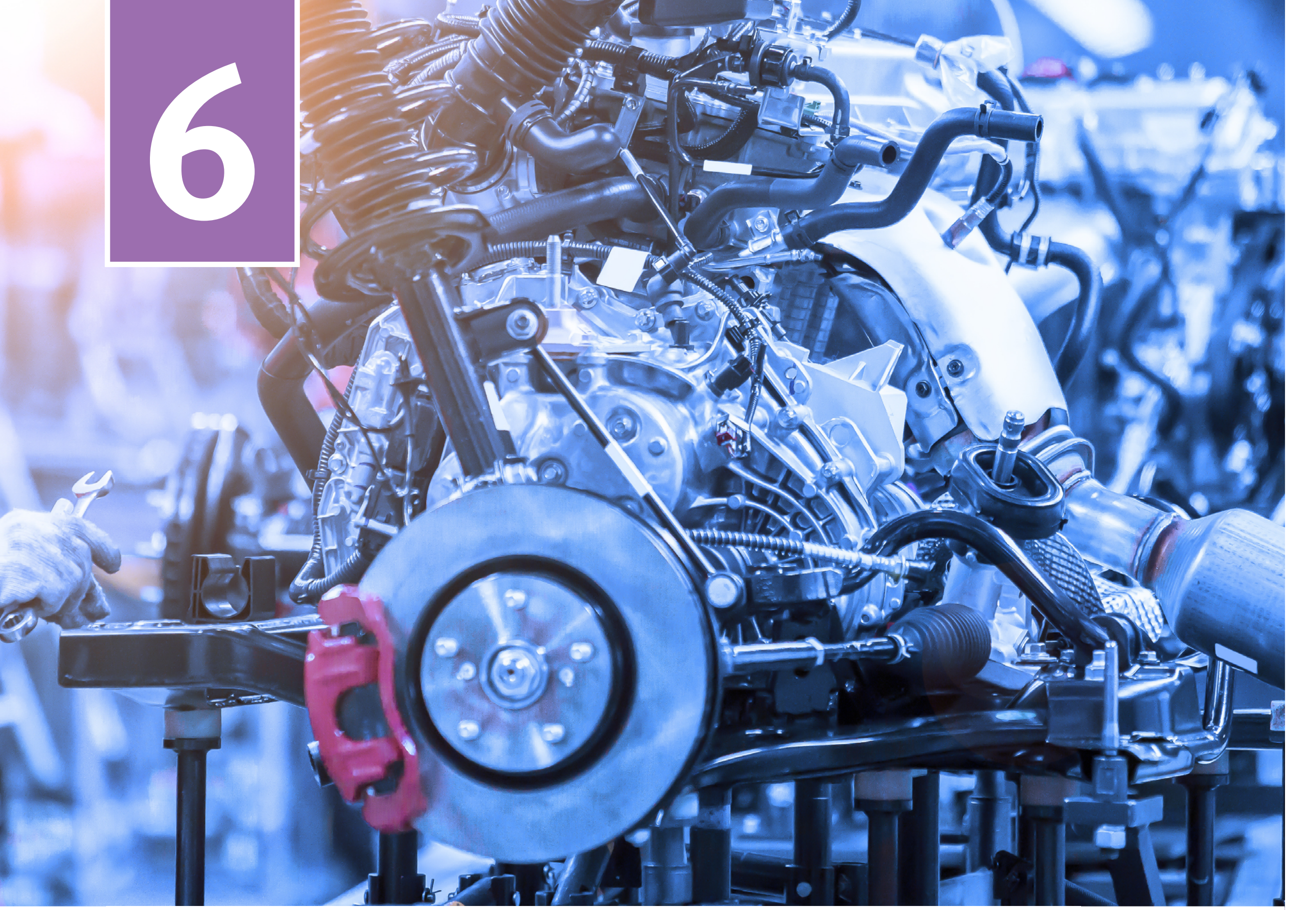


Figure 23 – Potential areas of improvement of the Digital Kaizen approach identified in Belarus

