LEAN THINKING FOR DOWNTIMES REDUCTION

Case study: Sisme S.p.A.

IMLab 2 – MASTER THESIS

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Abstract

The master thesis concerns the “lean thinking” application for downtime reduction in an electric motors manufacturing Company, Sisme S.p.A.

Lean is the concept of efficient manufacturing/operations that grew out from the Toyota Production System. It is based on the value definition from the customer’s viewpoint, by eliminating every use of resources that is wasteful or that does not contribute to the value goal.

Project procedure follows the general A3 sections (A3 is one of the most famous lean tool). They outline the chapters of this thesis.

Sisme GM 605-line is affected by high downtimes, 9734 minutes (in the period taken as a case study, from June 2019 until now). Downtimes are mainly caused by: maintenance & fault interventions, set up and technical problems.

The first weeks focussed on daily production routine observation and then on the data collection/elaboration phase.
This was fundamental for the following root-cause analysis step, aimed in the identification of the root-causes of the problem, on which the countermeasures will act. Countermeasures development phase was supported by a cost-benefit analysis. It was used as a countermeasures’ “feasibility” dashboard, highlighting hypothetical not convenient scenarios. Once countermeasures were developed and implemented, the last step concerns the monitor of the results. In this phase the verification of the project‘s target achievement is carried out.

This document does not contain classified information

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Executive Summary

1.1. Company Overview

Sisme S.p.A. is a manufacturing electric motor Company composed by three implants located in Italy, China, and Slovakia and more than 700 employees. Around 3 million of motors are worked every year, they are divided in four macro-categories: rotostators, air handling, water handling and automotive. The Company's mission is to satisfy the customer with excellent products, embracing modern production methodologies of "lean" and "zero waste".

1.2. The problem

Project's "philosophy" and procedure comes from the "lean" approach. Lean is the concept of efficient manufacturing/operations that grew out from the Toyota Production System. It consists in the value definition from the customer's viewpoint, by eliminating every use of resources that is wasteful or that does not contribute to the value goal.

In order to implement the "lean", several tools can be used. One of the most famous is the A3 framework. The different A3 sections correspond with the procedure followed during the project and outline the main chapter of this thesis.

605-line is affected by high downtimes, 9734 minutes. The period considered goes from June 2019 until now. Downtimes are mainly caused by: maintenance & fault interventions (4813 minutes), set up (3655 minutes) and technical problems (1165 minutes).

Maintenance & fault macro-item can be divided in: mechanic interventions (70%) and electric interventions (30%).

The current situation shows that sometimes mechanics are forced to manage different activities at the same time, so, one of the two must be postponed.

Electric operators walk the way from their HQ to the 605-line two or three times in order to get instruments necessary for the intervention.

Some set up activities are NVA. They are six quality checks (six out of twenty-three in the check list).

Most of the relevant set up information are written on paper and, in addition, there could be paper document out-of-date.

The set up scheduling is not optimized. For the "heavier" 605-line products, B13421 (8125 units produced) 52% set up are carried out with non-compatible products.

OEE related to the current situation is 88,7%. The availability is equal to 92,5%.

1.3. The goal

Project goal considers two different benefits: time and operational.

The first is related to the downtime reduction. The "must have" target imposes the achievement of 94% availability ("nice to have" 95%) reducing the impactful items up to 15%. The second regards the NVA activities reduction from 26% to 13% in the "must have" scenario, 0% in the "nice to have".

1.4. The analysis

The root-cause analysis highlights five main causes: human errors, time wasted in electric interventions, mechanic interventions and set up overlapped, NVA quality checks and a not optimal set up scheduling.

Human errors are caused by transcription/reading mistakes, related to the paper module called "Modulo di segnalazione cambio macchina" and out-of-date document (as for example the "Istruzioni di lavoro").

Time wasted in electric interventions is represented by the travel time from the electric maintenance HQ to the 605-line. There is not the material necessary for the intervention on site, so, the operators must retrieve it from the HQ.

For each batch, there is 50% probability that a mechanic intervention and a set up overlap. The impact on downtimes is dramatic because the mechanic is forced to postpone one of the two activities. This situation resulted from a progressive batch sizing reduction process. The Sales department has the duty to satisfy most of the customer needs. It is a Company corporate strategic decision.

Another Company decision defines quality as the most important KPI. This led the introduction of some excessive and redundant NVA quality checks.

The set up scheduling is not optimized. The MRP generates a production plan bound to the orders shipping dates. The planner carries out some switches considering other client constraints. No one evaluates parameters related to the production.

The Heijunka box countermeasure is designed for the human errors elimination. It cost 500 € and the implementation time is 5/10 hours. The potential annual economical saving is equal to 1500 €.

A tool-holder with the basic instrument for the most frequent electric interventions could solve the time wasted problem. The price for the tool-holder is 300 € and the countermeasure implementation time is 5 hours. It allows an annual economical saving equal to 1620 €.

Self-control process aims to reduce the overlap time and to eliminate the NVA quality checks. Time for the implementation is esteemed equal to 30 hours and it is related to an 11100 € annual saving.

The set up scheduling algorithm output is the production plan that minimize the total set up time and the number of machine set up interventions. Realization costs 40 hours and 3000 €, but the economical saving associated is equal to 23689 €.

1.5. The results

Considering the period between the 16th and the 27th of November (first two weeks in which countermeasures were applied) the “605-line Master file” highlight the availability increase (94,14%). “Must have” target is achieved. Unfortunately, time was non-sufficient to implement the set up scheduler, otherwise the simulation carried out proves the “nice to have” could be reachable.

NVA quality checks have been removed from the quality check list. So, the “nice to have” operational target is achieved.

Long-term objective of the project consists in the application of the procedure also for lines similar to the 605. 695-line is analogue. Most of the countermeasures were designed in a parametrizable way. They can be applied to different lines modifying the parameters considered, but the same basic countermeasures structure remains unchanged.

Introduction

2.1. Company Overview

Sisme S.p.A. is an Italian manufacturing electric motors Company since 1957. The headquarter is a 25.000 mq implant located in Olgiate Comasco (CO). The Olgiate Comasco plant is the nerve center of the Sisme's production activities, where the R&D, S&OP, Purchasing, IT, Sales and Quality departments are sited. Sisme group is also composed by other two productions sites located in China and Slovakia for a total amount of 700 employees and more than three million of items produced every year.

Sisme's range of product is divided in four categories:

- **Rotostators (Hermetic, semi-hermetic and LSPM/IPM)**
  Sisme's rotostators are 2/4 pole with different sizes and dimensions. Rotostators applications go from the industrial and domestic refrigeration to the air conditioning and the power generation. The most important specifications are: stack length (mm), nominal power (kW), voltage (V), frequency (Hz), torque (NM), efficiency (%), PF, current (A), LRA (A).

Figure 1 – Rotostator

- **Air handling (Cassettes, fan coil kitchen hoods and ovens)**
  They are asynchronous and brushless motors with high energy efficiency and low consumption. Air handling systems main features are: programmable electronic board, low noise and vibration, the possibility of combining motors with fans of different diameters and sizes and the power output between 20 and 300 Watt. Air handling applications go from the fan coil units to indoor and air conditioners.

Figure 2 – Fan coil

- **Water handling (Dishwasher motor pumps and rotary vane pumps)**
  Characteristics of Sisme's dishwasher motor pumps are: extreme compactness and solidity, high efficiency (class A++), integrated heating element, 360 mBar pressure and 50 L/min flow rate. They are suitable for both domestic and professional dishwashers. Rotary vane pumps are asynchronous and brushless motors for rotary vane pumps. Possible applications go from the professional coffee machines to drink dispensers.

Figure 3 – Motor pump

- **Automotive (Powertrain and other auxiliary devices)**
  Sisme offers a range of services aimed to develop innovative solutions to meet the challenge of electrification, both in terms of power applications (powertrain) and auxiliary devices**.** Powertrains find a correspondence in Sisme's skills developed in designing and producing rotostators for powers ratings up to 60 kW. For the other auxiliary devices Sisme draws on its experience for a wide range of motors in the air handling and pumps drives field.

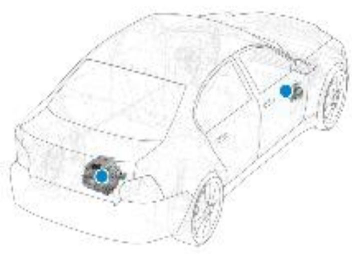


Figure 4 – Powertrain and other devices

The Company's mission is to satisfy the customer with excellent products, using modern technologies and procedures, reducing the impact on the environment. The vision is in line with current global policies on energy efficiency in which product sustainability have acquired fundamental importance.
Technological knowledge regarding manufacturing processes allows Sisme to display its value by integrating new methods of production and organization, embracing "lean" and "zero waste" concepts.

2.2. The Project Philosophy & Procedure

“Lean thinking for downtime reduction. Case study: Sisme S.p.A.”. This is the thesis title, the applied philosophy of the “lean” approach immediately stands out.

Lean is the concept of efficient manufacturing/operations that grew out from the Toyota Production System in the middle of the 20th century. It is based on the philosophy of defining value from the customer’s viewpoint, continually improving the way in which value is delivered, by eliminating every use of resources that is wasteful or that does not contribute to the value goal.

The Toyota Production System (TPS) was established based on two main pillars: Jidoka and Just-in-Time. The first can be loosely translated as “automation with a human touch” which means that, when a problem occurs, the equipment stops immediately preventing defective products from being produced. The second stands for making only what is needed. “The right part, at the right time, in the right amount”.

These two pillars are based on three important prerequisites:

- Standardization of the work
  All the operations should carry out in the same way (create a procedure, follow a protocol).
- Kaizen
  It stands for continuous improvement.
- Heijuknka
  Production levelling in order to balance the work content over time.

A lot of western companies have tried to imitate the TPS. Some frameworks have been developed to support the transition to the lean approach. A first framework includes:

- Flow

  Value should be added in a smooth, uninterrupted flow.
- Pace (or takt)

  Pace refers to the production rhythm guided by the customer demand.
- Pull

  Avoid overproduction and stockpiling.
- Zero defect

  Identifying errors and defects promptly, in a precise manner. It is important categorized between errors in order to do not commit them anymore.

A second important framework consist in five principles depicted by J.P. Womak and D.T. Jones in their book “Lean Thinking”:

- Identify value

  Benefits sought by the customers.
- Map the value stream

  Map the stream through which the value is created.
- Create Flow

  Make it not stop.
- Establish pull

  Let customer “pull” the demand.
- Seek the perfection

  Pursue perfection in activities, processes and products.

In order to put the lean concept into practice several tools can be used. One of the most famous is the A3 framework.

As mentioned in: “Understanding A3 thinking (a critical component of Toyota’s PDCA Management system)” a book written by Durward K. Sobek II and Art Smalley, the A3 can be seen at two different perspectives: a tool supporting problem setting and problem solving and a managerial approach to foster and develop a continuous improvement culture.

It is based on the Deming Cycle, a process method composed by four main activities: Plan (P), Do (D), Check (C), Act (A).

