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SMED & 5S ANALYSIS

Industrial Management Laboratory

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Written By:

Muhammad Shafique

Note: Certain words and sections of the report have been modified to maintain confidentiality.

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1. Executive Summary

2. ***** s.r.l. is a centenary company operating in the field of grinding machines with more than 5000 machines installed all over the word and with operative branches in different parts of the world. The product family of the company is composed by two types of lines: * line, centreless grinding machines and **, double disc grinding machines.
3. The company after the change of management and property in 2014 moved towards a radical transformation of its operation system due to an increase in customer demanding for customization, for this reason it has been decided to shift from a Make-to-stock policy to a Make-to-order one.
4. The focus of this report is concentred on the production department and on the increase of its productivity level to keep the pace of the assembly stage while avoiding outsourcing of components. The production department is composed by 4 main areas: cutting, lathe, milling and drilling. As starting point of our analysis, was retrieved from the ERP of the company the data related to the past production orders for the estimation of current performances then crossed with the next production campaign planned to be in the future to find the areas to prioritize for the next step when collecting actual information Gemba walking the department. From this analysis it resulted the milling and lathing area to be the most required so we decided from Gemba walks to concentrate the analysis over the less utilized one, the lathe.
5. In lathing there are two machines: L4. old and less automatic or advance and L3, new and more advance, with only one operator managing the two machines one at a time.
6. To dip dive the current situation we were utilizing stopwatch method to measure the duration of each operator and machine activity, we have made noteworthy observations. Over a span of four days, it was revealed that L3 experiences an average daily saturation rate of 18.6%, whereas L4 reaches 18.2%. By taking into account the utilization of these two machines, we have determined that the overall cell utilization stands at 18.4%. With a comprehensive understanding of the current situation, we convened a meeting with the operational manager and production department supervisor. Collectively, we established our targets for the overall cell utilization, aiming must have target of 27.5% and a nice to have target of 37.5%.

7. After setting our targets, our primary objective was to identify the root causes of the main issues. To accomplish this, we employed the Ishikawa diagram and utilized the 5 Whys technique. Through this process, we uncovered a principal problem: the non considering of levelling production from the supply chain department. This resulted in the issuance of small batches at once, rather than blending larger batches when single components were needed. Consequently, this approach restricted the operators from having machine idle. In addition to the planning issue, we highlighted a set of activities that required operators to leave the cell and one prominent example was the cutting of raw materials which, despite being value-added consumed an average of 43 min per day of the lather. Furthermore, non-value-added activities such as retrieving bits, samples, and tools, along with the opening and closing of ODP, were also identified as tasks requiring the operator to leave the cell.
8. The next step after plotting the problems on Ishikawa diagram was the developing and implementing of the countermeasures: 1) Loading one machine with larger batches and leaving the second with the manufacturing of single components and smaller batches in a way that the worker can set up the one in charge of larger ODPs and move to the second. 2) Supply chain responsible to share a constant mix of orders with large and small batch size in order that the formers are exploited to cover the manufacturing cycles of the latter. 3) Supervisor to cut raw pieces he had schedule and bring them to the lathe area. 4) Creating a list of tools, clamps and samples to share with every concerned department. 5) Creating and placing a station for opening/closing ODPs near the machines. 6) Standardization of the allocation and management of bits and samples with 5S.
9. We put the developed countermeasures into action by limiting the operator's activities within the cell and simultaneously, we monitored the progress using the same stopwatch method implemented while understanding the current situation. Due to the implementation of these measures and additional corrective actions for remaining raising issues, we attained finally 28.2% of utilization for the cell, slightly above the initial target of 27.5%.
10. The well known target was at the end achieved by consistently motivating and engaging the individuals involved and solving problems immediately that arose along the way, this does not mark the conclusion of the project. In order to ensure its sustainability and further enhance it, we implemented standardized procedures for operating machines and scheduling of the ODPs. Additionally, we developed standardized shared sheets to address from

upstream the problem of missing tools, bits, and samples, which were reoccured during the monitoring phase..

11. Company Overview

The Italian firm *** is a medium company operating and leader in the industry of grinding machine manufacturing. It is located in Northern Italy.

12. Introduction

Apart from the offices housed such as Technical, Designing, Purchasing, Sales and Marketing, the plant is subdivided into three floors, including the basement which is at the moment adopted as a warehouse for electrical components. The two primary departments each machine goes through after the designing phase are namely Production and Assembly who are physically separated since placed on different level of the building but connected via a trapdoor and freight elevator. On the first floor, more specifically, the components are produced, but about this more information will be provided in the "problem breakdown" chapter while, as concern the ground floor, there the same pieces are painted before being assembled to form the final machine. The assembly employs 10 workers specialized to work on a single machine line while the layout of the area is composed of two assembly lines who are both flexible to be exploited for either the Monza or Viotto model according the needs. Still on the same floor raw materials and parts arriving from external supplier are unloaded and subject to quality controls before moving on to the next stages.

13. Problem background

In this section a description of the current situation will be provided emphasizing on what's the issue that the company is facing with its operations and providing at the same time quantitative information to highlight the consequences it has from a strategic point of view and therefore what will be the object of our analysis.

Keeping in view the mission of the company: "We are proud to deliver precision, high technology and productivity in an attractive design able to satisfy and delight our customer", Company aims to provide customer precise and high technological machine at the exact time. Currently, Company offers two prominent lines of machines, namely the Viotto and Monza lines, each featuring different versions tailored to specific industrial needs.

4.2 Transforming from MTS to MTO

Company initially followed a Make-to-Stock (MTS) policy, producing a predetermined number of grinding machines based on forecasts and keeping them in stock. However, as the demand increased along with the machine complexity and customization level, particularly after the introduction of Viotto, the company encountered challenges to schedule its production in advance and the need to store a variety of grinding machine variations resulted in multiple storage points, increased tied-up capital, and the high level of risk for unsold products if the forecasts were not accurate. However Company immediately recognized that customer requests were rapidly evolving because of the undergoing technological advancements and the increasing complexity within the industries who were necessitating more tailored units to properly perform more differentiated variety of processes. This realization, coupled with the keep growing number of product variations, led Company management team to initiate a shift in production philosophy abandoning the former Make-to-stock approach and introduce in 2014 the Make-to-Order (MTO) philosophy. The primary goal of this move was to reduce warehouse stocks and enable the customization level that it was needed by establish a seamless flow from individual component realization to the timely delivery of the final products eliminating all the time spent by items waiting between stages.

4.3 The Supply Chain System

The process begins with the customer selecting a machine and placing an order. Subsequently, the design department is in charge of developing the drawings respecting the expressed requests of the chosen model, and when they are ready, they are forwarded to the supply chain department who, on its turn is responsible of deciding the internal manufacturing of certain mechanical components and the external purchase of others; since internally can only be made the formers it requires for all the electrical parts of the finished machines to be retrieved from external suppliers. Once the decision regarding the supply strategy is done the orders to suppliers are placed and the components that are to be made internally are scheduled for the upcoming months and passed on to the production department who is responsible for their manufacturing. Before approaching the assembly of the final machine, each purchased unit undergoes the quality control to verify their conformity with specification and if not respected either sent back to the original provider for adjustment or internally reworked by the production department depending their urgency on the next phase. Finally all of them reach the assembly phase who puts together the final machines and runs tests before the final shipment to the customer.

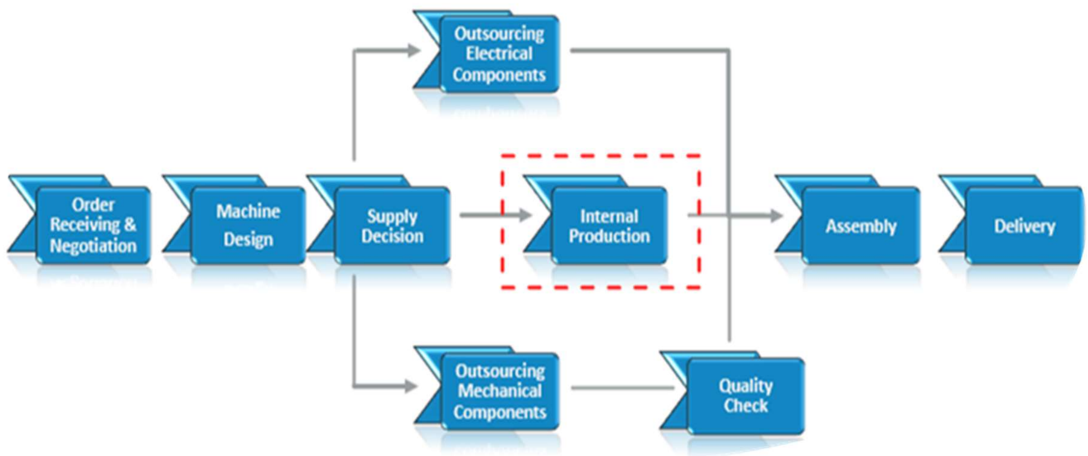

Figure 1: The supply chain process.

4.4 Problem Statement

As mentioned earlier, in 2014, the company transitioned from a MTS to a MTO production system configuration in order to lean its procedures and be more efficient while keeping the pace of the market. However, this shift did not occurred without drawbacks and soon it resulted in a productivity challenge within the production department who was not used to work with procedures combining the flexibility and productivity levels that were required to satisfy the next phase and leaving at the same time spare capacity of machines unexploited. This on its turn rose issues during the downstream assembly department causing long waiting time for missing components within the lines and forcing the company to resort to external suppliers in order to mitigate the consequences of the problem. In numbers we estimated the current weekly average output rate of the department to be ranging around 0.3 to 0.4 pc/hr/pr. that manage to satisfy only the 75% of the mechanical components the next phase was demanding thus leaving the remaining 25% of the parts to be outsourced in 2022 but that could have been otherwise manufactured internally if resources had been managed more efficiently. These delays ultimately have an effect on the profitability of the company that accounted last year for an additional financial expense of approximately **** and to be following the same trend in 2023. (**** already spent till march)

As a consequence of these problems, the company encountered difficulties in meeting clients demand within the designated timeframes who compromised its mission and at the same time the customers satisfaction level that they were able to deliver. Moreover, these challenges results in additional losses that are driven by out of specification discovered with quality controls carried out for inbound goods and following urgently demanded internal reworks in production for the same units. About the latter the company is already implementing a separate project for reducing quality issues.

This situation ultimately led us to define our problem statement as follow:

"The current procedures applied in the production department don't allow the level of productivity the company requires while leaving machines not fully exploited."

It was with this statement that we started our project with the goal of reviewing the production system the company was implementing by adopting lean methodologies to standardize procedures when possible and fostering agile coordination between workers whenever standardization was not appliable.

14. Problem breakdown

In this section we provide additional quantitative information explaining the big picture of the current situation the department is having to deal with and we go in dept having a focus on machines and operators in order to understand where the main inefficiencies are raising. We performed such analysis through the data we retrieved from the company information system and the various *"Gemba walks"* we had during the earlier phases.

5.1 Demand Analysis

The initial point we felt duly to start from was the understanding of the demand that the system has to satisfy and how the orders were managed from the department. With this goal we had a talk with the production supervisor who explained us that the requests they receive are in term of assembly groups of finished machines and each of them is composed of different order of production (ODP)[1], or batches of the same component to be realized. Those orders should be differentiated under two categories that are the low and high priority ones. As concern the formers, they are batches who are planned to be realized in one or more months perspective, however every Monday an updating meeting is held with the supply chain responsible communicating which of them to anticipate or set

[1] Note: one order of production (ODP) is one batch of the same article/component ordered at a specific time, it might be the size of one piece or more.

after depending on assembly needs. Regarding the latter instead, they are highly unpredictable and they are singularly released ODPs that represents urgencies who need to be fulfilled outright and the vast majority of time have a size of no more than one piece. The causes of them are many and might be due to last minute orders; reworks coming from assembly for non compliant components either outsourced or internally produced or customized parts needed to support the OEM maintenance program that the company cater to the owners of its machines. Just to give a quantitative idea, from the information system of the company we retrieved the data of production related to January-march 2023, the most reliable and representative of the next period and we computed that on average the scheduled orders account for the 65.1% of ODPs while the urgencies represent the remaining 34.9%, moreover we would like to acknowledge that regarding the interruptions due to quality reasons the company is already undergoing a separate project for their tackle.

From the same data we wanted to measure the repetitiveness of components and the batch composition and, as shown in *Table 3,* if we considered only the planned ODP, we got that it never happens that one article is realized with a frequency greater than once a month and that over a total of 212 articles in the whole period, 176 were requested no more than one time with about the 36% of them customized items, therefore unlikely to be called again in the future. We profiled then the composition of the planned batches *Figure 3* and we noticed that about the 80% of them have a size that is not greater than six pieces, with an average of about 4 pcs/batch, who drops to 3 pcs/batch if considering the urgencies as well.

Number of articles	Occurrence in the last 3 months
176	1
25	2
11	3

Table 1: Occurrence Frequency of the batches.