Area of improvement	Recommendation	Impact
1 SINGLE SOURCE OF TRUTH FOR MATERIAL RESERVATION	▪ Build a database based on existing data providers ▪ Approve and submit daily material requests digitally	Gains in working time - HIGH
2 INTRODUCTION OF INFORMATION SCREENS IN WORKSHOPS	▪ Install central information screens in workshops ▪ Use them for information about current production, quality-control achievements, repetition of training, safety information, etc.	Quality improvement - MEDIUM
3 INTEGRATION OF BLANKS AND MANUAL PROCESS STEPS INTO THE ERP SYSTEM	▪ Enter each set of data into digital forms ▪ Transmit the forms for further approval, processing or analysis in digital form	Gains in working time - HIGH
4 DIGITAL TRACKING OF MATERIAL FLOW	▪ Introduce a digital interface to the ERP system at the points in the shop where parts are handed over (e.g. scanners) ▪ Use them as a digital mechanism to confirm the handing over of parts	Gains in working time - HIGH
5 WORK INSTRUCTION SCREEN	▪ Introduce a screen with working instructions at each workstation ▪ Enter working instructions digitally (into the ERP system) and link screens to ERP ▪ Enable direct feedback from workers to part constructors using "red pen" technology, and introduce a digital mailbox for workers' ideas and remarks	Quality improvement - MEDIUM
6 AUTOMATED PLANNING OF PARTS MANUFACTURING	▪ Enable digital production planning by combining product and production data ▪ Record manufacturing process, lead times, etc., and keep them up to date ▪ Use algorithms to centrally plan the daily production programme	Gains in working time - HIGH
7 DIGITAL LOGISTICS TRIGGER	▪ Digitally notify carriers when parts are ready for transport ▪ Submit transportation paths to carriers and print ID tags for parts automatically	Gains in working time - HIGH
8 DIGITAL STORAGE LOCATION FINDER	▪ Assign raw materials to specific storage locations ▪ Scan delivered materials to locate correct storage rack ▪ Information about storage location of material can be accessed when production workers receive jobs for parts	Financial gain - HIGH



6

Final Remarks

The tools and methodology presented are a part of the UNIDO Shop Floor Programme for the automotive industry implemented in Belarus. The general project implementation framework is divided into the following phases:

1. INTRODUCTORY PHASE
2. PROJECT IMPLEMENTATION, consisting of two types of activities:
   a) Process optimization and productivity gain arrangements
   b) Educational and awareness-raising activities
3. THE FINAL PHASE, aimed to ensure the sustainability and institutionalization of results.