In detail A3 sections are:

- P
  - Problem background (Why are we talking about it?)
  - Problem background – Current situation (Where do we stand?)
  - Target (Where do we need to be?)
  - Root Cause analysis (What are the root causes of the problem?)
  - Develop Countermeasures (What are the proposed countermeasures?)
- D
  - Implement countermeasures (What is the action plan?)
- C
  - Monitor results (How can I check the results? How can I validate the project success?)
- A
  - Standardize & share success (Can I replicate the procedure?)

The different sections of the A3 framework correspond with the procedure I followed during the project and outline the main chapter of my thesis.

Problem Background

The first step of the A3 framework has the purpose to answer the question: "Why are we talking about it?"

The first day in Sisme the head operations showed me the line I would have work on, the GM 605-line. This line is also identified with the abbreviation "190-198" because it produces stators with a diameter of 190 and 198 millimetres.

The company's goal was clearly communicated from the beginning: "lean thinking application for downtimes reduction". Downtimes correspond to any moment in which the line is stopped (in the time available).

From the data referred to the production, taking on as a case study the period from June 2019 to September 2020, it was evident that high downtimes were the main problem of the line. In the above-mentioned period, the GM 605-line was affected by 9734 downtime minutes.

MODELLO	ARTICOLO	DATA	Ta	UPTIME	DOWNTIME	VOLUME (OUTPUT)	Manutenzione Guasti	Set Up	Problemi Tecnici
49139050000	B13905	03/06/2019	60	60	0	31	0	0	0
49126120000	B12612	03/06/2019	180	170	10	81	0	10	0
49126120000	B12612	03/06/2019	120	120	0	57	0	0	0
49129840020	B12984/20	03/06/2019	120	110	10	69	0	10	0
49128760000	B12876	04/06/2019	240	215	25	108	15	10	0
49140920000	B14092	04/06/2019	240	130	110	36	0	20	90
49141550000	B14155	05/06/2019	60	30	30	11	0	0	30
49141520000	B14152	05/06/2019	60	30	30	11	0	0	30
49141530000	B14153	05/06/2019	60	30	30	11	0	0	30
49128740000	B12874	05/06/2019	90	90	0	35	0	0	0
49131880000	B13188	05/06/2019	90	90	0	36	0	0	0
49133300000	B13330	05/06/2019	60	50	10	36	0	10	0
49133300000	B13330	06/06/2019	120	100	20	73	0	0	20
49129120020	B12912/20	06/06/2019	120	110	10	72	0	10	0
49125590010	B12559/10	06/06/2019	120	105	15	70	0	15	0
49125590010	B12559/10	07/06/2019	60	60	0	21	0	0	0
49131230000	B13123	07/06/2019	390	370	20	160	0	20	0
...	...	...	...	...	...	...	...	...	...

Table 1 – 605-Line Master file

This Excel table is a reduced extract of the "605-line Master file". It is a file that I built combining 605-line data from different sources.

The Master file is composed by all the batches produced. Each item is listed and characterized by the most important production parameters: Modello, Articolo, Nome, Famiglia, Cliente, Data, Volume (Output), Input, Pezzi buoni, Pezzi riparati, Pezzi smantellati, Quantità fatturata, Fatturato, Margine, Cadenza teorica, Persone a ciclo, Persone utilizzate, Cadenza reale, Disponibilità, Uptime, Downtime, Capacità teorica, Capacità reale, Manutenzione & Guasti, Set Up, Problemi tecnici, Numero di Set Up, Note. All the data that will be shown in this thesis are referred to the Master file.

Line downtimes are mainly caused by three items: maintenance & fault interventions, set up (activities and scheduling) and technical problems. Maintenance & fault interventions are esteemed equal to 4813 min (4,5% of the time available) set up 3655 min (2,7% of the time available) and technical problems are 1165 min (0,9% of the time available). Maintenance & fault intervention consists in all the micro and macro stoppages caused by scheduled maintenance interventions, but also unexpected and unprogrammed failures.

Set up are divided in activities and scheduling because they are two distinct concepts with two different downtime weights. Set up activities impact on downtimes due to their processing time. Set up scheduling is referred to the production plan. There are products that require a lot of set up interventions because they differ considerably from the product that precedes them. On the contrary, there are other products more similar where set up is almost null or takes only few minutes.

Technical problems correspond to human errors, blackouts, strikes and other similar production stoppages.

MAINTENANCE & FAULT INTERVENTIONS	SET UP	TECHNICAL PROBLEMS
4.5 %	2.7 %	0,9 %
Of the Time available	Of the Time available	Of the Time avilable

Figure 5 – Problem background synthesis

Problem Breakdown

4.1. GM-605 Line

Rotostators are electric motors formed by two main components: the rotor and the stator. The rotor turns inside the stator thanks to the interaction between two magnetic field. The first, generated by the electric current in the stator's copper wires and the second generated by the rotor.

Rotors and stators are produced separately. The GM-605 line produces stators with diameters of 190 and 198 millimetres.

The GM-605 line is quite complex. It consists in some automatic processing machines (such as Statomat winding machines) and manual stations (there are 27 stations).

The image below shows the line layout.

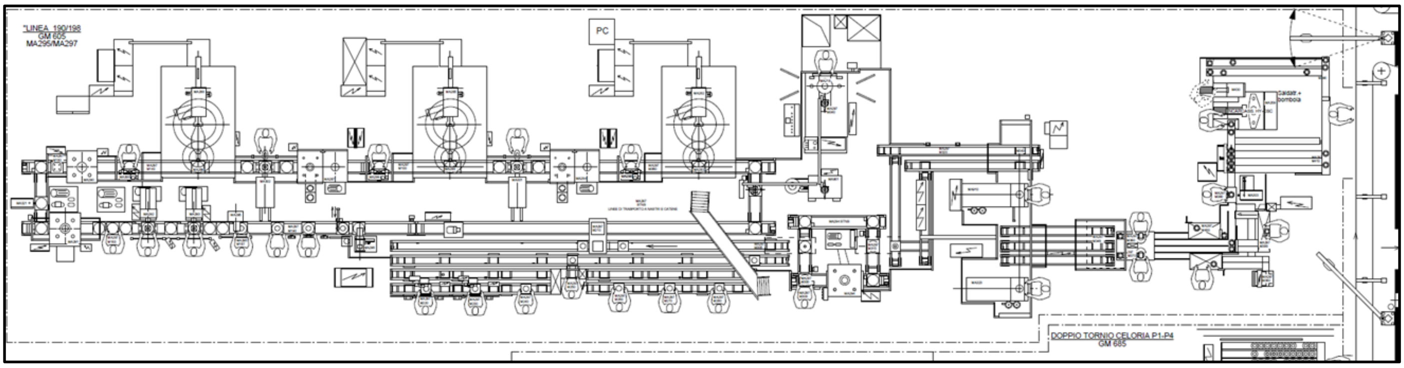


Figure 6 – 605-line layout

The production process is divided in steps (or phases). In details below a deeper analysis of the different production steps**:**

- **Step 10 | Steel sheet package preparation**
  In this phase an operator stacks the steel sheets on top of each other and prepares them to be placed in the stapling machine. The pack height check is very important in this phase. A weighing machine converts the weight of the pack into the exact number of sheets that should be stapled.


- **Step 20 | Pack insulation**
  The pack must be properly insulated. The copper wires must not to be in contact with the pack, otherwise the current disperses. The Myler insulation is placed inside the pack through an automatic processing machine.
- **Step 30 | 1° layer winding**
  The winding of the first skein of copper is performed by the first Statomat machine. The machine takes the copper from a barrel previously positioned on the line. Each copper wire is identified by a pair of values corresponding to the wire diameter and the number of sections.
- **Step 40 | Stripping, straws assembling and 1° layer arrangement**
  This phase corresponds to the station number two, where the operator's task consists in stripping the ends of the copper wires (where the crimping with the power supply unit will be placed). Then, the insulating straws are positioned and, finally, the assembly must be correctly arranged.
- **Step 50 | 1° layer punching and spreading**
  In this phase the stator passes through an automatic processing machine in which the skein is pierced and widened.
- **Step 60 | H-insulations of the 1° layer**
  Also in this case the copper wires must be properly insulated. For this reason, special H-shaped insulators are placed on the stator.
- **Step 70 | 2° layer winding**
  Rotostators produced by Sisme are three-phase, for this reason there are three copper skeins that must be wound on the stator.
- **Step 80 | Stripping, straws assembling and 2° layer arrangement**
  Same of step 40.
- **Step 90 | 2° layer punching and spreading**
- Same of step 50.
- **Step 100 | H-insulations of the 2° layer**
  Same of step 60.
- **Step 110 | 3° layer winding**
  Same of step 30 and 70.

- **Step 120 | Stripping, straws assembling and 3° layer arrangement**
  Same of step 40 and 80.
- **Step 130 | 3° layer punching**
  Same of step 50 and 90 excepts for spreading. The 3° copper skein is the last one, so, the stator must not be widened in this phase.
- **Step 140 | Pallet rotation**
  Pallets on which stator are placed are 180° rotated.
- **Step 160 | Pressing for initial forming**
  The shape of the stators' skein must be within the limits imposed by the design drawings. For this reason, the stators are pressed.
- **Step 190 | Thermistor Crimping**
  In this phase three operators in three different stations have to crimp the thermistors on the stator. Thermistors function is to protect the stator from overload.
- **Step 210 | Customer Code stamp at the top of the package**
  Each stator is identified by the customer code. It is printed on the top of the pack.
- **Step 219 | Connection Crimping and arrangement**
  At this stage, two operators in two different stations have to crimp the connection unit. Once the various parts are placed, the assembly must be correctly arranged and positioned.
- **Step 250 | Caps positioning**
  At this stage, three operators in three different stations are responsible for the insulation caps positioning.
- **Step 255 | DataMatrix marking**
  The stator is marked by a DataMatrix, a code that will allow the customer to uniquely identify the product.
- **Step 260 | Pressing for final forming**
  As for step 160, also in 260 the product is pressed in order to get the correct shape.
- **Stage 280 | Sewing**
  At this step, a sewing machine binds the stator through a string to fix all the components.

- **Step 300 | Electrical tests**
  The electrical tests are necessary to evaluate the conformability of each stator. Tests are responsibility of the quality control department.
- **Step 340 | Case welding**
  At this step, only for 198 diameter models, a case is welded around the stator.

Two more step should be considered. The first, concerns the repair station, where stators with repairable processing defects are reworked. The second, concerns a station where an operator carries out targeted tests in order to determine the conformity of each product.

At the end of the 605-Line production cycle, stators are hooked on a conveyor that will bring them to the impregnation tanks. Once impregnated, they undergo a second processing cycle through the 606-line. Then, products are finally ready for the shipment.

4.2. VSM

The Value Stream Map is a visual Lean Tool useful for mapping all the product process step from the raw material procurement to the final customer shipment.

As mentioned in: “Value Stream Mapping: A method that makes the waste in the process visible” a book written by Nuri Ozgur Dogan and Burcu Simsek Yagli, two type of flow are highlighted: the material flow and the information flow. All the events and the activities in the VSM must be correctly time-placed (into the Timeline). Each station is characterized by different parameters: Number of operators, Cycle time, Change-Over time and availability.