Figure 2: Batch size profile

5.2 Production department organization

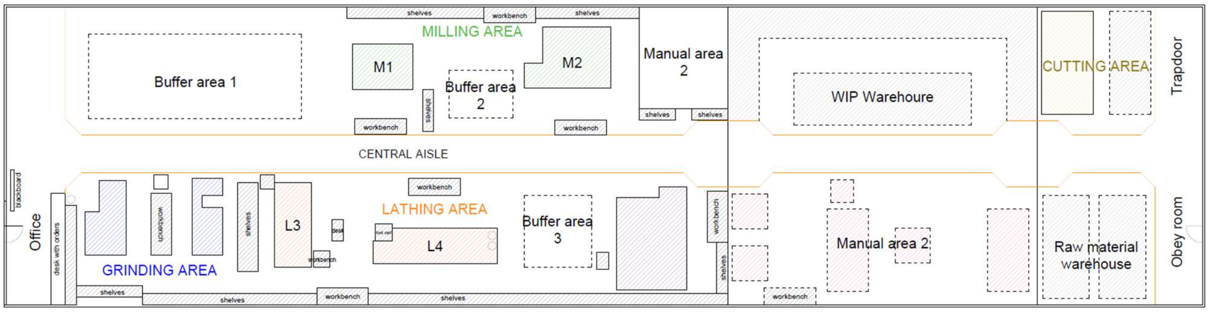

Figure 3: Production department layout

Moving on the next level of our analysis we want to provide an overview of the production department and, as were explaining earlier in the introduction, it is located on the second floor of the building and logistically is connected with the assembly through one trapdoor and one freight elevator. Speaking in term of organization only, is important to highlight that this environment had been planned according to a job shop configuration featured of four manufacturing areas that are the cutting, milling, lathing and grinding one and there three workers and one supervisor are employed with all of them dedicated to a specific manufacturing phase among the lathing milling and grinding, while regarding the not mentioned one *(i.e. cutting)* each of the operator is in charge of the cut of the raw pieces he is expected to be working on, on the basis of the amount of orders requested. The fourth worker, additionally, *(i.e. the supervisor)* is responsible of the grinding machines and because of their lower saturation *(see next chapter)* he employs the remaining portion of his time performing managerial tasks such as scheduling and reordering of raw materials and consumables.

The whole plant works on a single daily shift of 9 hours, but since there are total breaks equivalent to 1,5 hours the net available time for the workers becomes 7.5 hours per day.

Space wise instead, starting the description of the layout from the right *Figure 4*, the first room that we find is completely allocated to the raw materials and on its turn is divided into the cutting area equipped with one cutting machine that is positioned just in front of the trap door, while on the opposite side there is a warehouse with shelves storing bars, plates and tubes. Continuing along the corridor toward the left we run up a second room with another warehouse positioned on holding WIP and finished products that are the residuals of the former Make-To-Stock policy, while in front of there a manual area is equipped with manual machines like lathe, drillings, milling and sandblasting that are shared among all the operators and used in case of necessity for fast reworks from assembly and finishing of components.

Carrying on with the illustration we reach the principal room where the remaining three areas of the job shop are situated along with a small manual one that is visited only sporadically for extraordinary fast tasks. On the space in front of the machines there are workbenches while in between we found shelves holding tools along with designated areas (namely Buffer area1, 2, 3) equipped with few pallets that are left on the floor acting as buffer decoupling the different stages.

In total we have seven machines, where four of them are automatic CNCs, and because of operators' skills, all are used by no more than one worker among the 3. For their potentials given by the technology, these reasons we just mentioned and additional others we'll be explaining later in the next chapter, those machines are the center of gravity of the department and that's why they will become the focus of our report. More in detail M1 and M2 belong to the milling area and respectively are managed by Operator 1 and Operator 2, the latter more in deep is a 5-axis machine and its software is a step ahead respect to the others; while both L3 and L4 are lathes and are handled by the same Operator 3. Further if we consider the current procedures that are applied they cannot be working simultaneously and L3 is the most advanced and flexible one equipped with a CAD-CAM system enabling the graphical visualization and simplifying features when programming; L4's software contrarily lacks of a graphic interphase and simplified coding features that make the programming activity trickier and longer not enabling to check its properness before its running. Always the same machine is historical and has available on its archive far more programs of components done in the past, so more likely to have programs ready for few demanded pieces.

The fourth area, on the end is the one fully dedicated to the supervisor who is equipped with two simple machines different each other since the first work tangentially while the second on axis.

5.3 Scheduling and Urgency management

The daily allocation of the orders to the machine is done by the supervisor of the department who according his experience takes as reference the bunch of planned ODPs he received on Monday and decides the sequence of execution for each machine and operator by consequence. Actually this activity, not easy but underlying for the coordination of the department, is currently not aimed to optimize the utilization of the machines and it doesn't exist a specific procedure to follow, but the single criteria that is taken into account when selecting components is the priority only. The supervisor starts from the list of orders indicated to be prioritized, selects few randomly, estimates by experience the time it would take for their execution and one by one creates the sequence on the blackboard. More in detail the differentiation of what machine to select within the lathe area was done considering technological constraints of the same or choosing L4 if the program was already existing on its archive.

Regarding urgencies they are managed with preemptive priority, stopping the machine required for that job as they arrive.

5.4 Capacity Analysis

In this paragraph we'll be further analyzing the historical data related to the last three months of production in order to have an average estimation of the current performances of each of the area then we cross the result with the list of components the assembly would require in the period ahead in order to be able to operate uninterrupted, and that theoretically the department under our concern should be able to supply.

Before showing the results it's necessary to acknowledge the assumptions that we made to support the computation and the properness of the data we are using when related to our intentions.

In term of representation we consider these measurements pretty close to the future situation since, as our company tutor suggested, there have not been in the meantime any main factor changings who could have led to a diversion in performances and also considering the length of the observation time, the amount of data we retrieved are enough to compensate the variability of batch size and the variability given by the demand mix.

More specifically, starting from the previous components, we wanted to make a separation between the planned and the interruptions then we took under consideration only the formers because they are featured of different characteristics in term of batch size and because reasonably the time they take to be worked is generally less variable when compared to the seconds; moreover this partition would reduce possible sources of variability due to the low clear classification of the causes interruptions arise from when reported within the information system by workers. Due to this all the urgencies will be aggregated within the same pool of sample and treated likewise.

We computed the average throughput time one planned piece took in the past for each of the stages of production *Table 4* then taking as reference the next mechanical pieces who might be required to be supplied to the assembly between May the 22nd and the end of July we estimated for each of the manufacturing area the required number of hours they should be expected to be working in that period getting through the number of pieces the area should deliver by considering the production cycles of each component. We assume moreover, the separation of jobs between machines belonging the same area equally split as long as parallelization was enabled considering the current constraint arising from the number of operators available.

As final step we compared that estimation we made with the amount of time the department has on its availability to dedicate to the production of those pieces between May the 22nd and July the 31st. We started from the scheduled calendar working days and we reduced by the time that would be on average allocated for the interruptions, that we measured weighting for about the 20% of the latter, and the operator and machine availability close approximately to 98% of the scheduled calendar working days.

Production area	TTH [min/pcs]	Required capacity [pcs]	# Machine in parallel	Required time [hr]	Net available time [hr]
Grinding	84,38	242	2	170,2	352,8
Lathing	51,44	550	1	471,3	352,8
Milling	78,62	615	2	403,1	352,8
Cutting	29,8	537	1	266,7	352,8

Table 2: Required capacity of each area till 31st July

As a result of this, as we are showing in the table above, the lathing and the milling stages are those that are most likely to be suffering to keep the pace dictated by the market since they are short in hours they could dedicate that category of components for 118.5 and 50.3 respectively and because of this evidence there, we decided to move the focus of the analysis.

5.5 Utilization Analysis

Arrived to this stage, with a narrowed area to work on, we needed to go more in dept on the problem and to collect more actual information, both qualitative and quantitative, that at the time we were missing so to grasp the priority of machines to work on and understand the procedures currently applied. We had for this reason many *Gemba walks* targeting the bottleneck areas and we measured over a sample of four observation the daily amount of time on average each machine was actually spending working on the piece, and as *Table 5* reports, both of the lathes are the ones performing poorly amongst all showing the lowest values in term of utilization rate.

Production area	Machine	Available daily run time [hr]	Avg. daily machine time [hr]	Avg. Utilization rate [%]	Operator
Milling	M1	09:00:00	02:37:54	29,2%	1
Milling	M2	09:00:00	03:59:00	44,3%	2
Lathing	L3	09:00:00	01:40:12	18,6%	3
Lathing	L4	09:00:00	01:38:18	18,2%	3

Table 3: Current Saturation of Milling & Lathing machines

Referring to the operators instead, we noticed that all of them have approximately the same efficiency managing their time in running the machines[2], confirming the similarity of the procedures they are now adopting.

We computed then the cell utilization as consequence and as a result it came up to be 18,4%[3] for the lathe area and 36,8%[4] for the milling.

It's because of these results and the target we agreed with the project stakeholders that regarding the first area will be related the next measurements we are reporting now on.

5.6 Stopwatch Analysis

Quantitatively, from the same consecutive production days we were observing the worker performing his activities, we developed the stopwatch and we organized the day by day information in an excel table that we are reporting in *Figure 6* just to show an example of the sequence on average the worker undergoes for each ODP and the relative machine status in the meanwhile. Before starting we explain that since the machine didn't undergo maintenance the observed days the status it could have been reported were: working, standby and idle. From there we summarized those measurements into *Table 7a* and *Table 7b*. It resulted the lathe machines laying in an idle[5] state for an average of about 61.1%[6] of its daily available time *(9 hours)* and the sub-reasons of this, excluding the time the operator was breaking was because of the usage by the worker of a different machine or committed to cut raw pieces for the ODP he just started *(avg. 43 mins/day)*[7] before making program on machine side, setting it up, and starting on. Moreover observing the operator activities while at least one lathe was working *Table 7b* a good portion of time was spent waiting the machine to end its job instead of preparing for the next one.

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[2] Estimated as machining time over time dedicated to the machine by the operator.

[3] Computed as $\frac{1{:}40{:}12 + 1{:}38{:}18}{9{:}00{:}00 + 9{:}00{:}00}$

[4] Computed as $\frac{2{:}37{:}54 + 3{:}59{:}00}{9{:}00{:}00 + 9{:}00{:}00}$

[5] With Idle time we mean the machine is under the condition of performing the required function but not operating because during the non-required time. We considered the required time when the operator is intended to use the machine; starting when he indicates the beginning of the job on the information system and lasting till the unloading of the last piece of the batch, excluding the time he was breaking.

[6] The total idle time is computed as Idle time during operator available time + break time – running during breaks (see *Table 7a*)

[7] Daily average idle time divided by reasons: operator break (1:31:55), raw material cut (0:43:00), working on another machine (3:14:30), total (5:29:25).

start [hh:mm]	end [hh:mm]	interval [hh:mm]	Operator's activities	Lathe L4	Lathe L3	Cutting machine
07:30:00	07:45:00	00:15:00	Set Up	I	SB	I
07:45:00	07:52:00	00:07:00	Set Up	I	SB	I
07:52:00	08:30:00	00:38:00	Waiting	I	W	I
08:30:00	08:37:00	00:07:00	Manual job	I	SB	I
08:37:00	08:51:00	00:14:00	cleaning	I	SB	I
08:51:00	08:56:00	00:05:00	New ODP	SB	I	I
08:56:00	09:22:00	00:26:00	Programming	SB	I	I
09:22:00	09:32:00	00:10:00	Set Up	SB	I	I
09:32:00	09:38:00	00:06:00	Piece changing	SB	I	I
09:38:00	09:39:00	00:01:00	Waiting	W	I	I
09:39:00	09:41:00	00:02:00	Waiting	W	I	I
09:41:00	09:42:00	00:01:00	Check	SB	I	I
09:42:00	09:48:00	00:06:00	Set Up	SB	I	I
09:48:00	09:50:00	00:02:00	Waiting	W	I	I
09:50:00	09:51:50	00:01:50	Check	SB	I	I
09:51:50	09:55:20	00:03:30	Waiting	W	I	I
09:55:20	09:56:20	00:01:00	Set Up	SB	I	I
09:56:20	10:00:00	00:03:40	Waiting	W	I	I
10:00:00	10:13:45	00:13:45	Set Up	SB	I	I
10:13:45	10:23:00	00:09:15	Break	I	I	I
10:23:00	10:29:00	00:06:00	Set Up	SB	I	I
10:29:00	10:31:14	00:02:14	Waiting	W	I	I
10:31:14	10:34:00	00:02:46	Check	SB	I	I
10:34:00	10:35:30	00:01:30	Waiting	W	I	I
10:35:30	10:39:40	00:04:10	Check	SB	I	I
10:39:40	10:42:00	00:02:20	Piece changing	I	I	I
10:42:00	10:45:00	00:03:00	New ODP	I	I	SB
10:45:00	10:54:00	00:09:00	searching RM	I	I	SB
10:54:00	11:01:00	00:07:00	RM picking	I	I	SB