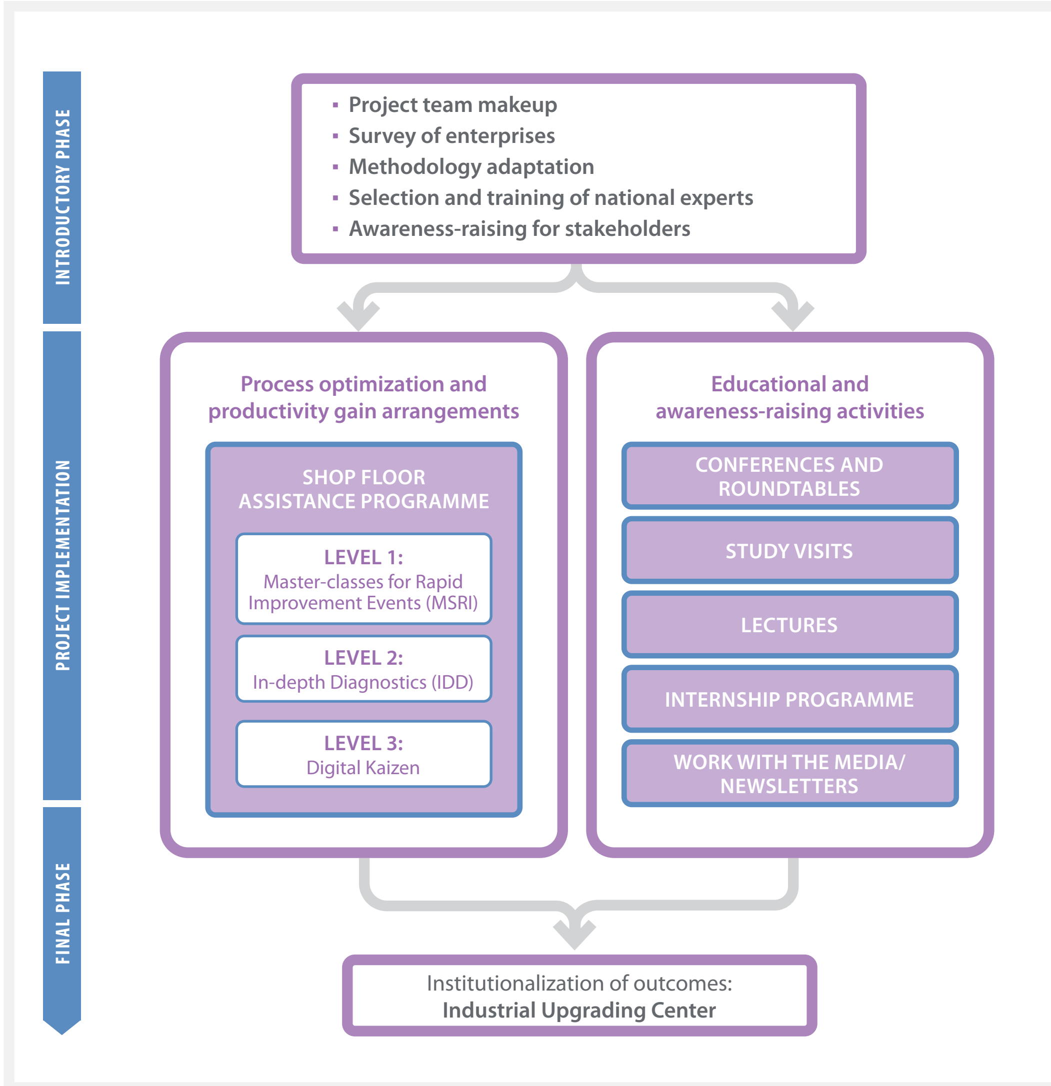


Figure 24 – Main phases of the project implementation framework

The introductory phase includes a survey of enterprises, methodology adaptation, project team makeup, selection and training of national experts, as well as introductory lectures and workshops to disseminate information about the project, methodologies used and activities planned.

Activities for process and productivity optimization include the search for, and negotiations with, the enterprises that acted as project customers, as well as direct implementation of the project services.

Educational activities and information dissemination include study visits, lectures within the framework of professional development courses for specialists and managers of enterprises, and internship programmes.

Acronyms

AI	Artificial Intelligence
BNTU	Belarusian National Technical University
CAD	Computer Assisted Design
CPS	Cyber-Physical Systems
CRM	Customer Relationship Management
CSR	Corporate Social Responsibility
ERP	Enterprise Resource Planning
GM	General Motors
GPS	Global Positioning System
GVC	Global Value Chain
IAI	Industrial Artificial Intelligence
ICT	Information and Communication Technology
IDD	In-Depth Diagnostics
IIoT	Industrial Internet of Things
IoT	Internet of Things
JIT	Just in time
IT	Information Technology
KPI	Key Performance Indicator
MCA	Master Class Approach
ML	Machine Learning
MRP	Manufacturing Resource Planning
MSRI	Master-classes for Rapid Improvement events
OEM	Original Equipment Manufacturer
PoET	Proof of Elapsed Time
PoS	Proof of Stake
PoW	Proof of Work
Q-C-D	Quality-Cost-Delivery
QDT	Quality Defect Tolerance
RFID	Radio Frequency Identification
SME	Small and Medium Company
SMED	Single Minute Exchange of Die
TPM	Total Productive Maintenance
TPS	Toyota Production System
UNIDO	United Nations Industrial Development Organization
VSM	Value Stream Maps
WIP	Work in Progress

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