Due to the complexity of the 605-Line during the first week I decided to map the process through the VSM following the most produced stator, the Performer Danfoss (49134210000, B13421).

In the tables below are listed the most important VSM parameters.

MODELLO	49134210000
NOME	DANFOSS STAT.198 2P 142 PERF.1 DA IMPR.
DEMAND [u/d]	30
Ta [min/d]	250
shift [d]	1 shift f 8 h
Supp. Forecast [d]	30/60
Supp. Orders	Weekly orders
Supp. Delivery	Weekly
Client Forecast [d]	30/60/90
Client Orders	Weekly orders
Client Delivery	Weekly
Machine Plan	Once every two weeks

FASE	DESCR.	MACCHINA	CT [s]	CO [min]	A	Stock
10	Preparazione pacco (Postazione 1)	218	60	8	92,5%	30
20	Isolamento del copro centrale	901	30	5	92,5%	3
30	Bobinatura/inserimento 1°strato	282 & 283	30	4	92,5%	5
40	Spelatura,montaggio cannucce e sist.capi 1° strato (Postaizone 2)	298	90	1	92,5%	3
50	Bucatura e allargatura 1°strato	284	30	3	92,5%	3
60	Montaggio isolanti H 1° strato (Postaizone 3)	301	60	-	92,5%	3
70	Bobinatura/inserimento 2°strato	285 & 286	30	4	92,5%	3
80	Spelatura,montaggio cannucce e sist.capi 2° strato (Postaizone 4)	299	90	1	92,5%	3
90	Bucatura e allargatura 2°strato	287	30	3	92,5%	3
100	Montaggio isolanti H 2° strato (Postaizone 5)	302	60	2	92,5%	3
110	Bobinatura/inserimento 3°strato	288 & 289	30	4	92,5%	3
120	Spelatura,montaggio cannucce e sist.capi 3° strato (Postaizone 6)	300	90	1	92,5%	3
130	Bucatura 3°strato	290	30	3	92,5%	3
140	Rotazione Pallet	M160	30	0,5	92,5%	5
160	Pressatura per formatura matasse	291	30	12	92,5%	5
190	Agraffatura termistori (Postazioni 7, 8 e 9)	295	90	3.5	92,5%	10
210	Timbratura codice cliente in testa pacco	296	30	0,5	92,5%	3
219	Agraffatura connessioni (Postaizoni 10 e 11)	M220 & M230	60	9	92,5%	5
255	Sistemazione gruppo conduttori e marcatura cluster (Postazioni 13, 14, 15 e 16)	MA1365	60	2	92,5%	5
260	Pressatura di formatura finale	294 & 297	30	12	92,5%	10
280	Cucitura matasse (Postazione 17 e 18)	323 & 910	60	15	92,5%	5
300	Collaudo elettrico e timbratura finale (Postazione 19)	303	60	0,5	92,5%	5
340	Incarcassamento e saldatura carcassa (Postazione 20)	209	90	22	92,5%	5

Tables 2 and 3 – VSM data

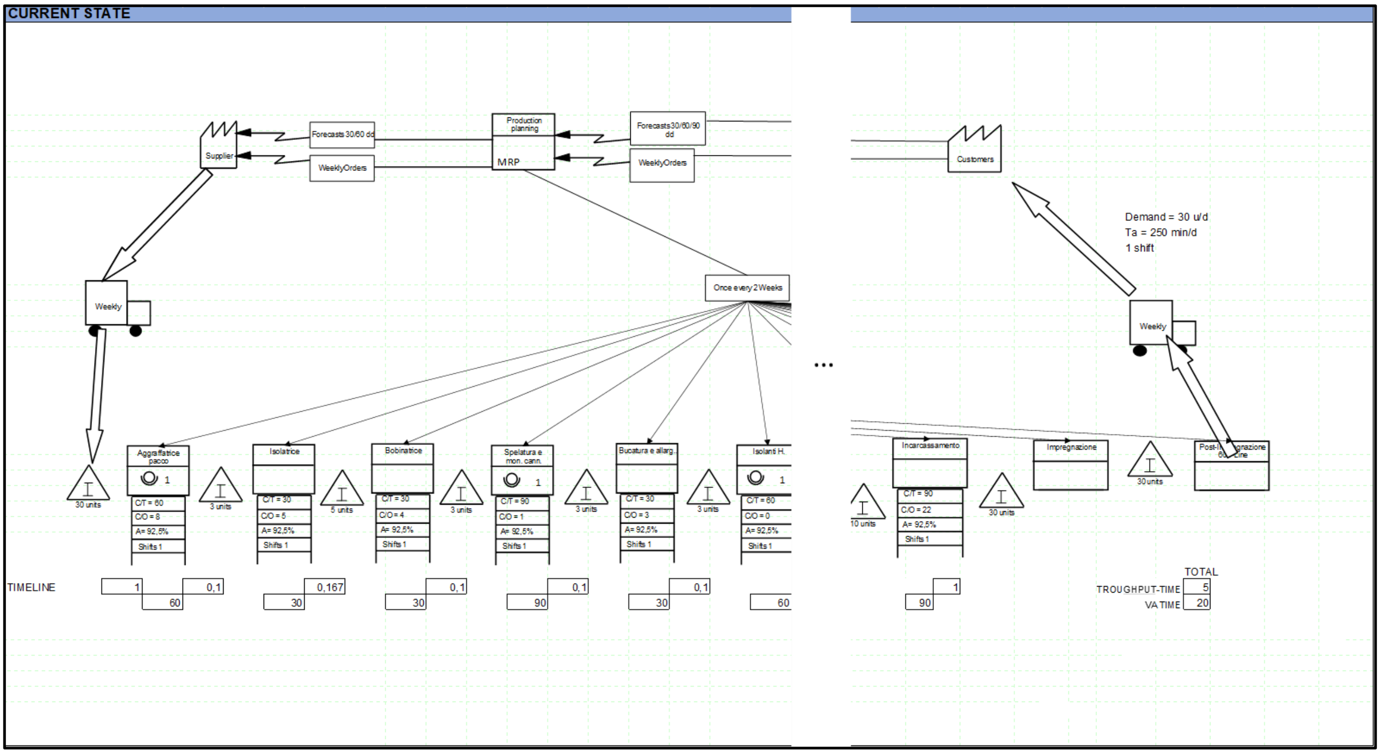


Figure 7 – 605-line VSM

The figure above represents the 605-Line VSM.

In order to make the image readable the central part is cut. The full version is in the attachments. However, from this version is possible extract some information: the throughput time is 5 days and the VA (Value-Added) time is 20 mins.

4.3. Observation, data collection & data analysis

"Downtimes are mainly caused by maintenance & fault interventions, set up and technical problems" but "Where do we stand?". This is the "problem breakdown" question.

The first weeks focussed on daily production routine observation and then on the data collection/elaboration phase.

I tried to go deeper within the three macro issues of maintenance & fault, set up and technical problems.

For what concern the maintenance & fault interventions, it is important to discriminate between micro and macro stoppages. Micro-stoppages impact for less than 15 min on downtimes. All the other interventions are macro-stoppages. The average time for a maintenance & fault intervention is 22 minutes.

MODELLO	ARTICOLO	NOME	DATA	Manutenzione Guasti [min]	Micro/Macro	NOTE
49128760000	B12876	ST.BTZ 198 DA IMPREGNARE	04/06/2019	15	Microfermata	\
49135260000	B13526	DANFOSS STAT.198 2P 129 PERF.1 DA IMPR.	10/06/2019	45	Macrofermata	\
49139090000	B13909	EMERSON STAT.190 2P 160 LCS	12/06/2019	5	Microfermata	\
49116530020	B11653/20	DANFOSS STAT.190 DA IMPR.	12/06/2019	20	Macrofermata	\
49126080000	B12608	EMERSON STAT.190 2P 129 SPECTER DA IMPR	17/06/2019	5	Microfermata	\
49139050000	B13905	EMERSON STAT.190 2P 142 LCS DA IMPR.	17/06/2019	20	Macrofermata	\
49139050000	B13905	EMERSON STAT.190 2P 142 LCS DA IMPR.	18/06/2019	10	Microfermata	\
49139090000	B13909	EMERSON STAT.190 2P 160 LCS	20/06/2019	5	Microfermata	RIPRISTINO AGGR. PACCHI
…	…	…	…	…	…	…

Table 4 – Maintenance & fault data

In the period considered, 217 maintenance & fault intervention were carried out. 44% are macro-stoppages, 56% micro-stoppages.

In the table below are listed the most frequent micro-stoppages. They came from the observation phase taken during the first weeks and from maintenance operators' interviews.

Microfermate			
Intervento	**Responsabilità**	**Frequenza**	**Tempo [min]**
Cambio Profibas	Operatore elettrico	2/3 volte al giorno	Variabile
Ripristino macchina	Operatore meccanico o elettrico	1 volta al giorno	3
Sostituzione di un sensore Micro	Operatore elettrico	1 volta a settimana	Variabile
Sbloccaggio isolatrice	Operatore meccanico	1 volta a settimana	10
Riparazione di un tubo dell'aria	Operatore meccanico	1 volta a settimana	10
Cambio di un mandrino	Operatore meccanico	2 volte a settimana	5
Sostituzione componenti macchina rotti	Operatore meccanico o elettrico	1 volta al mese	Variabile

Table 5 – Frequent maint. intervention

Four out of seven of the most frequent interventions are electric maintenance interventions (highlighted in yellow).

Following some of these interventions emerged that the electric maintenance Head Quarter is located far away from the 605-line.

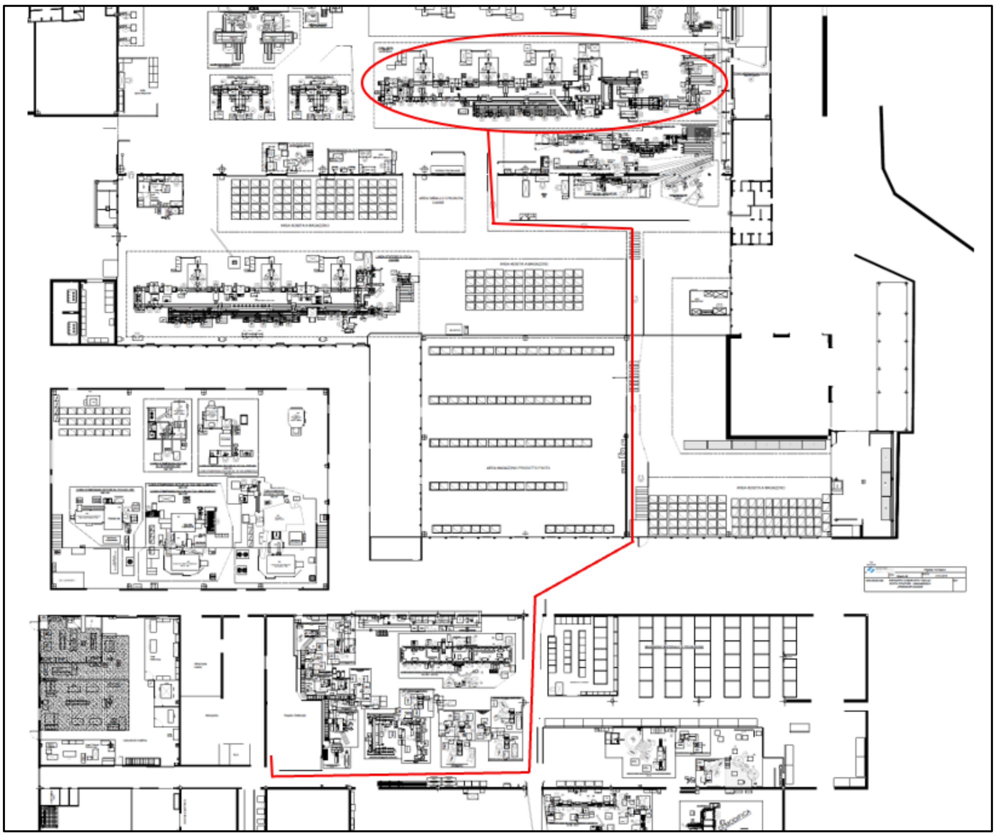


Figure 8 – El. maint. HQ to 605-line way

This figure illustrates the way from the electric maintenance HQ and the 605-line (highlighted in red).