start [hh:mm]	end [hh:mm]	interval [hh:mm]	Operator's activities	Lathe L4	Lathe L3	Cutting machine
11:01:00	11:12:00	00:11:00	Programming	I	I	SB
11:12:00	11:17:00	00:05:00	RM picking	I	I	SB
11:17:00	11:22:10	00:05:10	Set Up	I	I	SB
11:22:10	11:54:00	00:31:50	Waiting	I	I	W
11:54:00	13:00:00	01:06:00	Break	I	I	I
13:00:00	13:20:00	00:20:00	Waiting	I	I	W
13:20:00	13:25:00	00:05:00	New ODP	I	SB	I
13:25:00	13:37:00	00:12:00	Programming	I	SB	I
13:37:00	13:45:00	00:08:00	Set Up	I	SB	I
13:45:00	13:48:00	00:03:00	Waiting	I	W	I
13:48:00	13:49:00	00:01:00	Check	I	SB	I
13:49:00	13:56:10	00:07:10	Waiting	I	W	I
13:56:10	13:57:10	00:01:00	Manual job	I	SB	I
13:57:10	14:05:00	00:07:50	Waiting	I	W	I
14:05:00	14:06:40	00:01:40	Check	I	SB	I
14:06:40	14:08:15	00:01:35	Waiting	I	W	I
14:08:15	14:26:00	00:17:45	Set Up	I	SB	I
14:26:00	14:29:00	00:03:00	Waiting	I	W	I
14:29:00	14:36:00	00:07:00	Piece changing	I	SB	I
14:36:00	15:05:00	00:29:00	Waiting	I	W	I
15:05:00	15:24:00	00:19:00	Break	I	I	I
15:24:00	15:26:00	00:02:00	Waiting	I	W	I
15:26:00	15:36:00	00:10:00	Programming	I	SB	I
15:36:00	15:40:00	00:04:00	Piece changing	I	SB	I
15:40:00	15:54:00	00:14:00	Waiting	I	W	I
15:54:00	15:58:00	00:04:00	Manual job	I	SB	I
15:58:00	16:13:00	00:15:00	Waiting	I	W	I
16:13:00	16:18:00	00:05:00	Piece changing	I	I	I
16:18:00	16:30:00	00:12:00	Set Up	SB	I	I

Table 4: Monitoring of machines.

Lathes status during operators' available time		
monitored time	09:00:00	100%
break time	01:36:25	-17,9%
scheduled operators' available time	07:23:35	82,1%
stand-by time during the operators' available time	01:51:20	-20,6%
Idle time during the operators' available time	03:57:30	-44,0%
machining time during the operators' available time	01:34:45	17,5%
running during breaks	00:04:30	0,8%
total daily running time	01:39:15	18,4%

Operator state while at least one lathe was working		
Waiting	02:09:45	66,1%
other	00:55:23	28,2%
Break	00:09:00	4,6%
Parallel working	00:02:11	1,1%
Total	**03:16:19**	**100%**

Table 5 a and b: 7a on the left and 7b on the right

5.7 Stand-by time Analysis

The second reason that we noticed of non-working state was because of the machine laying in stand-by, this means by technical definition that it was under "healthy" conditions of performing the job but not operating during the required state. We considered the latter starting when the machine related phase for that ODP was being opened[8] and ending upon last piece of the batch unloading excluding the time the worker was breaking[9]. From the pareto graph reported below *Figure 5* the main sub-reasons of stand-by were due to set ups and programming. The latter should theoretically be part of the former however, since highly variable in proportion with the jobs difficulty we reported it separately, and still regarding the set-up time it embeds both the activities required to start the machining of new ODPs and technical adjustments after the first piece had been completed.

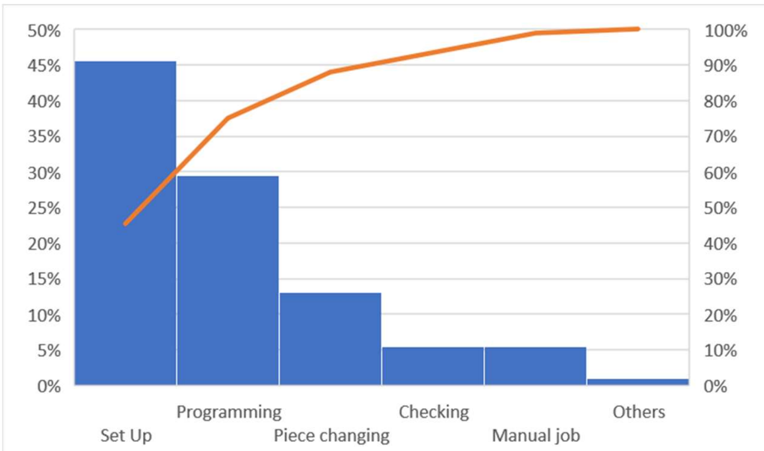


Figure 4: Weight of machine reasons of Standby.

5.8 Movement Analysis

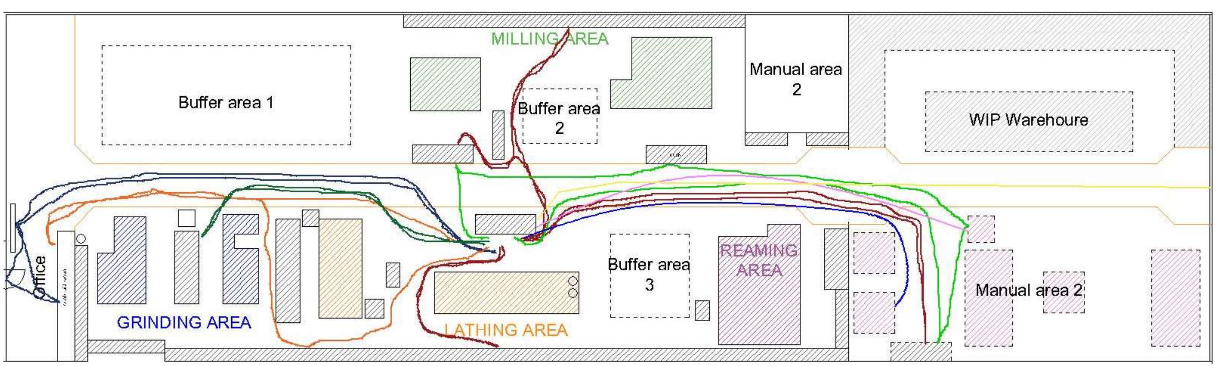


Figure 5: Spaghetti chart of the current condition, different colors are representing different causes of movements, they are reported with the same chromatic scale of the next picture.

Always from the same working days we just explained we drew the complementary Spaghetti chart enabling to map the daily special distribution of the activities carried out by the operator. We simplified the final output and reported in *Figure 6* only the reasons for the operator to leave the

[8] When the worker indicates on the information system of the company he is starting working on it.
[9] Not working time during operator break is considered as machine idle time

cell and estimated in *Table 8* the relative time spent away and frequency of occurrence accordingly in order to list and quantify the interruptions preventing the operator to work fluently.

By now, despite the majority of movements while programming and monitoring the machine while working are spread around the lathes there are still many of them that are dispersed around the shopfloor and by consequence not adding value to the work.

Causes	Avg. Time	Avg. Frequency
Cutting raw materials	43 min	once a day
Closing/opening ODPs	3 min	twice a day
Manual reworks	15-40 min	less than once a day
Retrieving bits	3-4 min	twice a day
Retrieving samples	3-4 min	once a day
Briefing from supervisor	5 min	more than 5 per day
Retrieve centesimal comparator	< 3 min	less than once a day
Retrieve deburring tool	< 3 min	three per day

Table 6: Causes for the operator to leave the cell with relative frequency of occurrence and time spent outside

Few of these like cutting of raw materials and performing of manual jobs on the manual area have already been mentioned in the previous paragraphs, and their causes are paradoxically the performing of value added activities either finishing or preparing for the next job. Regarding the former it often happens the machine to be occupied by other workers so worsening the entity of the inefficiency, while for the latter instead it may last from 15 mins for finishing the current order (drilling, threading…) or up to 40 mins if they are non value added activities for urgent rework from assembly. Then there are others like opening / closing of ODPs and retrieving bits or samples, their place simply is situated far from the cell, but as concern the last two the time spent away can significantly increase up to *20-30 mins* because of searching for the item that often is not there and consequently asking for their position and making arrangement with the supervisor. For the bits additionally it doesn't exist a specific place the operators know where to look at but there are four of them (one behind the lathe, one on the manual area and two more on the milling area for the respective machines).

Briefing from supervisor: the reasons are many but can be recalled back to two main categories that are operator training (asking for information on how to work or clamps pieces, what raw materials to cut, asking for confirmation for the finished piece…) and making arrangement for fixing problems we've just explained earlier like missing tools, clamps or sample.

Finally there are tools that are shared between all operators like the one for deburring and other like the centesimal comparator that is the same used for the manual lathe as well; when they are not within the area the worker exits moving for their retrieval or asking his colleagues who is using it.

15. Target Setting

On the light of the results we were showing in the previous section we had a meeting with the stakeholders of the project (Operations Manager and Production supervisor) and with them we agreed to fix the attention of our work to the area that is hampering the most the system: the lathe. The reasons who drove us to make this decision were coming from the information we obtained from the comparisons we made that clearly showed the criticality of the shop arising from the low availability of operator, the level of utilization the machines on average currently achieve and the required capacity estimated in hours for the period ahead.

We decided for our project to adopt as main indicator measuring the performances the average utilization rate of the cell, estimated on a four days base coherently with our observations and computed as the sum of the total amount of time the two machines actually spend working the piece over the sum of two machines' theoretical continued nine hours they could potentially be running per day, thus involving also on average the total 1.5 hours the operators spend pausing. And we agreed with the company tutor to be achieving by the 1st of July as must-have result of the project to slightly increase the cell utilization from a present value of 18.4% to 27.5%, and to further improve to 37.5% as nice-to-have goals, that definitely means training and enable the operator to use the two machines simultaneously.

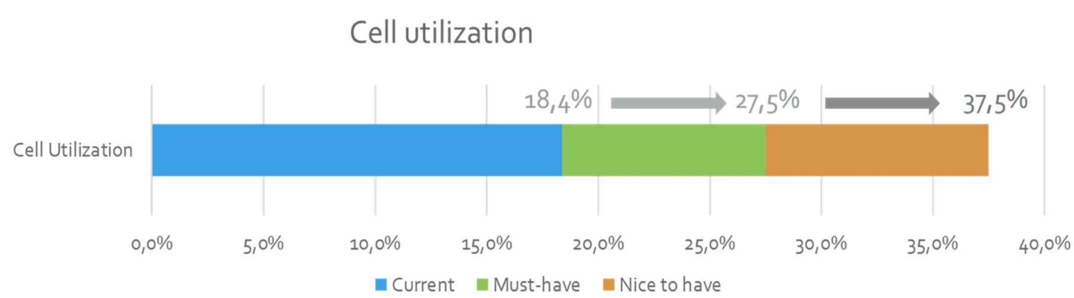


Figure 6: Target Setting

16. Root cause analysis

Because of the broadness of the topic we were still covering after the target we set, we needed to go into details and further break the problem down into smaller categories. We had *Gemba walks* to understand the activities undergoing in the shopfloor and we tried to answer the question “Why the machine is stopped?” any time it was in order to make a brainstorming of the causes we observed and organize all of them into a Ishikawa diagram, then giving a priority each we got to the reasons of the problem for the most impactful branches.

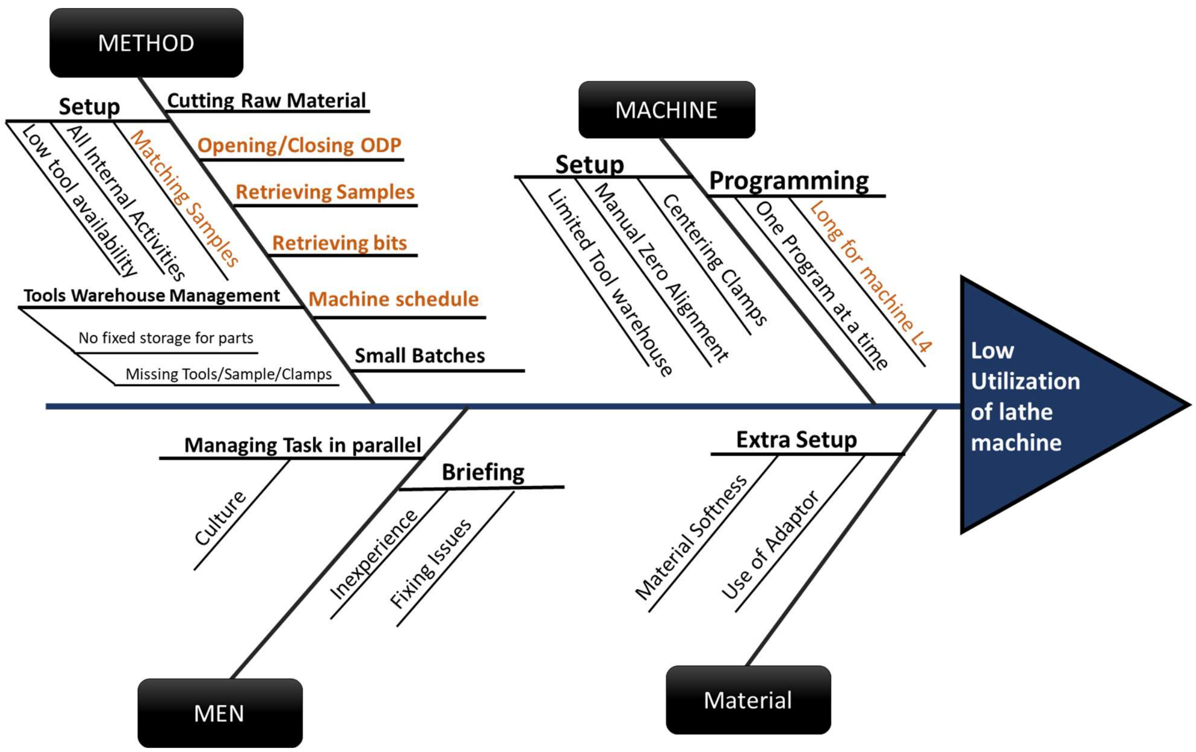


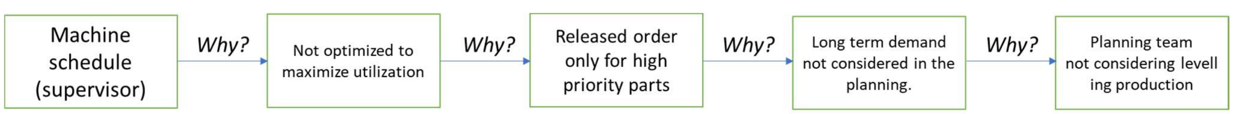
Figure 7: Ishikawa diagram with causes for the low utilization of lathes machine, the points highlighted in orange will be further analyzed with 5 why analysis.