On average for each interventions an electric operator has to walk this way two or three times in order to get some instruments from the HQ with a wasted travel time that can be up to 8 minutes in some cases.

Also observing and interviewing the mechanical operators during their daily work something interesting emerged. Sometimes they must manage multiple and contemporaneous activities. When these situations happen, the mechanic tries to ask the collaboration of a co-worker, but this is not always possible. Therefore, they are often forced to choose the most urgent activities and postponed the other one with a consequent dramatic impact on downtimes. (One of the clearest examples is the case in which a mechanic is working on a fault, but in that moment also a Set Up should be done).

605-line set up activities are carried out by three figures: the mechanic, the quality control specialist and the line-operators (in collaboration with the line-supervisor). In the table below, all the set up activities are listed. Each one is characterized by the correspondent processing time.

Fase	Descrizione Fase	Operazione	Tempo [min]
10	Preparazione pacco	Impostazione altezza sulla macchina	1
		Verifica dei parametri impostati in aggraffatrice pacco	0,5
		Cambiare campana, piattello e pinze	7
20	Isolamento pacco	Cambiare il Mylar	6
30	Bobinatura 1° strato	Impostazione prg. Winder e prg. RWE	1
		Impostazione altezza sulla macchina	0,5
		Sistemazione del fusto di rame	2
		Controllare che il rame corrisponda a quello previsto e controllo dei param. bobinatrice	1
40	Spelatura,montaggio cannucce e sist.capi 1° strato	Impostazione prg. Spelatura	0,5
		Impostazione prg. Sollevatore	0,5
		Verifica dello stato di usura di spazzole e matasse (assenza di graffi e incisioni)	1,5
		Cambio periodico delle spazzole	2
50	Bucatura e allargatura 1°strato	Cambiare il puntale del bucatore. L'allargatore non cambia mai	3
60	Montaggio isolanti H 1° strato	Controllo visuale dello statore e del suo corretto isolamento	1
70	Bobinatura 2° strato	Impostazione prg. Winder e prg. RWE	1
		Impostazione altezza sulla macchina	0,5
		Sistemazione del fusto di rame	2
		Controllare che il rame corrisponda a quello previsto e controllo dei param. bobinatrice	1
80	Spelatura,montaggio cannucce e sist.capi 2° strato	Impostazione prg. Spelatura	0,5
		Impostazione prg. Sollevatore	0,5
90	Bucatura e allargatura 2°strato	Cambiare il puntale del bucatore. L'allargatore non cambia mai	3
100	Montaggio isolanti H 2° strato	Montare l'anello (se H pacco>160)	2
110	Bobinatura 3° strato	Impostazione prg. Winder e prg. RWE	1
		Impostazione altezza sulla macchina	0,5
		Sistemazione del fusto di rame	2
		Controllare che il rame corrisponda a quello previsto e controllo dei param. bobinatrice	1
120	Spelatura,montaggio cannucce e sist.capi 3° strato	Impostazione prg. Spelatura	0,5
		Impostazione prg. Sollevatore	0,5
130	Bucatura 3°strato	Cambiare il puntale del bucatore	3
140	Rotazione Pallet	Impostare il selettore su "INCLUSA" o "ESCLUSA"	0,5
160	Pressatura per formatura matasse	Cambiare del piattello superiore	5
		Regolazione della pressata superiore	1
		Cambiare del piattello inferiore	5
		Regolazione della pressata inferiore	1
190	Aggraffatura termistori	Misura delle resistenze, altezza pacco e quote Flat. Controllo visuale	7
		Impostare il selettore su "INCLUSA" o "ESCLUSA"	0,5
		Cambio delle graffette	3
		Verifica del posizionam. dei termistori rispetto al disegno	1
		Verifica dell'altezza delle graffette	2
		Prove di trazione	1
210	Timbratura codice cliente in testa pacco	Impostare il selettore su "INCLUSA" o "ESCLUSA"	0,5
		Controllo timbratura	0,5
219	Aggraffatura connessioni	Impostare il prg. Aggraffatrice	1
		Verifica dei parametri impostati in aggraffatrice	0,5
		Controllo altezza graff. e assenza di bave	1
		Prova di trazione manuale	1
		In base all'accoppiamento Grnd. Attrezz. - Svil. Graff. devono essere cambiate le componenti	8
250	Sistemazione gruppo conduttori	Sistemazione del gruppo conduttori	1
		Verifica posizionamento cappucci	0,5
		Controllo posizione protettore, uscita conduttori e loro lunghezza	1
255	Marcatura cluster	Impostare il prg. Marcatura	0,5
		Verifica Set Up dell'apparecchiatura e posizione Data Matrix	1
		Sostituzione del blocchetto	2
260	Pressatura di formatura finale	Cambiare del piattello superiore	5
		Regolazione della pressata superiore	1
		Cambiare del piattello inferiore	5
		Regolazione della pressata inferiore	1
		Tassello "SI" o "NO"	0,5
		Posizionamento selettore in base al diametro del lamierino	0,5
280	Cucitura matasse	Impostazione del prg. della cucitrice	1
		Impostazione dell'altezza	0,5
		Cambiare tasselli dei Flat sulla base del diametro	5
		Sostituzione spago in base all'altezza	8
295	Inserimento dei faston sul protettore	Verifica del corretto inserimento dei faston sul protettore	1
300	Collaudo elettrico e timbratura finale	Timbratura "INCLUSA" o "ESCLUSA"	0,5
		Controllo timbratura	0,5
		Verifica dei parametri in A3 e del circuito terra/presenza pezzo	1
340	Incarcassamento e saldatura carcassa (solo per 198)	Impostazione del prg. Dell'incarcassatrice	1
		Cambiare i distanziali di callettamento	7
		Cambiare i distanziali di saldatura	5
		Cambiare la chiavetta	3
		Cambiare il perno di saldatura	4
		Cambiare la campana di protezione	2
		Verifica di codice carcassa, quota incarcassamento e posizione saldature	1
		Controllo visuale generale & Controllo posizione protettore, uscita conduttori e loro lunghezza	1

Table 6 – Set up activities


The activities highlighted in grey are responsibility of the mechanic, the green ones are the quality checks and the blue ones are the line operator tasks. White activities are the easiest, they can be carried out by anyone.

MECC
QUAL
LINE OP
EXTREM. EASY

Table 8 – Set up act resp.

These activities can be divided into: value added activities and non-value added activities. The firsts are those the customer is willing to pay for. The second ones are those that do not contribute to the value recognised by the customer. They represent opportunities for time-cost reduction. Non-value added activities can be further distinguished in: non-value added activities unavoidable in the short term and non-value added activities avoidable in the short term. The non-value added activities avoidable in the short term are the ones highlighted in red below. They are all quality checks, six out of twenty-three activities in the quality check list (26%). If there is the possibility to avoid them in the short term, the Company must consider these activities just as a waste. According to the Ohno subdivision, seven different types of wastes exist (TIMWOOD) and they are: transportation, inventory, movement, waiting, overproduction, overprocessing and defect. In 605-Line all the six activities considered as NVA are affected by waiting and overprocessing. Waiting is referred to the waiting time of pieces to be processed and, in this case, the six checks increase downtimes. They are also overprocessed. Overprocessing is everything that exceed the essential.

Verifica dei parametri impostati in macchina aggraffatura pacchi
Verifica dei parametri impostati in 1° bobinatrice (n° spire, codice modello), Ø filo rame e n° sezioni, presenza marchio "G2"
Verifica dei parametri impostati in 2° bobinatrice (n° spire, codice modello), Ø filo rame e n° sezioni, presenza marchio "G2"
Verifica dei parametri impostati in 3° bobinatrice (n° spire, codice modello), Ø filo rame e n° sezioni, presenza marchio "G2"
Controllo timbratura codice compressore (dove previsto)
Verifica dei parametri impostati in aggraffatrice

Table 8 – NVA quality checks

The number of set up of related to a specific product in a year depend on its production volume. In order to prioritize the actions, a Pareto analysis can be carried out. The Pareto analysis is a useful tool based on the ABC clusters. Cluster A products have a cumulated percentage on volume lower than the 90%. B products are between the 90% and the 95% and C are the remaining. This type of analysis is called "Pareto analysis" because follows the 80-20 Pareto principle: "for many outcomes, roughly 80% of consequences come from 20%".

A	26	Da 8175 a 840 u
B	8	Da 791 a 287 u
C	21	Da 269 a 60 u
C-	25	Da 54 a 5 u

Table 9 – ABC clusters

In addition to the usual clusters, I added the C-. C- cluster has a percentage cumulated over the 99%. It was necessary to add this cluster because 25 out of 80 are C- product with less of 54 unites produced.

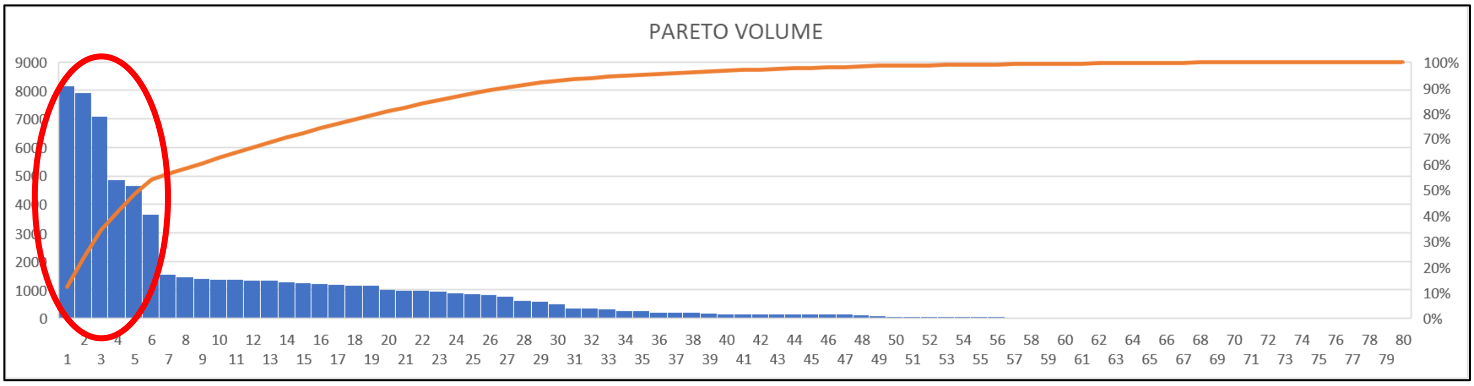


Table 10 – Pareto chart

The first six products are the most produced by Sisme, the ones with the highest production volume (within the red circle in the Pareto chart). Those six products cover the majority of Sisme's production (more than the 50%).