On the light of the data we were showing during the problem breakdown related to the idle time and stand by time *(when the machine was not working)* and the high variability of the demand, we came up with the conclusion that the worker was the scarce resource required to saturate the machines who needed to be more efficiently exploited by concentrating his activities within the area and enabling him to work on more machines parallelly in order to achieve a good level of saturation. For the same reasons the causes we wanted to further explain are those linked to managing tasks in parallel, programming, setup and out of the cell movements.

7.1 Managing tasks in parallel

We wanted to go deep on this topic because, as explained earlier, hampering the achievement of a proper level of utilization for the 59%[10] of the total idle time. With this goal we interviewed the worker and the supervisor together asking the obstacles preventing to leave the machine while working and from that conversation we understood it was operator willingness and unnegotiable condition the one of attend the lathing of the first piece of the batch step by step since many technical issues, he had not forecasted during programming, might occur. So we studied the problem from a different perspective implementing a 5 whys analysis digging to find out the reasons why larger batches were not exploited during *machine schedule* to saturate machines when single components were demanded, and concerning this point the supervisor told us that none of them was available among the issued assembly groups while from the supply chain argued that such were ready, but not yet visible to production because not yet released. These batches are actually not components of new machines but parts destinated to replenish the spare parts warehouse that the company holds for its customers and they were intended to be released separately later in the month once the formers had been finished because, despite they were required, their priority was considered slightly lower.

On the end the first root causes that we point out is the not consideration of the long term demand upon schedule because the planning team is not considering levelling the production with different batch size.

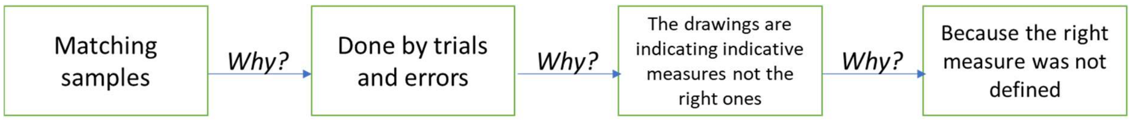


7.2 Setup Analysis

From the Pareto chart that we were showing in the previous chapter the activity of set up was generating about the 44% of the machine stand by time and for this reason we thought it deserves a more accurate analysis of the root causes. Looking at the Ishikawa diagram we notice there are many branches related to this job, but we wanted to focus the attention on few of them not requiring technological investment thus leveraging only on methods. Starting from the illustration of the reasons of down time one of these is the complete *internal execution of activities* and this on its turn is given by the absence of a standardized procedure.

[10] Avg. daily machine idle time: 5:29:25; avg. idle time due to operator working on another machine: 3:14:30

Still on the methods it happens that when having to deal with parts that have to *fit in samples* their execution is done by trials and error where the benchmark of the output is the sample because the drawing is indicating an indicative measure and not the right one and so the underlying reason of the inefficiency is the not definition of the right measure.



Having a look at the complementing spaghetti chart there are many times the operator leaves the cell, but this aspect will be treated in the next paragraph.

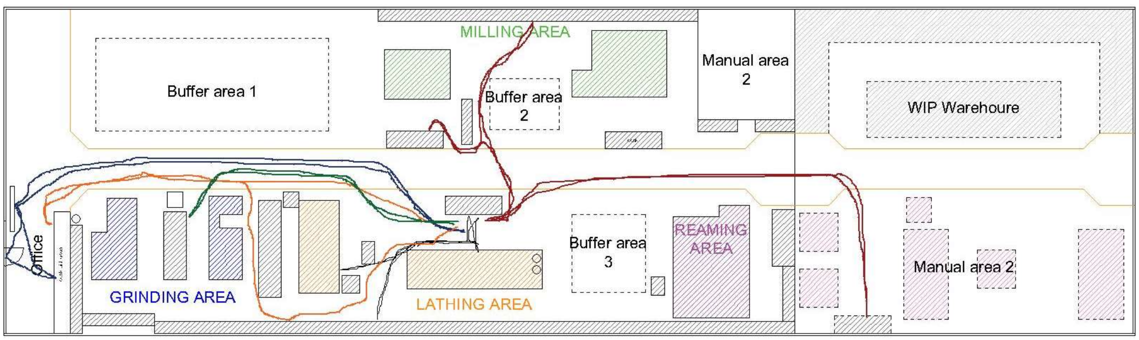
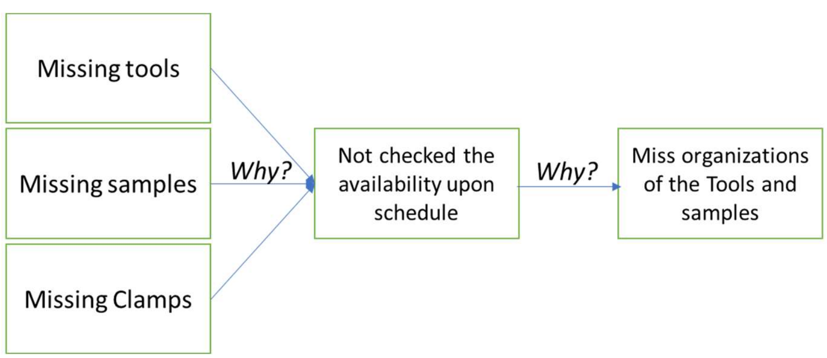


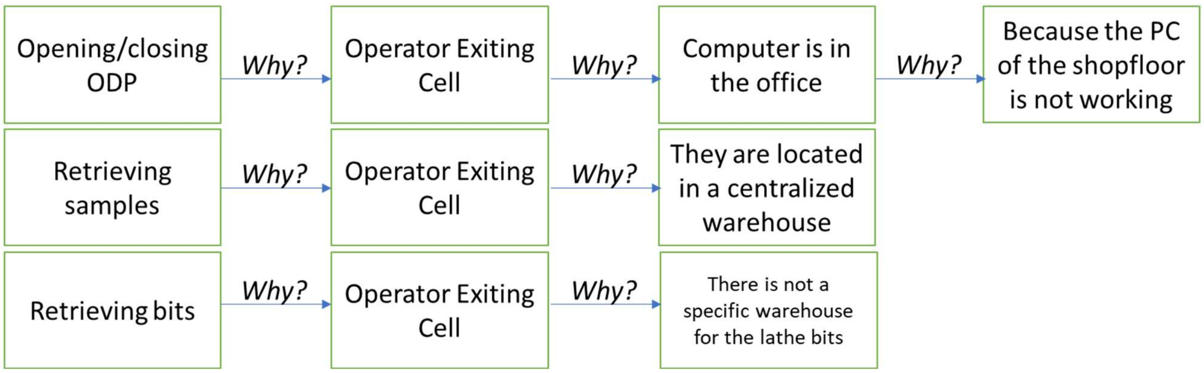
Figure 8: Spaghetti Chart representing movement of the operator.

To close this topic it often happens that the operator when retrieving bits and samples has to search for them because there is *no fixed storage for* those *parts*; and additionally often *instruments* are *missing* and this occurs because it's not checked their availability upon schedule, because there is a miss organization of the items where as consequence the supervisor is not aware of what's available on the department.



7.3 Out of the cell movements

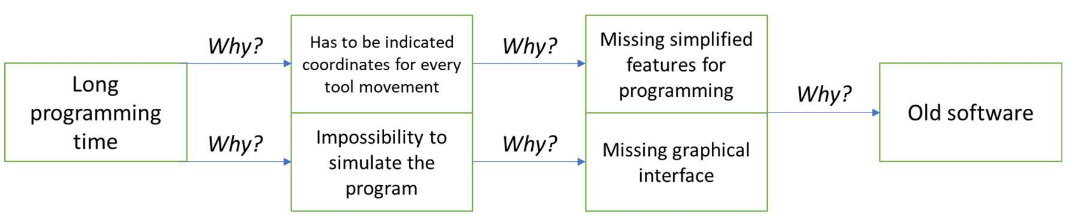
As previously anticipated often the operator has to deal with tasks like opening and closing ODPs, retrieving of sample and retrieving of bits that become a problem because the operator for their accomplishment has to get out the working area, but each of them actually has a specific different cause. About ODPs the reason is coming from the PC that is used the one in the office, because the laptop on the shopfloor is not working. Samples wise their position is simply located in a centralized drawers and it is the same for all the workers. Finally for the bits there is not a specific place for those used when lathing but they are positioned either behind the lathe, in the manual area or on the workbenches of the respective two milling machines.



7.4 Programming

The problem of programming is worsened by the fact that for both the lathes the buttons for commanding the machine while working and making the program are shared, so it's not possible to do the two activities concurrently. However, even if it was, the time it takes is still very large, with machine L4 being the slowest even when programs for the parts already exist on its archive because it is operator willingness to check the parameters first by reading again the code.

Analyzing the problem with a 5 whys approach we explain the reason of the *long time* arising from the fact that the operator for every movement of the tool has to write a raw of code indicating relative speed and coordinates it should be moving from-to, because there are missing simplified features for programming since the software is old. Moreover when he wants to review the program done it is not possible to simulate it because the software is lacking of a graphical interface since it is old, .



17. Developing countermeasures

After having plotted the Ishikawa diagram with all the causes of the problem of low utilization and having further analyzed the root causes of the issue we met with the company tutor and we discussed possible solutions for the main causes related to organizational reasons, then we involved the other stakeholders of the project like the operator, shopfloor supervisor and the supply chain responsible in order to find solutions for the most technical aspects and engage them on developing appliable countermeasures in order to minimize resistance upon the implementation phase, considering that one of the aspects that was required to change was the workers culture and the organization system they were used to work with. We want to bear in mind that the leading goal we have been pursuing was the one of letting the worker do his job uninterrupted and foster his changing of the culture of organizing jobs on one machine at the time by putting on the conditions necessary to work in parallel independently the demand that comes.

Going in order of importance the first countermeasure we developed was related to the scheduling approach. The idea was of parallelize the work on the two machines by loading one with larger batches and leaving the second for the manufacturing of single components and smaller batches in a way that the worker can set up the one loaded of larger ODPs, run the first piece, then when ready while the machine works the next, move the attention to the second lathe scheduled to produce smaller batches and keep staggering the changing of the pieces and setting up for the next phases likewise giving continuity to the cell output *Figure 10*. To do this however it was required the availability of levelled production orders, so for this reason as second countermeasure we asked the supply chain responsible to share a constant mix of orders with large and small batch size in order that the machining of the formers are exploited to cover the manufacturing cycles of the latter.

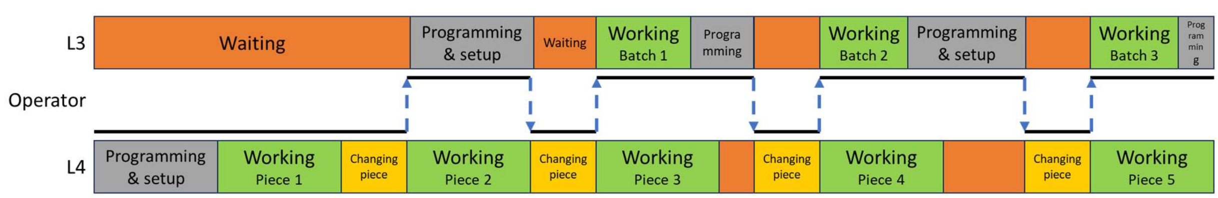


Figure 9: Ex. Of the sequence for the operator to manage the two machines.