ORDINE	MODELLO	VOLUME (OUTPUT)	%	% CUM	ABC
1	49134210000	8175	12,13%	12,13%	A
2	49139090000	7927	11,76%	23,89%	A
3	49139050000	7104	10,54%	34,43%	A
4	49141560000	4858	7,21%	41,64%	A
5	49126070000	4659	6,91%	48,55%	A
6	49126120000	3648	5,41%	53,97%	A

Table 11 – "Heavier" products

B13421 is the most "heavier" 605-Line product, with 8175 units manufactured in the period considered. It is a Performer Danfoss.

The average Set Up time for this product is 7,97 minutes. Discussing with the head of operations, the line-supervisor and other planning department employees, we established that if a B13421 set up was longer than 10 minutes, it was combined with non-compatible product ("NOK set up"). NOK set up occurs between two very different products, for which a lot of set up machine interventions are needed.

MODELLO	ARTICOLO	DATA	COMPATIBILITA'	Set Up
49134210000	B13421	10/06/2019	NOK	10
49134210000	B13421	21/06/2019	NOK	10
49134210000	B13421	01/07/2019	NOK	10
49134210000	B13421	11/07/2019	OK	5
…	…	…	…	…

Table 12 – B13421 set up data

"NOK" B13421 set up are equal to 52% while "OK" are 48%. It is clear product set up scheduling is not the optimal one.

NOK	17	52%
OK	16	48%

Table 13 – "NOK" and "OK" B13421 percentage

Below, all the B13421 non-compatible products are listed.

B13526
B12736
B13407
B12315/10
B13331
B13309
B13254
B12912/20
B11671/20
B13909
B12734
B11869/10
B14153

Table 13 – Non-compatible B13421 products

The same analysis is carried out also for the other five products showed in table 11. The result are summarized in the Excel tables below.

B13909

ARTICOLO	DATA	COMPATIBILITA'	Set Up
B13909	43627	NOK	10
B13909	43654	NOK	10
B13909	43672	OK	5
B13909	43679	OK	5
...	...	...	...

NOK	10	37%
OK	17	63%

B13910/5
B12612
B12907/20
B13331
B12607
B14156
B13175
B14153

AVG Time
6,70

B13905

ARTICOLO	DATA	COMPATIBILITA'	Set Up
B13905	20/09/2019	OK	5
B13905	02/10/2019	NOK	10
B13905	06/11/2019	OK	5
B13905	15/11/2019	OK	5
...	...	...	...

NOK	9	39%
OK	14	61%

B12612
B12907/10
B13175
B12607
B13905
B13331
B14153

AVG Time
6,81

B14156

ARTICOLO	DATA	COMPATIBILITA'	Set Up
B14156	29/01/2020	NOK	10
B14156	14/02/2020	OK	5
B14156	04/03/2020	NOK	10
B14156	14/04/2020	NOK	10
...	...	...	...

NOK	9	75%
OK	3	25%

B13421
B13468
B13909
B12736
B14260
B14264
B12912/20

Tempo medio
9,00

B12607

ARTICOLO	DATA	COMPATIBILITA'	Set Up
B12607	43629	OK	5
B12607	43662	OK	5
B12607	43675	NOK	10
B12607	43705	NOK	10
...	...	...	...

NOK	7	27%
OK	19	73%

B13912/5
B13309
B13421
B12734
B12921
B13608
B12912/20

Tempo medio
6,46

B12612

ARTICOLO	DATA	COMPATIBILITA'	Set Up
B12612	31/08/2019	OK	5
B12612	10/09/2019	NOK	10
B12612	18/09/2019	NOK	10
B12612	09/10/2019	OK	5
...	...	...	...

NOK	7	33%
OK	14	67%

B13421
B12735
B13921
B13608
B12912/20
B13912/10

Tempo medio
6,88

Table 15 – "Heavier" prod. set up data

The situation appears slightly better than B13421, however all the products show a "NOK" percentage higher than 30%. Certainly, there is margin for improvement.

As mentioned before, in the “problem background” phase, within the technical problems item there are also downtimes related to human errors.

The 605-line routine provides the most important production parameters are written on a paper module called: “Modulo di segnalazione cambio macchina”. It is manually filled daily by the line-supervisor. This module contains information useful for both mechanics and line-operators.

During the first observation weeks, I noticed an error related to this module. It happened the line supervisor transcribed the wrong product code on the “Modulo di segnalazione cambio macchina”. Instead of “B12612”, he wrote “B11612”. Fortunately, product code “B11612” does not exist and a mechanic responsible for the set up detected the error. If the production would have started with a wrong product, when the error discovered, all process would have been stopped causing the loss of the products produced up to that moment.


sisme MODULO DI SEGNALAZIONE CAMBIO MACCHINA

Data .... Turno .... Stima orario cambio ....

Linea .... DA modello ....

A modello .... H pacco .... H mylar .... n° spire ....

Filo rame: Ø .... n° sez .... Ø .... n° sez ....

Note capo linea ....

PZ .... Firma richiedente ....

n° Ordine ....

GRAFFETTA GRANDE ☐

GRAFFETTA PICCOLA ☐

Scarto lamierini KG ....

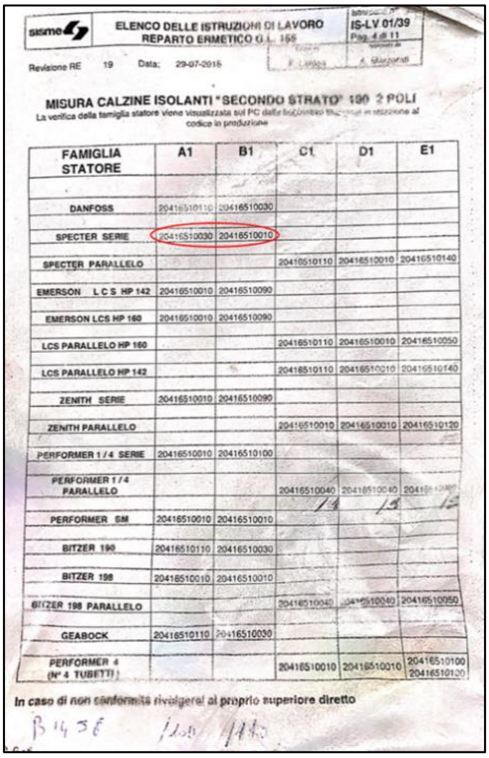
Scarto fine rocchetto Ø .... KG ....

Scarto fine rocchetto Ø .... KG ....

Scarto rame ins. KG ....

Figure 9 – “Modulo di segnalazione cambio macchina”


In addition to this module, some other set up and production parameter are contained in two documents kept on board line: “Libro macchina” and “Istruzioni di lavoro”. Also in this case, these are paper document, so, it happened that they were out-of-date. For example, the insulation straws circled in red are not the correct one.



sisme

ELENCO DELLE ISTRUZIONI DI LAVORO
REPARTO ERMETICO G.L. 155

IS-LV 01/39
Pag. 4 di 11

Revisione RE 19 Data: 29-07-2015

MISURA CALZINE ISOLANTI "SECONDO STRATO" 190 2 POLI

La verifica della famiglia statore viene visualizzata sul PC ... in relazione al codice in produzione

FAMIGLIA STATORE	A1	B1	C1	D1	E1
DANFOSS	20416510110	20416510030			
SPECTER SERIE	20416510030	20416510010			
SPECTER PARALLELO			20416510110	20416510010	20416510140
EMERSON L C S HP 142	20416510010	20416510090			
EMERSON LCS HP 160	20416510010	20416510090			
LCS PARALLELO HP 160			20416510110	20416510010	20416510050
LCS PARALLELO HP 142			20416510110	20416510010	20416510140
ZENITH SERIE	20416510010	20416510090			
ZENITH PARALLELO			20416510010	20416510010	20416510120
PERFORMER 1 / 4 SERIE	20416510010	20416510100			
PERFORMER 1 / 4 PARALLELO			20416510040	20416510040	[illegible]
PERFORMER SM	20416510010	20416510010			
BITZER 190	20416510110	20416510030			
BITZER 198	20416510010	20416510010			
BITZER 198 PARALLELO			20416510040	20416510040	20416510050
GEABOCK	20416510110	20416510030			
PERFORMER 4 (N° 4 TUBETTI)			20416510010	20416510010	20416510100 20416510120

In caso di non conformità rivolgersi al proprio superiore diretto

Figure 10 – “Istruzioni di lavoro”

Usually thanks to their work experience, line operators can avoid the out-of-date errors because they know the correct specification by heart, but due to operators different level of experience, sometimes an error occurs.

4.4. OEE (Overall Equipment Effectiveness)

One of the most used line effectiveness indicator is the OEE. The OEE is the results of three factors multiplicated: Availability, Efficiency and Quality.

The availability is computed as the ratio between the uptime and the time available. The time available is the time dedicated to the production (the 605-Line work on one shift per day).

The uptime is computed as: time available minus downtimes. The 605-Line availability is 92,5%.

Uptime = Time available - Downtime

Availability = Uptime / Time available

The efficiency stands for the performance of the line. It is computed as the ratio between the output and the theoretical capacity (in the time available). The theoretical capacity is given by the Line balance time, computed as the ratio between the number of operators in a cycle and the effective number of operators used, multiplied for the theoretical cadence of the line (1 pc/min). The 605-Line efficiency is 96,0%

*Line balance = (Op. in a cycle / Op. used) * Theor. Cadence*

Theor. Cap. = Ta / Line balance

Efficiency = Output / Theor. Cap.

Quality is computed as the ratio between the output and the input. Input includes all the stators produced, considering also reworked product and rejects. Output are good pieces and reworked. The 605-Line quality is 99,9%.

Quality = Output / Input

The OEE is equal to 88,7%.

OEE = Availability * Efficiency * Quality

Target Setting

As shown in the "problem background" Company's main goal related to the project is: 605-line downtime reduction. For this reason, the target will be set on the availability. The current situation analysis highlight that maintenance & fault interventions caused downtimes for 4813 minutes in the period considered. The objective to achieve is the reduction up to the 15%, from 4813 to 4091 min. The same for set up and technical problems. The first amount to 3655, the objective is to go from 3655 to 3107 min. the second is equal to 1165, so, we want to go from 1165 to 990. The total time savings is 1445 min and the availability should increase to 94%.

Manutenzione/Guasti	Set Up	Problemi Tecnici
4813	3655	1165

Target Manut	Target Tech. Prob	Target Set Up
4091,05	990,25	3106,75

Time saving	Target Downtime	Target Up
1444,95	8238,05	127931,95

Avaliability
93,95%

Table 16 – Availability data

This is the "must have" target. It is set in a cautious way. It must be got absolutely in order to the consider the project as a positive improvement for the Company.

It's useful also to set a more ambitious target, the "nice to have". The "nice to have" target is very optimistic, but it is not mandatory to achieve. It provides to get an availability of 95% related to a 20% reduction of the three downtimes items.

However, time benefit is not the only result achievable with this project.

I decided to set also a target on the reduction of the complexity in terms of operations performed. It allows achieve an operational benefit. The operational "must have" target provides the reduction of the quality checks number (in the check list) from 23 to 20 (13% less). In the "nice to have" in the check list we would have 17 checks, 26% reduction.

To sum up,

Time benefit → Down Time reduction

Maintenance & Fault intervention from 4813 to 4091 mins
Set Up from 3655 to 3107 mins
Technical problems from 1165 to 990 mins

"Must have" Availability

92,5 % ⟹ 94,0%

"Nice to have" Availability

95 %

Operational benefit → Complexity reduction

"Must have" NVA activity reduction

26% ⟹ 10%

"Nice to have" NVA activity elimination

0%

Fig. 11 – Target setting synthesis

Root-Cause analysis

6.1. Root-Cause analysis (Fishbone and Five Whys)

The root-cause analysis is a problem-solving method useful for the identification of the root-causes. The starting point correspond to the main causes' definition. In order to fix them, there is a useful visual lean tool called "Fishbone" or ("Ishikawa diagram").

Mr. Ishikawa was convinced that 90% of the problems in a company could be solved with simple visual tools and the "Fishbone" is one of them. The "Fishbone" is a five-framework diagram composed by "five M": machine, man, management, method, and material. In the "fish's head" there is the problem, while on the different frameworks there are the main causes.

This is only the first step of the root-cause analysis. Then, each main cause must be traced back to find the root-causes, on which countermeasures will act.

The fishbone diagram is built through intense brainstorming session, in this phase, it is important to identify all the possible main causes. I discussed with several people in S&OP, Sales and production department, asking for feedback. The result is reported in the below figure.

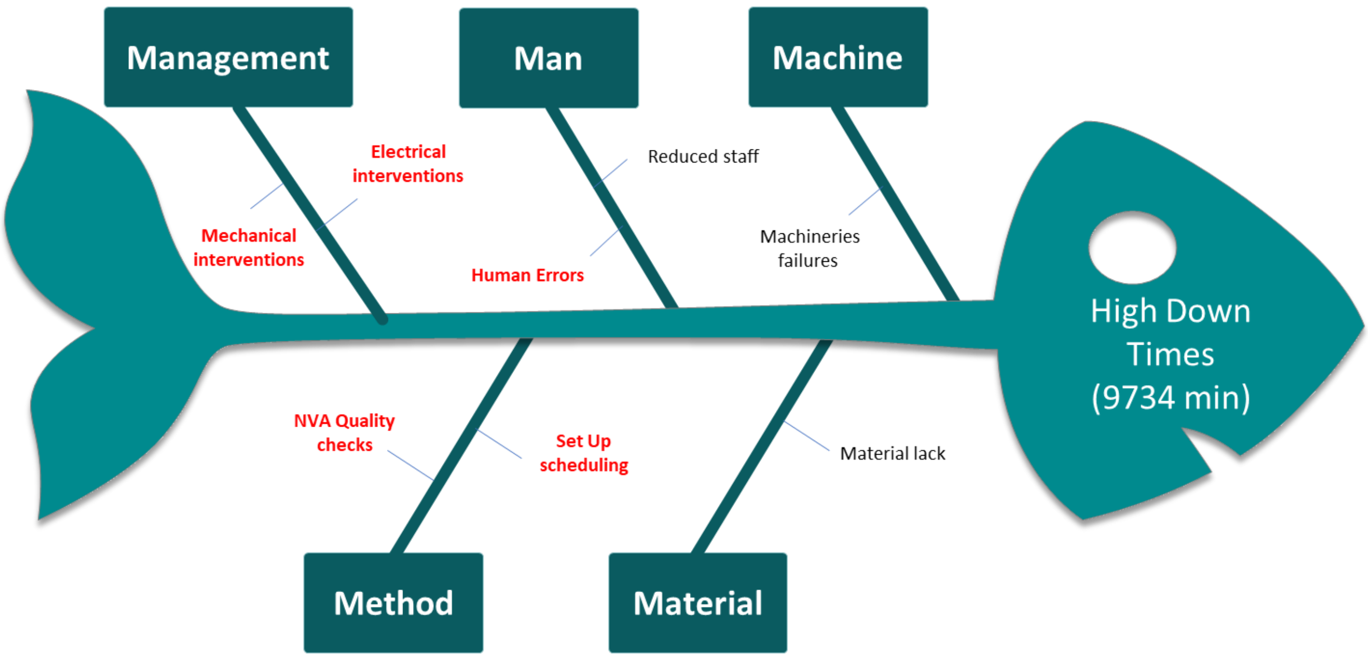


Figure 12 – Fishbone

The first framework analysed is the “machine” one. Machine could have an impact on downtimes for different reasons.

- Machine failure
  In Sisme, the 605-Line is composed by a fair number of automatic processing machines. Most of them are “old”, for this reason, they are subjected to planned maintenance interventions, but this is not enough. The reliability rate is quite high, so, failure is very frequent.

The “man” framework regards all the errors related to people.

- Reduced staff
  Sometimes stoppages could be longer than expected because an activity carries out by one operator should be managed by two or more. This is a crucial point for companies and also for Sisme. The size of the staff choice is a corporate-strategical decision taken in collaboration with the HR department.
- Human errors
  As machine failure, also human errors have an impact on downtimes. They are classified as technical problem. In Sisme I noticed two types of frequent mistakes: transcriptions/reading errors and out-of-date. The first imply an incorrect set up parameter setting. The second regards set up specification documents available on the line that could be out-of-date.
  In both the cases, when these kinds of errors occur, the line must be stopped, the error solved and products processed up to that moment scrapped.

In the “management” framework problems arise from an incorrect operational process management.

- Electric intervention
  Both electric and mechanic interventions are part of the maintenance & fault item. Differently from mechanic operator (which work is almost completely focused on a single line) the electric operators must intervene for any kind of electrical fault in the whole Company. For this reason, the Electric maintenance HQ is positioned about in the middle. But, the 605-Line is far from the electric maintenance HQ and the operator had to walk this way two or three times per interventions. The time spent from the HQ to the Line is wasted and increment downtimes related to the intervention.
- Mechanical intervention
  The 605-Line current situation shows that sometimes mechanics are forced to manage at the same time both maintenance or fault urgent intervention and set up. This issue has a considerable impact on downtimes because one of the two activities must be postponed.

All companies follow structured method and procedure to carry out their business. Sometimes these methods should be revised to identify opportunities for improvements.

- NVA Quality checks
  26% of quality checks in the quality check list are non-value added. This means that they do not contribute to increase the final value perceived by the customers. They could be avoided.

- Set Up scheduling

  Products scheduling generated by the planning department determines the set up on the 605-line. There can be set up easier than others. The optimal scenario is the one in which the set up combination planned minimise the set up time and the number of set up machine interventions. Otherwise, downtimes dramatically increase.

The "material" framework considers both the movement and the procurement of the material necessary to produce.

- Material lack

  In 605-Line sometimes a lack of materials problem occurs. Materials are not immediately available for operators on the line. There are several different causes. For example, it may happen that the line supervisor forgets to send the material order to the warehouse, or else, the material is not available in the warehouse because not received yet from the supplier.

Once the main causes are clearly identified and visually represented in the fishbone, the next root-cause analysis step is the root-cause definition. It is performed through another simple visual tool, the "Five Whys".

Some of the macro-causes in the fishbone are highlighted in red. These are the most critical for the 605-line, so, a deep-dive analysis is necessary. Through the five whys, we must persist asking what's the problem cause until we find the root-cause.

The first "red" main cause are human errors, in the "man" framework. I've already explained the two possible reasons: transcription/reading errors and out-of-date documents.

In Sisme the most important set up information for the 605-Line are written on a paper module called: "Modulo di segnalazione cambio macchina". This procedure generates a lot of inefficiencies, for example, transcription and reading errors. The line supervisor read the wrong product code on the computer screen and also write it wrong on the module or the line operators is not able to read the calligraphy of the supervisors.

The second type of errors regard a set up specification document called: “Istruzioni di lavoro”. If a specification change, the new updated version of the document should be printed and replaced, but this does not always happen. If no one change the out-of-date version, it can stay wrong for weeks.

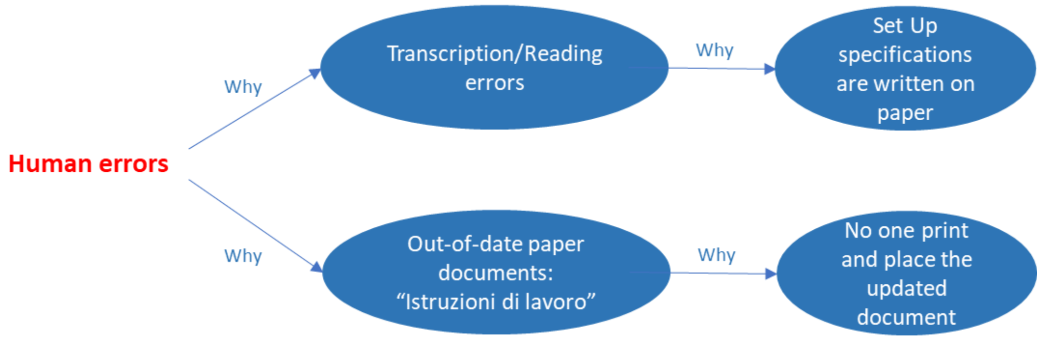


Figure 13 – Human errors five why

In the “management” framework there are two “red” main causes: electric interventions and mechanic interventions

In the current situation I noticed that the electric maintenance operators have to take a two minutes’ walk from the electric maintenance department HQ to the 605-Line. This is time wasted. Electric operators have to come back to the HQ in order to retrieve some specific tool for the intervention (on 605-Line there are not the technical electric maintenance instruments for the interventions).

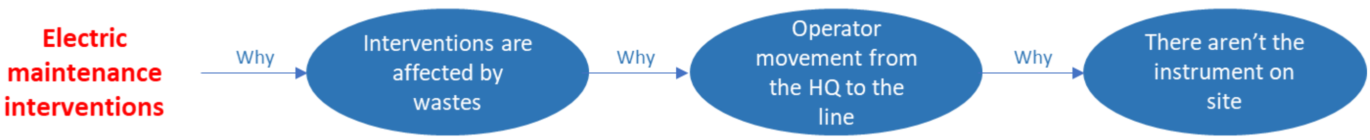


Figure 14 – El. int. five why

As mentioned, there are situations in which mechanic interventions and set up overlap. This issue came from a progressive batch sizing reduction process. Customers ask for small quantity of each product with a short time between the orders. The sales department has the duty to satisfy every customer need because this is a Company corporate-strategical decision.