We started then thinking about the time the operator was distracted from the working on the two machines and as regards the material handling we asked the supervisor to take care of the cutting of raw pieces he had schedule, and bring them to the lathe area in order to eliminate the time the machines spent idle because the worker was committed with the raw material cut, and avoid further consequences like misunderstanding and making arrangement with the supervisor for what bar to cut or matching on the needs of the machine with other workers.

For what concern the problem encountered during the set ups for missing of tools, clamps and samples necessary to work the piece the solution that was developed at the beginning was related with the creation of a checking list for the supervisor of what to control before proceeding with the scheduling of orders[11], however we sooner understood that he actually was not aware of what's available within the department, so we decided to go deeper and make a list of tools, samples and clamps that can be used to make the parts and complement it with the related machine limitations of clampable dimensions in order that can be checked upon schedule the possibility of making one component before its release to the operator and if deemed to be necessary by the supply department place an order to the supplier for missing equipment.

The next problems we tackled were related to the exiting of the area due to opening and closing of ODPs, retrieving of bits and samples and other responsible for the extension of the time spent away from the cell like searching for bits and samples. Regarding the first one we agreed with our tutor and the supervisor to fix the computer that since last year was used at the center of the shopfloor for communicating with the workers and move it and the blackboard used for scheduling by the supervisor from a position next to the office, but far from machines, to a more centralized place on the shopfloor easily reachable by all workers. Regarding the retrieval of the bits instead, their searching and the same for the samples the only solution was the one of implementing 5S and standardization on their allocation. For the samples it was later upgraded by asking the supervisor to bring them to the cell like he already should have done for the raw materials[12].

Finally but not least we wanted to reduce the time it takes for programming and tackle the problem related to the matching of samples encountered during setups. The countermeasures found for the second case were further split into a short term one, adding a note on supervisor's checking list for scheduling remembering to send the sample required to make the piece to quality department for detecting the measures before releasing the order; and a second long-term suggesting the company to review and update drawings with the actual measures.

As concern the time for programming it would have been required an upgrading of the software if existing or a session of training for coding shortcuts.

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[11] More details will be given on the *"Monitoring of the result & process"* chapter.
[12] More details will be given on the *"Monitoring of the result & process"* chapter.

Causes and root causes addresed	Countermeasure
Small Batches	Levelling production orders
Machine schedule - not considering levelling production orders	
Machine schedule	Scheduling loading two machines with different batch size
Cutting Raw Materials	Provided by the supervisor
Missing tools/samples/clamps	Creation of checking list before; Creation of availaility list later*
Missing clamps	Purchase**
Retrieve samples	Provided by the supervisor***
Opening/closing ODPs	Fixing PC and move centraly with blackboard
No fixed storage for parts	5S
Retrieving bits	5S - lathe specfic warehouse
Matching samples	Send sample to quality department for measures detection
Programming	Asking the existence of shortcuts & upgrades to the supplier

Figure 10: summary of countermeasures and causes addressed;
(**) see "Implementation of the countermeasures"; (*) (***) see "Monitoring of the result & process"
;

18. Implementation of the countermeasures

For this step of the A3 methodology we decided along with the stakeholder of the project to give the priority of implementation to quick win solutions that were those who would have allowed us to get the maximum out of it with the lowest cost of investment and staying within the time constraints of our project. For this reason we decided to exclude the long term countermeasure related to the *"matching of sample"*, but just curbing the effects with short term solutions and keep the one related to programming only as nice to have implementation since the process from getting in touch with the supplier to the possibility of seeing the result would have not been feasible within our time constraints.

1) "Levelling production orders" & "load two machines with different batch size"

As already anticipated these two correlated countermeasures were strongly changing the system the workers were used to work with and for this reason the rule driving the implementation plan was alignment between the departments in a way that both of them were aware of the goal we were pursuing. For this reason an introduction meeting explaining the situation with the parties involved was scheduled.

During the first scheduling we needed to set the guidelines for the process in order to make the supervisor independent; and along with him we decided to adopt machine L3 for the production of single components and small size batches while occupying lathe L4 with the larger ones requiring longer machining time in order to exploit the flexibility of the first machine while programming and making setups and amortize the initial longer time of preparation of the latter, if no technical constraint would have required the opposite.

Adopting this strategy is possible to easily cope with the sudden demand arising from urgent orders.

2) Raw materials provided by the supervisor

For what concern this countermeasure we were required to define standardized input and output zones for the cell so that it would have been straightforward for the operator to read from the blackboard the next job he was assigned with and find the raw pieces the supervisor cut; while the same for the supervisor recognize what pieces to move away from the area and where to put the next ones. To this goal we set out an input cart for both the machines and two distinguished pallets (one per machine) working as output zone between the two. Finally, technically wise, L4 is able to work longer pieces than L3 *(up to 1.2m length),* they are sporadically occurring, but because of this we outlined a farther input/output space left free on the floor for L3 *(see Figure below)*.

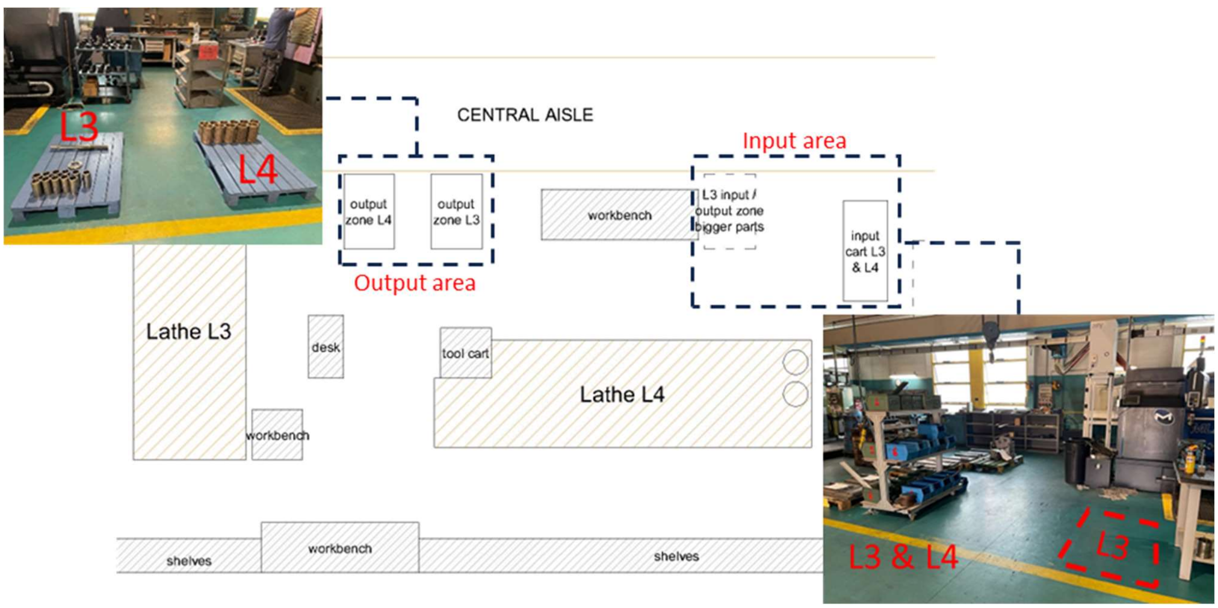
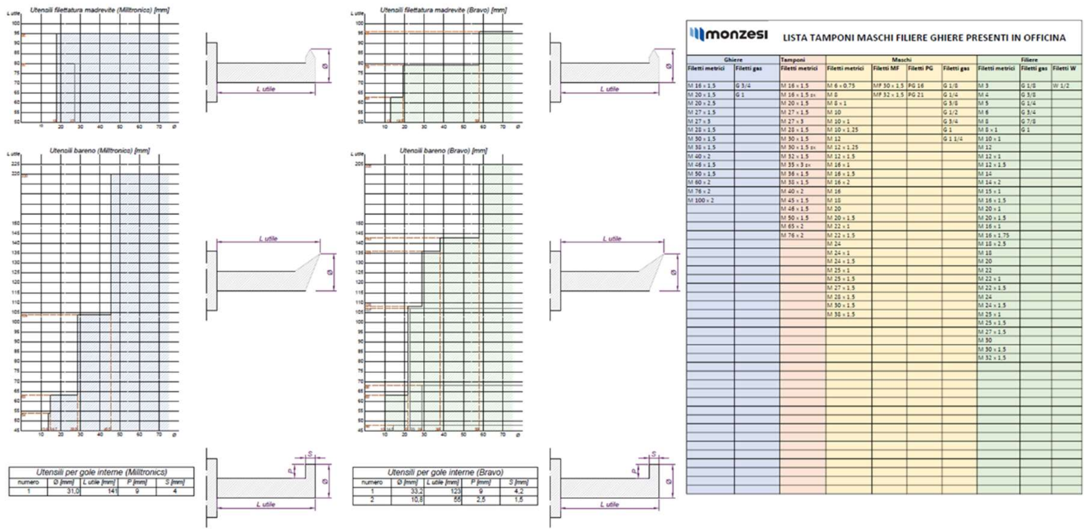


Figure 11: Input/output area of the cell

Still regarding this aspect we manage with the supervisor to deal with intermediate out of the cell manual activities, where he spontaneously took care of its accomplishment for then giving back again to the cell while letting the lathe operetor keep working in the meanwhile.

3) "Creation of availability list" & "clamps purchase"

As already anticipated about this point we decided at the beginning to implement a checking list for the supervisor with all the aspects to be verified upon scheduling, preventing later stoppages for missing items, however later we were required to upgrade it and prepare a full catalog of tools available for the two machines and samples[13].



numero	Ø [mm]	L utile [mm]	P [mm]	S [mm]
1	31,0	141	9	4

numero	Ø [mm]	L utile [mm]	P [mm]	S [mm]
1	33,2	123	9	4,2
2	10,8	55	2,5	1,5

monzesi LISTA TAMPONI MASCHI FILIERE GHIERE PRESENTI IN OFFICINA

Ghiere		Tamponi	Maschi				Filiere		
Filetti metrici	Filetti gas	Filetti metrici	Filetti metrici	Filetti MF	Filetti PG	Filetti gas	Filetti metrici	Filetti gas	Filetti W
M 16 x 1,5	G 3/4	M 16 x 1,5	M 6 x 0,75	MF 30 x 1,5	PG 16	G 1/8	M 3	G 1/8	W 1/2
M 20 x 1,5	G 1	M 16 x 1,5 sx	M 8	MF 32 x 1,5	PG 21	G 1/4	M 4	G 3/8	
M 20 x 2,5		M 20 x 1,5	M 8 x 1			G 3/8	M 5	G 1/4	
M 27 x 1,5		M 27 x 1,5	M 10			G 1/2	M 6	G 3/4	
M 27 x 3		M 27 x 3	M 10 x 1			G 3/4	M 8	G 7/8	
M 28 x 1,5		M 28 x 1,5	M 10 x 1,25			G 1	M 8 x 1	G 1	
M 30 x 1,5		M 30 x 1,5	M 12			G 1 1/4	M 10 x 1		
M 38 x 1,5		M 30 x 1,5 sx	M 12 x 1,25				M 12		
M 40 x 2		M 32 x 1,5	M 12 x 1,5				M 12 x 1		
M 46 x 1,5		M 35 x 3 sx	M 16 x 1				M 12 x 1,5		
M 50 x 1,5		M 36 x 1,5	M 16 x 1,5				M 14		
M 60 x 2		M 38 x 1,5	M 16 x 2				M 14 x 2		
M 76 x 2		M 40 x 2	M 16				M 15 x 1		
M 100 x 2		M 45 x 1,5	M 18				M 16 x 1,5		
		M 46 x 1,5	M 20				M 20 x 1		
		M 50 x 1,5	M 20 x 1,5				M 20 x 1,5		
		M 65 x 2	M 22 x 1				M 16 x 1		
		M 76 x 2	M 22 x 1,5				M 16 x 1,75		
			M 24				M 18 x 2,5		
			M 24 x 1				M 18		
			M 24 x 1,5				M 20		
			M 25 x 1				M 22		
			M 25 x 1,5				M 22 x 1		
			M 27 x 1,5				M 22 x 1,5		
			M 28 x 1,5				M 24		
			M 30 x 1,5				M 24 x 1,5		
			M 38 x 1,5				M 25 x 1		
							M 25 x 1,5		
							M 27 x 1,5		
							M 30		
							M 30 x 1,5		
							M 32 x 1,5		

Regarding the clamps we meet the problem upon schedule that the current limit in term of maximum clampable diameter of 12 cm for L3 was too stringemt, while for the following weeks were planned to be produced by both lathes 6/26 ODPs larger than the current limit, for this reason has been decided with the supply chain responsible to proceed with the purchase of clamps holding diameters up to 20cm.

4) **"Fixing PC and move centrally with blackboard"**

As anticipated in the explanation of the countermeasures *Figure 13* shows the changing, additionaly it was defined an apposit place, previously missing, were workers place drawings of just finished ODPs avoiding their spreading around as it was used happening.

[13] More details will be given on the *"Monitoring of the result & process"* chapter.

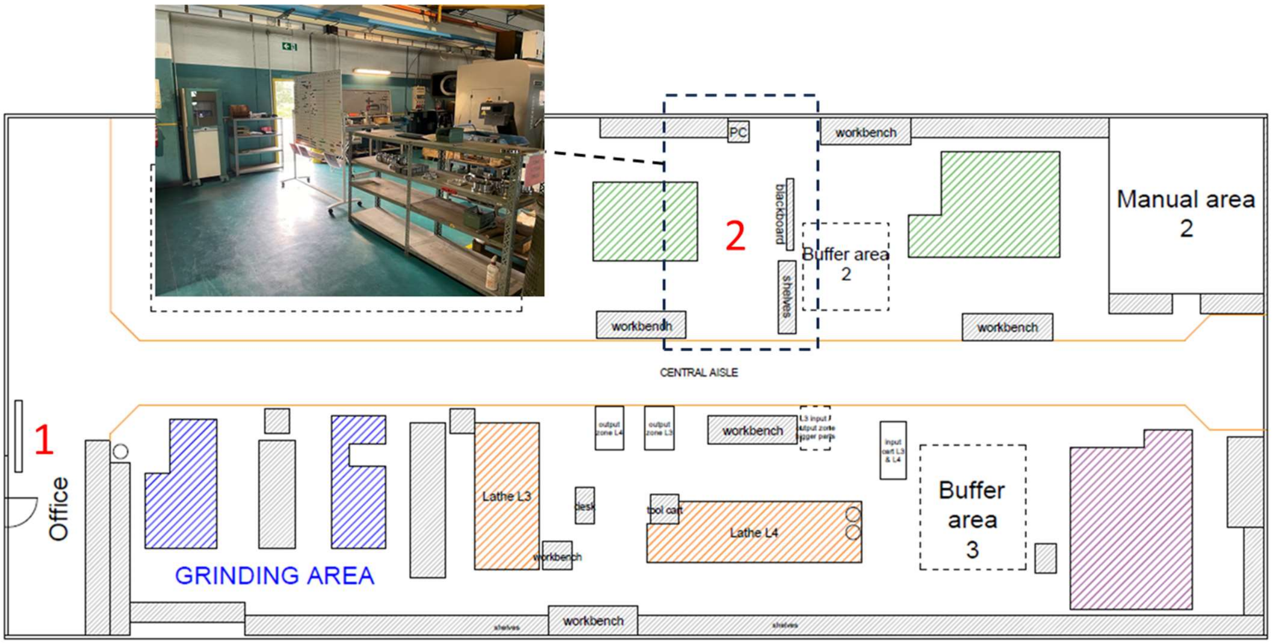


Figure 12: "1" indicates the position before the move; "2" indicate the new position after the implementation.

5) "5S"

This countermeasure was put in place with the goal of eliminsting the problem of searching for tools and samples by making them findable at first sight. However with it we manage also to mitigate the consequences of low availability of tools, that entails the frequent changing of drilling bits from the same tool during set ups and the aftermath of missing items where the operator keeps searching when the item is not present.

The items under question were two, bits and samples.

Regarding bits they are spread in four different places around the department but each of them are organized in a messy way with twice or more the same measure in the same store. We organized for this reason a specific place for the lathe area by undergoing all of the 5S steps. It was started with "*sorting*" and defining what's required, we need first to differentiate between normal and hard metal bits, the first are cheaper and because of this we took one each measure of diameter; regarding the second instead (more expencive) a more accurate analysis was necessary. Taking the list of upcomming drawings in the next month was estimated the frequency for the most used dimentions *Figure 14*, then for the selection we compared the result asking for confirmation to the supervisor what to add or eliminate according his experience. *"set in order"* with the operator were identified places where it was familiar and immediate for him to place the tools within the cell and then *"shine"* was made a mutual arangement with the operator to tidy out their position at evening every day before leaving. For *"standardize"* were posted on the wall pictures of the situation before and after and it was asked the supervisor to become responsible of its maintainment over time.

Finally *"sustain"* where our tutor took the responsibility of making the check list and verify on an ordinary base their maintenment overtime by observing and comparing pictures with the actual situation.

For the samples we did the same but fortunately one specific position they were placed was already existing and it was the same for all the machines *Figure 17*.

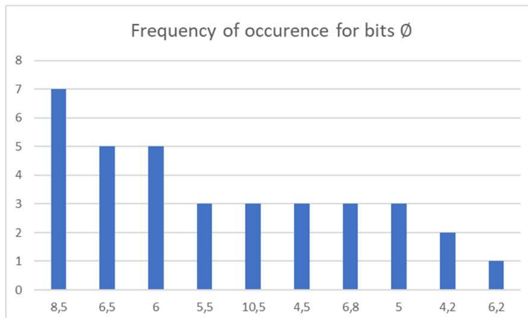


Figure 13: (x axis) bits distinguished as measure of the diameter (y axis) number of time has been necessary over a sample of 50 drawings.

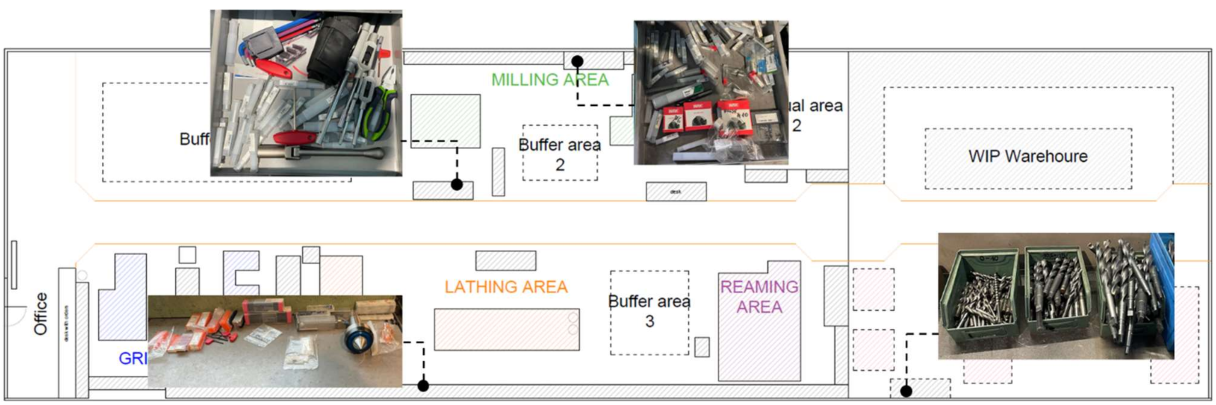


Figure 14: situation before implementation of 5S for bits

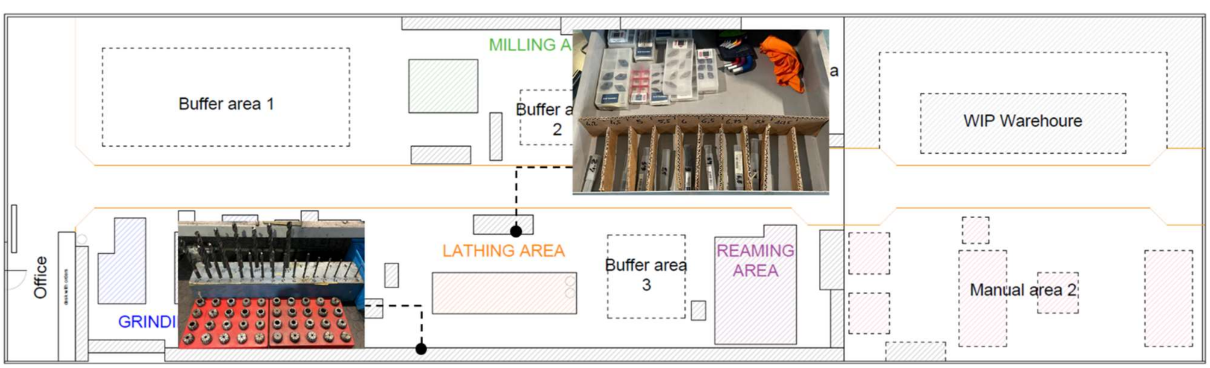


Figure 15: situation after the implementation of 5S for bits

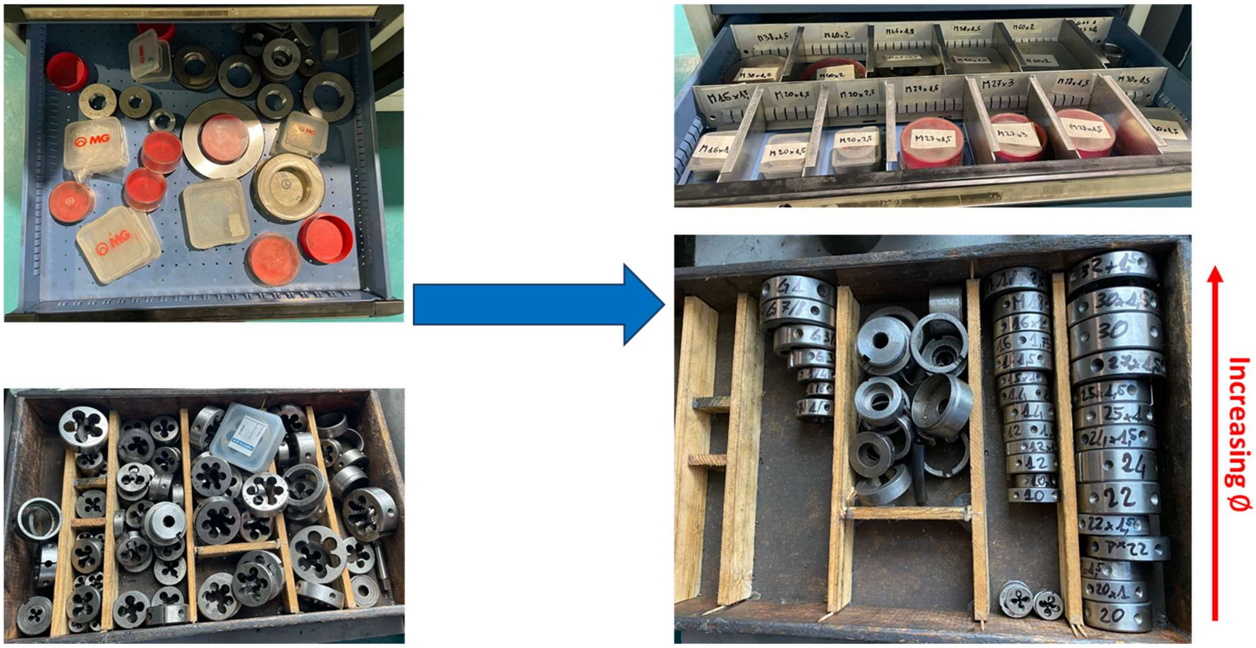


Figure 16: situation before and after the implementation of 5S for samples

19. Monitoring of the results & process

After the implementation of the aforementioned countermeasures and a short period of employee training, the following step to be carried out is the monitoring and measuring of the results for the work done in order to understand wether the actions put in place were enough to hit the targets we had set or requiring additional ones. As it was done for the stopwatch analysis this phase has been conducted through the observation of the operator performing his daily work, following simple guidelines in order to avoid long machine downtimes and in order to maximize the value-added time both for the operator himself and the machine.

Starting from May the 29th, first day of implementation of the new scheduling and material handling system different samples have been taken by staggering our presence at the company and constantly attending continuous production days from the start to the end in order to have the most reliable and reppresentatve picture of the outcome and averaging any type of variability in performances while chatching the most of further raising issues. The focus of the measurements had been mainly the targeted utilization rate of the cell complemented with the motion of the operator, in order to identify if the goal of letting him work uninterrupted within the cell had been achieved. Morever it should be highlighted that a quantitative assessment of the effectiveness of each of the countermeasure over the target could have not been measured properly but estimated since all of them, apart from the new method for scheduling, have been implemented parallely in a second moment. Also because of this the second analysis.

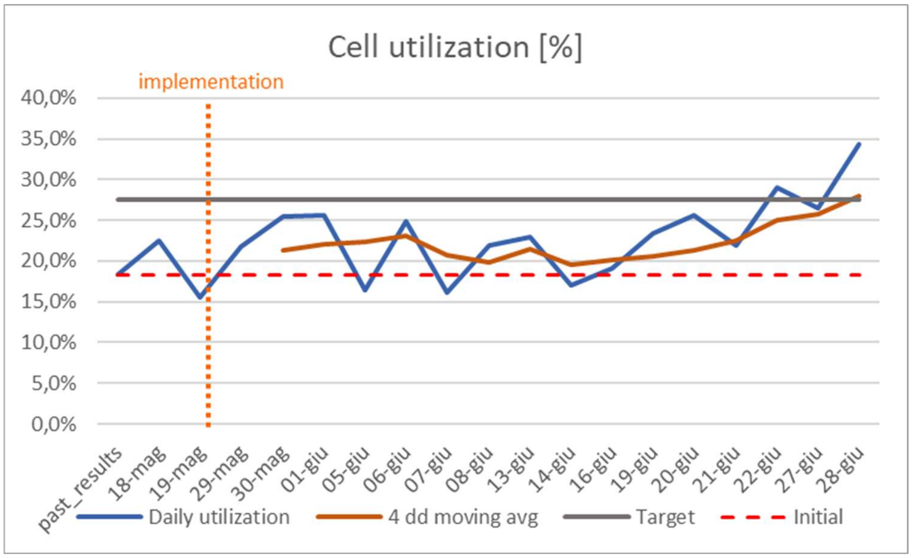


Figure 17: Graph representing Cell Utilization approaching target.