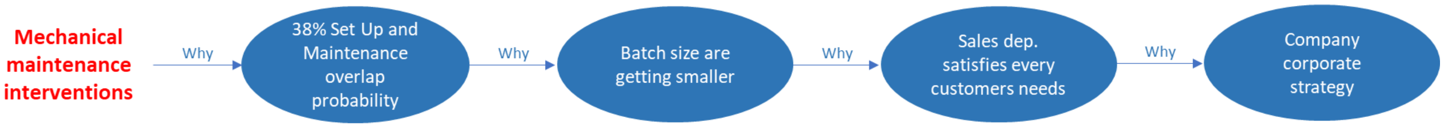


Figure 15 – Mech. int. five why

In the “method” framework there are the last two “red” main causes: NVA quality checks and Set up scheduling.

There are some quality checks in the check list that can be considered NVA. They are affected by wastes. The reason behind some of these excessive and redundant quality checks is Company decision. Through the years, Sisme decided to develop a strength and efficient quality control system. This “culture” derived from the perception of quality as the most important KPI. But this trend is continuing to expand and recently, it led to the introduction of some excessive and redundant quality checks.

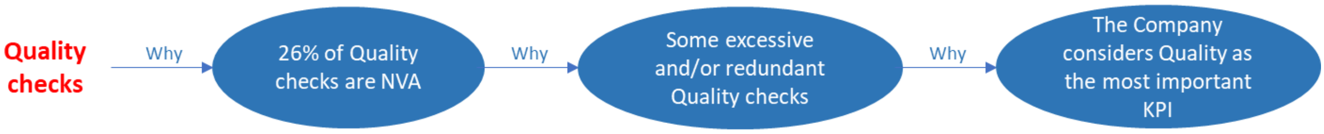


Figure 16 – Quality checks five why

The second “method” main cause concerns the set up scheduling. In Sisme the MRP (Material Requirements Planning) proposes a production plan based on the shipment date of the different orders. The plan generated by the MRP is analysed by the planner and, taking into consideration other client constraints, he switches some positions identifying the definitive production plan.

In the planning department no one considers any parameter related to the production process. For this reason, the line supervisor performed the tasks to manipulate the order, making the plan achievable.

Line supervisor considers different types of parameters (according to listed order of importance): the type of steel sheet (190 or 198), the pack hight, the product family and the copper wire. The more these parameters are the same between two consecutive products, the easier the set up results and lasts less. This optimization process is performed by the line supervision once a day for the current production plan.

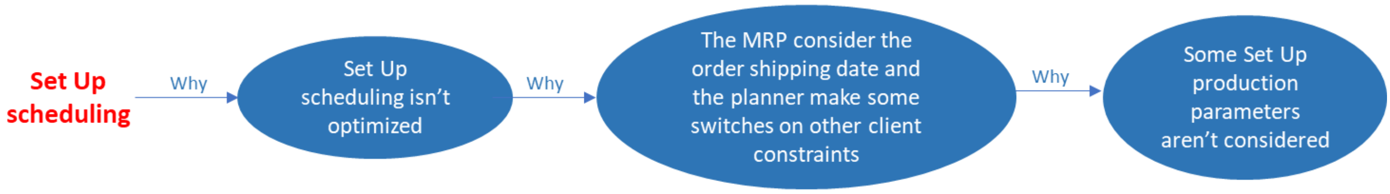


Figure 18 – Set up sched. five why

6.1. Root-Cause KPI

In order to make measurable the impact of the different problems identified, KPIs were defined. They are listed in the table below.

Problem	Root-cause	KPI
Transcription/Reading errors	Paper document	Human errors Down. / Tot. Down.
Out-of-date documents		
Electrical interventions time waste	There aren't the instruments on site	Wasted Time / Tot. Downtime
Mechanical interventions & Set Up overlap	Customer care Company corporate strategy	Overlap / Tot. Downtime
NVA Quality checks	Company "culture" of Quality	NVA Checks Time / Tot. Check List Time
Not optimal Set Up scheduling	Production parameter aren't considered	Set Up Overtime / Tot. Downtime

Table 17 – KPI

In the “605-line Master File” human errors are not individually registered, but they are included into the technical problems. The only possibility to collect some data was through staff interviews. Human errors occur on average once a week and the impact on 605-Line downtimes is 8 min. The best KPI is the ratio between downtimes caused by human errors on total downtimes.

$$KPI_{Human\ errors} = Human\ errors\ Downtime\ /\ Tot.\ Downtime$$

There are 50 working weeks in a year, so, multiplying the average human errors downtime impact for the fifty working weeks, the result is 400 minutes.

4,93% of total downtimes are caused by Human errors. They are 40,17% of technical problems.

Also for electric maintenance interventions, in the first week, I registered the time spent by the electric operator walking from the HQ and the line, but also the number of times this distance was travelled on average for each intervention. The KPI to demonstrate this type of problem is the ratio between the time wasted walking along the way on total downtimes.

$$KPI_{El.\ Interv.} = Wasted\ Time\ /\ Tot.\ Downtime$$

The wasted time is computed subtracting from the time spent for the electric maintenance interventions in a year (number of interventions in a year multiplied for the average time for an intervention) the time without wastes (number of interventions in a year multiplied for the average time for an intervention minus 2 minutes multiplied for 2,5 occurrences).

22,53% of time for an electric intervention is wasted by the operator walking through the HQ and the 605-Line. This has an impact on downtimes equal to 5,35%

The most suitable KPI for the mechanic intervention and set up overlap problem is the ratio between the overlap time on total downtime.

$$KPI_{Overlap} = Overlap\ Time\ /\ Tot.\ Downtime$$

The average time spent from the mechanic in set up activities is equal to 45 minutes. The "yellow" probability values are computed taking into consideration the mechanic intervention and set up simultaneously even if they are overlapped just for a minute (because for any situation in which a mechanic is forced to postpone an activity, downtimes increase).

This situation occurrence probability is on average the 50%. In other words, for each batch, there is 50% probability during set up activities a mechanic is also called to manage another task or vice versa.

MODELLO	ARTICOLO	DATA	PERSONE UTILIZZATE	DISPO. MINUTI IMPIANTO	VOLUME (OUTPUT)	Manutenzione Guasti	Set Up	Problemi Tecnici	NOTE	Numero set up	Manut&Guast + Set Up	% conincid. M&S
49128760000	B12876	04/06/2019	10	240	108	15	10	0	\	1	60	25%
49135260000	B13526	10/06/2019	11	160	61	45	5	0	\	1	90	56%
49116530020	B11653/20	12/06/2019	10	90	37	20	5	0	\	1	65	72%
49139050000	B13905	17/06/2019	10	440	224	20	5	0	\	1	65	15%
49116710020	B11671/20	20/06/2019	15	70	46	10	5	0	\	1	55	79%
49129840020	B12984/20	20/06/2019	15	95	69	10	5	0	profibus	1	55	58%
49134210000	B13421	21/06/2019	13	240	144	10	10	0	\	1	55	23%
49116530020	B11653/20	25/06/2019	10	210	92	20	5	10		1	65	31%
…	…	…	…	…	…	…	…	…	…	…	…	…

Table 18 – Maintenance & set up data

In order to evaluate the overlap time, during the first week, I observed all the situations in which a mechanic was forced to postpone an activity due to an overlapping situation and I registered the related downtime. These values were also verified through interviews at mechanics, who, thanks to their experience, confirmed they were good approximation of real situations.

The average overlap time registered was 5 minutes. Multiplying this value for the number of set up in a year and for the overlap probability, the overlap time is equal to 1110 minutes, 13,76% of total downtimes.

NVA quality checks is the only problem in which it is impossible to evaluate the impact on downtimes. Sometimes they could be in parallel with set up activities, some other times they directly affect downtimes. There is not a fixed situation. The best way to measure this inefficiency is a ratio between the NVA checks time on total check list time

$$KPI_{NVA\ checks} = NVA\ Checks\ Time\ /\ Tot.\ Check\ List\ Time$$

Time spent for the whole check list is 46 minutes. NVA checks are equal to 9 minutes, around the 20% (they are 6 out of 23, the 26%).

KPI for set up scheduling is the ratio between set up overtime on total downtime.

$$KPI_{Set\ up\ scheduling} = Set\ Up\ Overtime\ /\ Tot.\ Downtime$$

Overtime is used to emphasise how long set up exceed the acceptable time. It is computed as set up time minus the average set up time for the product considered. According to the Pareto analysis (showed in the "Problem Breakdown" chapter), I've computed the calculation for the six 605-line "heavier" products.

MODELLO	ARTICOLO	VOLUME (OUTPUT)	Overtime	Set Up time
49134210000	B13421	8175	34	263
49139090000	B13909	7927	28	181
49139050000	B13905	7104	25	169
49141560000	B14156	4858	11	108
49126070000	B12607	4659	30	168
49126120000	B12612	3648	27	156

Table 19 - Overtime

On average, 15% of set up time is overtime. The annual downtime related to set up is 3046 minutes, so, the overtime is 457 minutes, 6,03% of total downtimes.

The table below summarize the KPI results.

Problem	KPI	%
Transcription/Reading errors	Human errors Down. / Tot. Down.	4,93%
Out-of-date documents		
Electrical interventions time waste	Wasted Time / Tot. Downtime	5,35%
Mechanical interventions & Set Up overlap	Overlap / Tot. Downtime	13,76%
NVA Quality checks	NVA Checks Time / Tot. Check List Time	19,96%
Not optimal Set Up scheduling	Set Up Overtime / Tot. Downtime	6,03%

Table 20 – KPI results

Develop Countermeasures

7.1. Countermeasure identification

Once root-cause are defined and measured, the next A3 step is the “developing countermeasures”. For each root-cause a specific countermeasure must be defined.

Based on the available data collected and on a countermeasures cost-benefit analysis, in collaboration with the head of Sisme’s operations, the IT manager, the maintenance manager, the quality manager and the 605-line supervisor, we tried to develop the most suitable countermeasures for each root-cause identified in the root-cause analysis.

In the table below, problems, root-causes and countermeasures are listed.

Problem	Root-cause	Countermeasure
Transcription/Reading errors	Paper document	Heijunka Box
Out-of-date documents		
Electrical interventions time waste	There aren’t the instruments on site	Carriage with basic instruments
Mechanical interventions & Set Up overlap	Customer care Company corporate strategy	Self-Control
NVA Quality checks	Company "culture" of Quality	
Not optimal Set Up scheduling	Production parameter aren't considered	Set Up scheduling tool

Table 21 – Countermeasures list

The Heijunka box is the countermeasures designed to eliminate all the paper documents, root-cause of “transcription/reading errors” and “out-of-date documents”.

The Heijunka box is a lean tool represented physically by a big board subdivided in the weekdays. Each of them is characterized by different little box in which the product order labels are placed (Kanban cards).