Starting from the target, as *Figure 18* can witness, definetly the utilization achieved can reasonably be considered improved compared the initial situation level *(18.4%)* since the line plotting the 4 days moving average is stationary above the one reporting previous performances. Unfortunately not the same can be told concerning the target and it requires additional considerations to grasp the result.

Starting from the 29th the new approach of scheduling and material handling were showing to be delivering well, but after the first week unfortunately a different set of additional problems previously unexperienced started to show up. Mentioning the most importants, one of these was the happening again of the missing of samples, the operator indeed prepared the machine with both program and set up then before starting, while was searching for the sample of the thread, discovered that it was not there. This forced us to review the root cause analysis we did and it was found that that component had already been done in the past but with a thread different from what indicated by the drawing, therefore the root cause of the problem was again the not updating and not right definition of the drawings. So we decided (as described in chapter 8) to integrate the initial checking list reporting the points to be controlled by the supervisor upon schedule with a broader one with diagrams of workable measures by the tools and samples available within the department and then to share them with supply and design department, so to prevent from upstream the occurrence of the problem and anticipate the ordering of the required equipement still before the release of orders in production. Additionally we asked the supervisor to take in charge the task of preparing along with the raw material the sample required to make the piece definetly eliminating a further cause of out of working area movements for the worker.

As second example we are reporting that we faced but not negligeble was instead purely related to the operator behave and the culture. He showed resistence when he was asked to enter the new system and move to work on a second machine even if the conditions he was complaining as necessary to work on two machines simultaneously were there. That problem was later worsened during the wormer last weeks and for the solution we tried first to challenge the worker sharing with him the KPIs we were measuring and setting daily targets for him, then the intervention of the company tutor was needed to have his greater collaboration on the project.

For what is concerning the motion analysis the spaghetti chart reported in *Figure 19* shows the evolution of the operator movements with the new situation. Eliminated the needs of exiting the cell for the cut of raw materials, the retival of bits and samples and the escalation of the activities between the two lathes it started to become more seenable and frequent others that previously were less afecting the performances. We proceeded with this goal with the purchase of the deburring tool and the centesimal comparameter for the elimination of the last causes forcing the worker to get out his area. These are actually daily adopted tools and low cost but previously it was shared among all workers the tool for deburring and with the manual lathe te second, now the two lathes have his own comparameter (the one of L4 and L3 are different) and each operator has his own deburring instrument. Qualitatively, from *Figure 19*, the greater portion of the movements is now concentrated between the two lathes and apart the opening/closing ODPs the only reason that is now remaining for exiting the working area is the one of briefing with the supervisor but the root cause of the problem here was partly reppresented by fixing issues that now should be removed and others like the operator's inexperience because of his young age (working as lather for 1.5 yares). We expect over time tis factor to be improving and reducing, like for his collegues, the frequency of necessity of asking for informations about the piece to be worked. Finally we wanted to eliminate more evident movements between the two lathes coming from the forgetting on the two machines related workbenches frequently used tools during set ups like the wrenches for changing tools and mooving clamps, they have been placed one on each of the relative workbench.

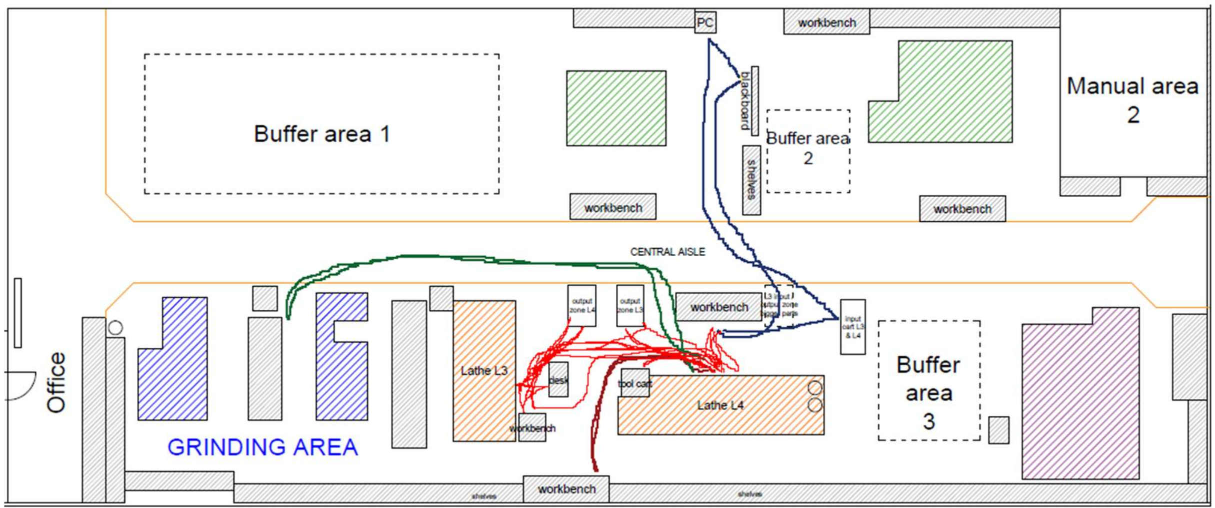


Figure 18: Spaghetti chart after implementation, the legend is the same of Figure 6.

A general estimation summurizing the daily savings in term of time the operator was previously distrupted to work on the machines is reported in *Table 9* and as it is shown more than the 59% of the total reduction has been obtained with the elimination of the cutting of raw materials, while for what concern the manual reworks of the piece we consider those that are coming from the assembly to be still responsibility of the lathe operator, while for the intermediate steps of reworks for finishing the part not to be completely zeroed but anyway less frequently performed depending on supervisor's availability. As a total we managed to decrease the average daily time spent outside the area for an amount of 1 hour and 12 minutes that now can be allocated to run the machines.

Causes	Old		New		daily savings
	Avg. Time	Avg. Frequency	Avg. Time	Avg. Frequency	
Cutting raw materials	43 min	once a day	0 min	never	00:43:00
Closing/opening ODPs	3 min	twice a day	2 min	twice a day	00:02:00
Manual reworks finishing parts	15 min	once every 2 days	15 min	once every 4 days	00:03:45
Manual reworks from assembly	40 min	once every four days	40 min	once every four days	00:00:00
Retrieving bits	3,5 min	twice a day	20 s	twice a day	00:06:20
Retrieving samples	3,5 min	once a day	0 min	never	00:03:30
Briefing from supervisor	5 min	more than 5 per day	5 min	5 per day	00:05:00
Retrieve centesimal comparator	2 min	once every 2 days	0 min	never	00:01:00
Retrieve deburring tool	2,5 min	three per day	0 min	never	00:07:30
				total daily savings	1:12:05

Table 7: Time taken by each activity.

As final result the last week should be considered as the most representative of the future performances because additional remaining issues had been solved and our intervention while giving indication to people on the shopfloor were not necessary. That time the daily target indicator managed to achieve a maximum peak of 34.4% and the 4 days moving average, more long term oriented, closing just slightly above the must-have target for a final value of 28.2% *(27.5% must have target)* but showing a incrising trend. In favour of this it should be highlighted that during the monitored month the demand experienced was way different compared to the one explained during the problem breakdown of 4 pcs/batch since the company decided lately from may 22nd to underke a project for the manufacturing of a prototype new machine thus affecting the demand on the shoopflor and requiring lathe 3 with the manufacturing of only single custimized componets and a general averaged batch size of 2.8 pcs/batch. Morover if related to previous observations done for the assessment of the initial situation the average batch size measured was of 5.75 pcs, thus a further point strengthening the job we did, showing that there is still possibility for improvements.

20. Share and Standardize

This critical phase of the project aims at standardizing, sharing and sustaining the results achieved during the project, so that what has been implemented will remain effective in the future.

Our interventions and guidelines, developed together with the company tutor, follow two different paths. On one hand we established standard procedures in order to guarantee that the new and most critical activities introduced during the project will be executed correctly and effectively by the operators. On the other hand, instead, we introduced performance control procedures to be carried out periodically aiming at sustaining results and avoiding loss of performances.

11.1 5S

For the maintainment of the improovement over time has been appointed the supervisor as the person responsible for the maintening of the new standards achieved within the department and to this goal pictures reporting the previous and next situation have been attached to the wall in front of the rearanged boxes/drawers in order to instill the workers with the new culture of keep in order. Finally our company tutor took the responsibility of preparing the checking list of the boxes/drawers to be controlled and have a tour on the department on an ordinary base to verify its maintainment.

Regarding sharing instead has been agreed to reorganize likewise the bits on the other two drawers of the respective milling machines and centralise those items present twice or more in a single centralized position as central “warehouse” so to keep locally only the strictly necessary elements for the daily tasks and having the workers to get out of the area only when they are required to take a new one. This system would be helpful for the supervisor to have a straightforeward understanding of the replenishment needs by reducing the points to control and minimize the risk of loosing expencive parts.

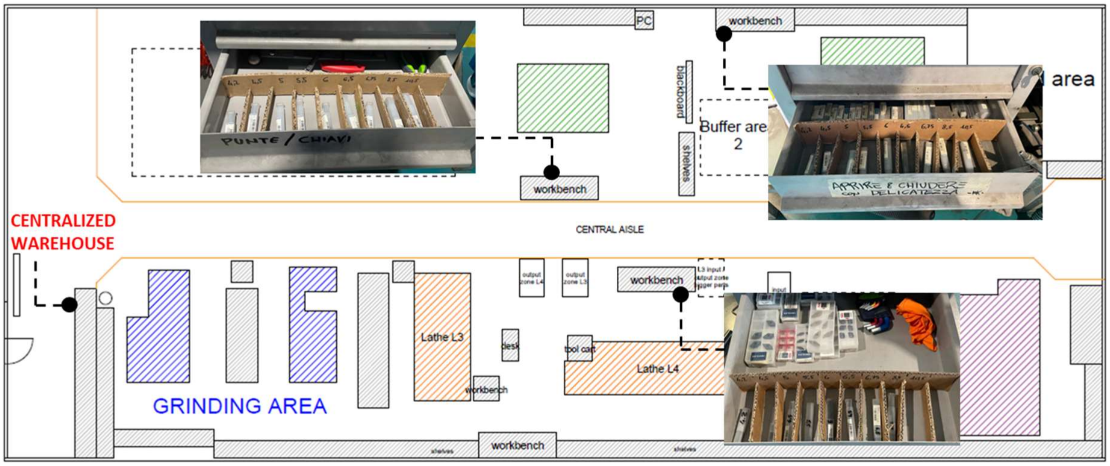


Figure 19: Situation after standardization of 5S for bits.

11.2 Load two machines with different batch size

The following flow chart has been developed in order to explain the procedure that the supervisor is expected to go through when making the schedule.

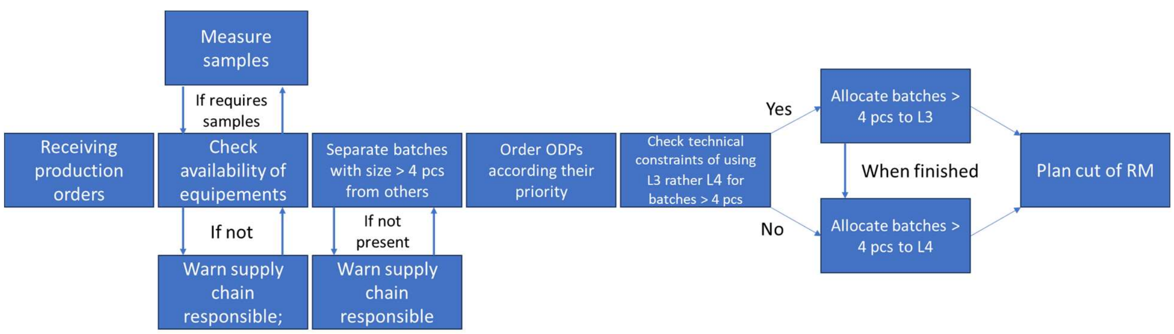
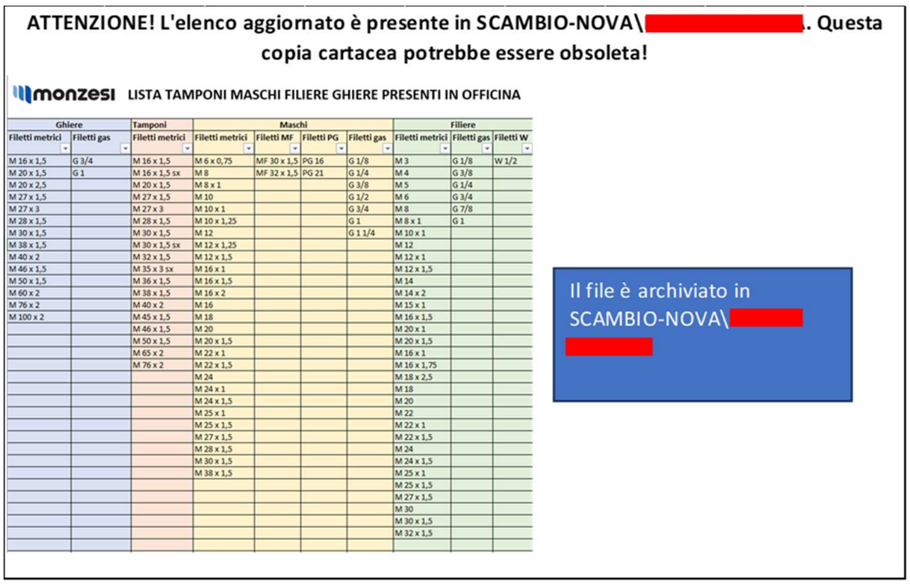


Figure 20: Graphical representation of the algorithm for schedule.

11.3 Creation of availability list

Regarding this countermeasure the critical point to be faced was again the enabling of the alignment between the departments, it was not enough indeed to share the printed list reporting the current availability with the other parties involved but it was required also the updating of the sheets and enable the awareness of all the parties anytime a new object was decided to be purchased. To this goal a shared excel file reporting the tables and the relative updating procedure was created within the information system of the company and the indications regarding its location among the system has been written on the distributed printed tables. The procedure that has been set out for the update starting from the purchase is the following:

- Upon purchase of the new tool the supply department who contrlos the orders is responsible of updating the excel file by writing the name of the new tools/samples in orange, meaning that it had been ordered but not yet available.
- When it arrives the writing is turned into black by the production supervisor, who is the one who physically receives the ordered item and stores it on the position that items is physically kept.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monzesi LISTA TAMPONI MASCHI FILIERE GHIERE PRESENTI IN OFFICINA

Ghiere		Tamponi	Maschi				Filiere		
Filetti metrici	Filetti gas	Filetti metrici	Filetti metrici	Filetti MF	Filetti PG	Filetti gas	Filetti metrici	Filetti gas	Filetti W
M 16 x 1,5	G 3/4	M 16 x 1,5	M 6 x 0,75	MF 30 x 1,5	PG 16	G 1/8	M 3	G 1/8	W 1/2
M 20 x 1,5	G 1	M 16 x 1,5 sx	M 8	MF 32 x 1,5	PG 21	G 1/4	M 4	G 3/8	
M 20 x 2,5		M 20 x 1,5	M 8 x 1			G 3/8	M 5	G 1/4	
M 27 x 1,5		M 27 x 1,5	M 10			G 1/2	M 6	G 3/4	
M 27 x 3		M 27 x 3	M 10 x 1			G 3/4	M 8	G 7/8	
M 28 x 1,5		M 28 x 1,5	M 10 x 1,25			G 1	M 8 x 1	G 1	
M 30 x 1,5		M 30 x 1,5	M 12			G 1 1/4	M 10 x 1		
M 38 x 1,5		M 30 x 1,5 sx	M 12 x 1,25				M 12		
M 40 x 2		M 32 x 1,5	M 12 x 1,5				M 12 x 1		
M 46 x 1,5		M 35 x 3 sx	M 16 x 1				M 12 x 1,5		
M 50 x 1,5		M 36 x 1,5	M 16 x 1,5				M 14		
M 60 x 2		M 38 x 1,5	M 16 x 2				M 14 x 2		
M 76 x 2		M 40 x 2	M 16				M 15 x 1		
M 100 x 2		M 45 x 1,5	M 18				M 16 x 1,5		
		M 46 x 1,5	M 20				M 20 x 1		
		M 50 x 1,5	M 20 x 1,5				M 20 x 1,5		
		M 65 x 2	M 22 x 1				M 16 x 1		
		M 76 x 2	M 22 x 1,5				M 16 x 1,75		
			M 24				M 18 x 2,5		
			M 24 x 1				M 18		
			M 24 x 1,5				M 20		
			M 25 x 1				M 22		
			M 25 x 1,5				M 22 x 1		
			M 27 x 1,5				M 22 x 1,5		
			M 28 x 1,5				M 24		
			M 30 x 1,5				M 24 x 1,5		
			M 38 x 1,5				M 25 x 1		
							M 25 x 1,5		
							M 27 x 1,5		
							M 30		
							M 30 x 1,5		
							M 32 x 1,5		

Il file è archiviato in SCAMBIO-NOVA\[redacted]

Figure 21: ex. Of sheet printed and distributed to technical department

11.4 Maintenance of the performance

For what is concerning the maintainment of the ultimately achieved performances keeping up the utilization rate of both of the machines and to further pursuing additional improvements we suggest the company to implement a performance measurement system shared to the operator while setting daily targets that can be achieved so to foster his motivation to improve not negletting one machine rather than another and getting back to the initial situation. Of sure the utilization rate as it's measured now is not sustainable in term of measurability, even if it could with the installation of sensors on machines. What we would strongly recommend is the implementation, if required, with a future project of the "day by hour" production schedule methodology that we had not time to test because of the effort it would still take for its implementation but that potentially would enable to pursue the aforementioned goal and give the possibility to plan production in a more quantitavive way while comparing the gap of the plan respect to the position they actually stand. Morover this tool is beneficial to definetly eradicate the operator culture of working on a single machine, since it was noticed during the initial stages of implementation that it was operator tendency the one of prioritize machines giving continuity to the one scheduled with batches.

21. Conclusion

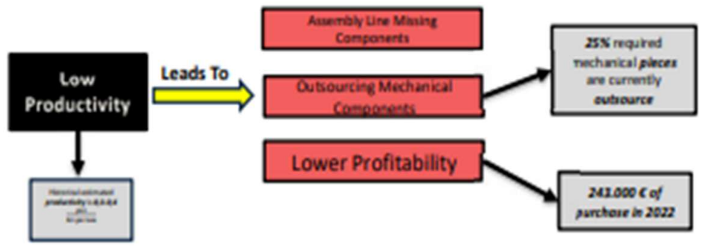
In the end, the project at Company commenced with the identification of challenges concerning low productivity and machine utilization. Through a dedicated and focused approach, we conducted a comprehensive evaluation of the production department, meticulously identifying and addressing each issue with a range of effective countermeasures. It was not easy at the beginning to drive the attention to a restricted number of subcathegories for predominant problems since making a classifion each of them were representing the same values in term of frequency of occurrence and magnitude of consequences, but on the end we revealed the prime source of inefficiency to be the unawareness of machines capabilities and absence of support when releasing and planning orders for the department due to missing of methodologies to do that. Likewise it happens for singular component linked inefficiences that in view of the sporadicicty of the requests had never been tackled by the department but unfortunately all toghater frequently occuring since the highly variabile demand. As the project draws to an end, we take great satisfaction in exceeding our initial objectives of increasing cell utilization more than what was set by a slight margin. This achievement, coupled with a thorough analysis of the graphical data, instills in us a strong sense of optimism for witnessing further remarkable advancements in the future. The project has not only successfully addressed the challenges of increasing machines and cell utilization, but hopefully will also lead to foster productivity and cost reduction.

In conclusion, the successful completion of this lean project marks a significant milestone in company journey towards operational excellence. We extend our heartfelt gratitude to everyone involved in this project, including our colleagues within the company, specially company tutor and our methodological tutors, and all the dedicated individuals at Company. It has been an absolute pleasure collaborating with them, and we emerged from this experience significantly enriched and improved. As we wrap up this project, let us celebrate our achievements and embrace the lessons learnt. We must carry forward the spirit of lean thinking, embracing it as a way of life, and applying its principles to future endeavors. With a solid foundation in lean methodologies, we are well-equipped to tackle future challenges and drive sustained growth.

A3

1. Clarify the problem / Problem Backgroud / Current situation

Problem statement: *"The current procedures applied in the production department don't allow the level of productivity the company requires while leaving machines not fully exploited"*



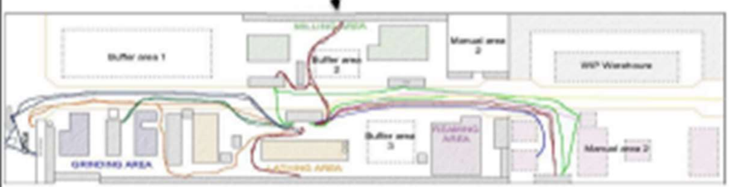
2. Breakdown the problem

Production Area	Required Time(hr)	Net Available Time(hr)
Lathing	471.3	352.8
Milling	403.1	352.8
Grinding	170.2	352.8
Cutting	266.7	352.8

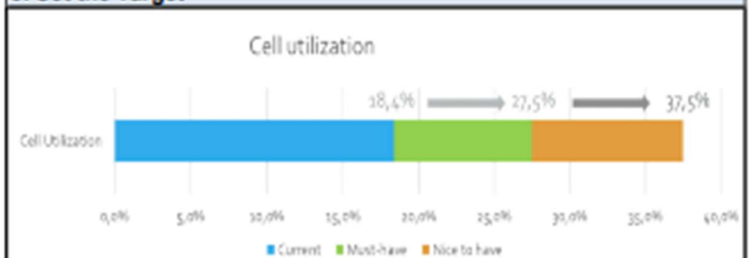
Machine	Avg. Utilization	Operator
L3	18.6%	3
L4	18.2%	3
M1	29.2%	1
M2	44.3%	2

Causes	Avg. Time	Avg. Frequency
Cutting raw materials	43 min	once a day
Closing/opening ODPs	3 min	twice a day
Manual reworks	15-40 min	less than once a day
Retrieving bits	3-4 min	twice a day
Retrieving samples	3-4 min	once a day
Briefing from supervisor	5 min	more than 5 per day
Retrieve centesimal comparator	< 3 min	less than once a day
Retrieve deburring tool	< 3 min	three per day

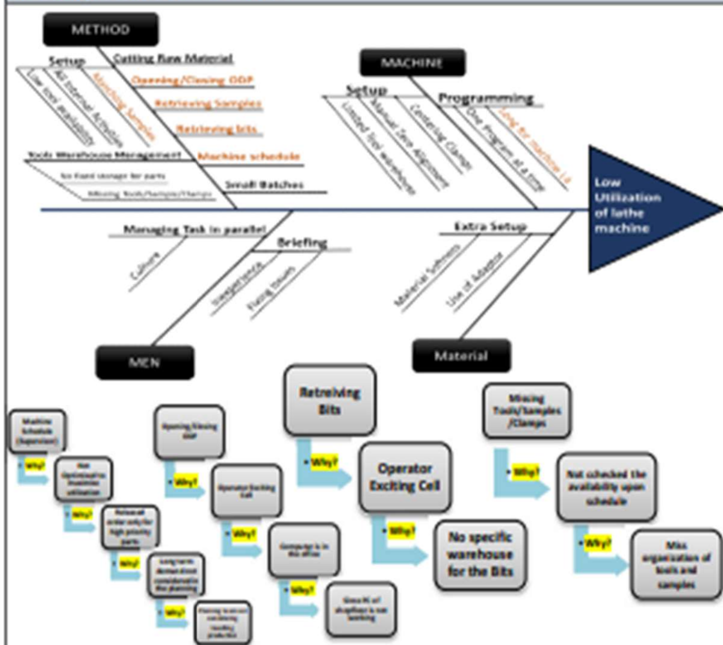
Lathes status during operators' available time		
Monitored time	9:00:00	100%
Break time	1:36:25	-17,9%
Scheduled operators' available time	7:23:35	82,1%
Stand-by time during the operator available time	1:51:20	-20,6%
Idle time during the operators' available time	3:57:30	-44,0%
Machining time during the operators' available time	1:34:45	17,5%
Running during breaks	0:04:30	0,8%
Total daily running time	1:39:15	18,4%



3. Set the Target



4. Analyse the Root Cause



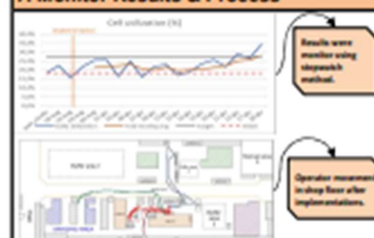
5. Develop Countermeasures

Causes and root causes addresed	Countermeasure
Small Batches	Levelling production orders
Machine schedule - not considering levelling production orders	
Machine schedule	Scheduling loading two machines with different batch size
Cutting Raw Materials	Provided by the supervisor
Missing tools/samples/clamps	Creation of checking list before; Creation of availaility list later
Missing clamps	Purchase
Retrieve samples	Provided by the supervisor
Opening/closing ODPs	Fixing PC and move centraly with blackboard
No fixed storage for parts	5S
Retrieving bits	5S - lathe specfic warehouse
Matching samples	Send sample to quality department for measures detection
Programming	Asking shortcuts the suppliers

6. Implement Countermeasure

Project	What	Who	When	Outcome
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

7. Monitor Results & Process



8. Standardise & Share Success