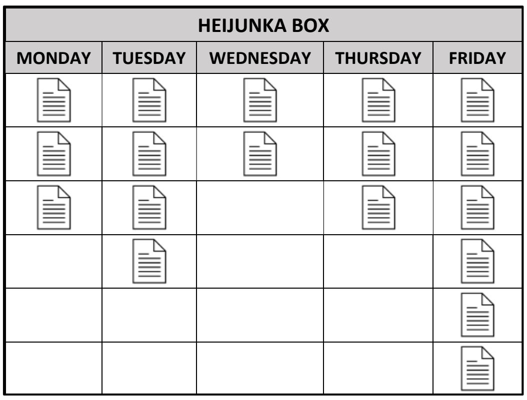


Figure 18 – Heijunka box

So, once every two weeks the production planning department generates the plan, every morning all the different product cards must be printed and placed in the Heijunka Box. The cards contain all the most relevant production and set up information, in order to avoid the transcription/reading errors. They are printed daily directly from an updated database. So, also the out-of-date document problem is eliminated.

Benefit of Heijunka box are not limited to these. Basically, The Heijunka box allows to an easy and visual daily control of a smoothed production schedule. For this purpose, two different cards will be created, one managed by the line-supervisor and the other for mechanics.

The production card contains all the information related to stators production process: BOM (Bill Of Material), Product Code ("Modello"), batch size, sheet diameter, pack height, Myler hight, product family, copper wires specification (n° of section and diameter), tips inclination, 2° station H insulation ring, press value, Datamatrix block and all the production programs that must be set on the machines.

The BOM information are useful for the line-supervisor. He has the tasks to make the material available on the line (according to the different stations) and to forward the order to the warehouse. The other important parameters are Product Code, batch size, sheet diameter, pack hight, product family and the copper wires specification. In particular, copper wires specification is useful for the operator that works on the winding machine. He has the task to place the correct copper barrel for the current order. Knowing in advance the material that will be used during the day, he can better organize his work.

The mechanic card is composed by some important information present in the production cards, but also all the set up specifications related to the interventions on the machine. Mechanic relevant information are: pack high, Myler hight, tips inclination, 2° station H insulation ring, press plates, press value, seamers couplings, welding machine specification (bending and welding spacers, key, bell and pin) and all the production programs that must be set on the machines.

The same consideration just outlined for the line-operator can be applied to mechanic.

Whit the introduction of the cards, they are not obliged to consult a lot of different paper document like “Istruzioni di lavoro” or “Libro macchina”, but they will find all the relevant parameters in the same place. They will also be able to organize their work optimally, knowing in advance the daily intervention to carry out.

This point introduces another important benefit of the Heijunka box related also to the self-control countermeasure. One of the critical points in the development of the self-control concerns information. As mentioned, currently, for all the set up intervention on machines, the mechanics read the relevant parameters mainly on two documents: “Istruzioni di lavoro” and “Libro macchina”. The self-control provides to shift some easy mechanic set up activities to line-operators. They do not have familiarity with these types of documents, so, the information retrieval could be a problem. But, introducing the Heijunka box all the information are easily accessible.

Countermeasure for the electric maintenance waste of time is a tool-holder with the instrument used in the most frequent interventions. The countermeasure directly derives from the root-cause of the problem: “there aren’t the instrument on site”.

In the last few years Company corporate strategy has determined two important crucial points: Sales department has to accomplish most of the customer requests and quality is the most important KPI. The first decision led to mechanics overwork due to small batch sizes. The second introduces some excessive and redundant quality checks.

For this reason, the last Board of Directors established to push operator self-control in order to limit these trends.

In practice, line-operators will have to deal also with some easy maintenance intervention and quickly quality checks.

First of all, for the identification of maintenance interventions and quality checks to shift, I’ve carried out a FMEA (Process/Product Failure Mode and Effect analysis).

The FMEA analysis consider different process step. For each of them the potential failure mode, the potential failure effect, the potential causes and the current control must be identified.

Then, the process step risk is evaluated through an indicator, the RPN (Risk Priority Number). The higher is the RPN, the greater is the risk. The RPN is computed multiplying three factors: Severity, Occurrence and Detection. Severity factors correspond to an impact assessment of the process step. Occurrence stands for the turn-out frequency. Detection is referred to the easiness with which the problem is noticed. A 1 – 10 scale is used for the three factors. So, the RPN will go from 0 to 1000.

SCALE	1	2	3	4	5	6	7	8	9	10
SEVERITY	Impossibility of occurrcence…………………………………………………………………………………………Certainty of occurrence									
OCCURRENCE	Minor severity……Major severity									
DETECTION	Easy detectable……Not detectable									

RPN
0………………………..1000
Zero risk……….High risk

Table 22 – FMEA scale

FMEA results are presented below.

MAINTENANCE PROCESS /PRODUCT FAILURE MODE and EFFECTS ANALYSIS															
Process Step	Potential Failure mode	Potential failure effect	SEVERITY	Potential causes	OCCURENCE	Current Controls	DETECTION	RPN	Action Reccommended	Resp.	SEVERITY	OCCURRENCE	DETECTION	New RPN
Cambio del Myler	Altezza Myler non corretta	La lavorazione deve essere interrotta e i pezzi lavorati con l'altezza Myler sbagliata devono essere rilavorati.	6	Errore di distrazione o specifica non aggiornata	1	I pezzi lavorati non correttamente sono immediatamente riconoscibili	1	6	Operazione deve essere svolta dall'operatore di linea. Il materiale è presente in postazione, l'informazione è scritta sull'erichetta Heijunka e per il primo periodo l'operatore dovrà essere affiancato dal meccanico. L'oprerazione sarà seguita anche dal resp. di linea	Operatore di linea	6	3	1	18
Cambiare il puntale del bucatore	Puntale sbagliato o inserimento non corretto	La lavorazione deve essere interrotta e i pezzi lavorati con puntale non corretto devono essere rilavorati. Se i pezzi sono lavorati con un puntale non inserito correttamente, devono essere smantellati	8	Errore di distrazione o specifica non aggiornata	1	I pezzi lavorati non correttamente sono immediatamente riconoscibili	1	8	Operazione deve essere svolta dall'operatore di linea. Il materiale è presente in postazione, l'informazione è scritta sull'erichetta Heijunka e per il primo periodo l'operatore dovrà essere affiancato dal meccanico. L'oprerazione sarà seguita anche dal resp. di linea	Operatore di linea	8	3	1	24
Montaggio anello (in iso. H 2° strato) per H pacco >= 160	L'anello non viene montato o viene montato quello sbagliato	Il pezzo non si inserisce nell'anello o la sua circonferenza è troppo piccola	4	Errore di distrazione o specifica non aggiornata	1	Non essendoci l'anello o essendoci l'anello sbagliato la lavorazione non può proseguire	1	4	Operazione deve essere svolta dall'operatore di linea. Il materiale è presente in postazione, l'informazione è scritta sull'erichetta Heijunka e per il primo periodo l'operatore dovrà essere affiancato dal meccanico. L'oprerazione sarà seguita anche dal resp. di linea	Operatore di linea	4	3	1	12
Regolazione della pressata	Errore regolare la pressata	Il pezzo viene schiacciato troppo o troppo poco. Individuati i pezzi lavorati non correttamente, devono subire una seconda rilavorazione	5	Errore di distrazione o specifica non aggiornata	1	Qualità in fase 170	2	10	Operazione deve essere svolta dall'operatore di linea. L'informazione è scritta sull'erichetta Heijunka e per il primo periodo l'operatore dovrà essere affiancato dal meccanico. L'oprerazione sarà seguita anche dal resp. di linea	Operatore di linea	5	3	2	30
Montare blocchetto DataMatrix	Blocchetto non corretto	I pezzi con Datamatrix sbagliato devono essere rilavorati. Il pezzo può arrivare al cliente	6	Errore di distrazione o specifica non aggiornata	1	Check del controllo qualità in fase 255	2	12	Operazione deve essere svolta dall'operatore di linea. Il materiale è presente in postazione, l'informazione è scritta sull'erichetta Heijunka e per il primo periodo l'operatore dovrà essere affiancato dal meccanico. L'oprerazione sarà seguita anche dal resp. di linea	Responsabile di linea	6	3	2	36
Cambio periodico delle spazzole	Spazzole non spelano e non svengono cambiate	I pezzi con rame non correttamente spelato devono essere rilavorati	4	Errore di distrazione	1	Check del controllo qualità in fase 219	2	8	Operazione deve essere svolta dall'operatore di linea. Il materiale è presente in postazione e per il primo periodo l'operatore dovrà essere affiancato dal meccanico. L'oprerazione sarà seguita anche dal resp. di linea	Operatore di linea	4	3	2	24
Programmi	Errore nel richiamare il programma sbagliato	I pezzi lavorati con il programma sbagliato devono essere rilavorati	4	Errore di distrazione	2	Check del controllo Qualità	1	8	Operazione deve essere svolta dall'operatore di linea. Attraverso l'etichetta Heijunka il check viene svolto dal responsabile di linea.	Operatore di linea	4	2	2	16

Table 23 – Maintenance FMEA

Only the easy and not-risky maintenance process tasks are taken into consideration (RPN<100) they are: Myler change, tips change, 2° station H insulation ring assembly, press regulation, Datamatrix printer assembly, periodic brushes change and machine programs set.

The FMEA clearly highlights that if Company decides to shift these tasks to line-operator the “new” RPN still remains low.

The same is for Quality. Quality checks considered are: pack seamer parameter check, copper barrel check, winder machine parameter check, stamp check and connection seamer parameter check.

QUALITY PROCESS /PRODUCT FAILURE MODE and EFFECTS ANALYSIS															
Process Step		Potential Failure mode	Potential failure effect	SEVERITY	Potential causes	OCCURRENCE	Current Controls	DETECTION	RPN	Action Reccommended	Resp.	SEVERITY	OCCURRENCE	DETECTION	New RPN
Verifica dei parametri impostati in aggraff. pacco		Errore nell'inserimento dell'altezza pacco	I pezzi con l'altezza sbagliata vengono smantellati (si recupera il pacco, mentre il rame viene scartato). Il pezzo non arriva al cliente	8	Errore di distrazione o di trascrizione su "MODULO DI SEGNALAZIONE CAMBIO MACCHINA"	2	Check del controllo qualità in fase 170 & controllo automatico della macchina che si ferma al rilevamento di grosse variazioni	1	16	Operazione deve essere svolta dall'operatore di linea. Attraverso l'etichetta prodotto il check viene svolto dal responsabile di linea.	Operatore di linea	8	2	2	32
Controllare che il fusto di rame corrisponda a quello previsto per la lavorazione	Analisi valida per tutte e tre le bobinatrici	Fusto di rame errato	I pezzi con rame sbagliato vengono smantellati (si recupera il pacco, mentre il rame viene scartato). Il pezzo non arriva al cliente	8	Errore di distrazione o di trascrizione su "MODULO DI SEGNALAZIONE CAMBIO MACCHINA"	4	Check del controllo qualità in fase 170 (misura delle resistenze)	2	64	Operazione deve essere svolta dall'operatore di linea. Implementazione di una Check list in cui l'operazione venga registrata	Operatore di linea	8	4	3	96
Verifica dei parametri impostati in bobinatrice		Errore nel richiamare il programma sbagliato o dei parametri impostati nel programma stesso	I pezzi lavorati con il programma sbagliato vengono smantellati (si recupera il pacco, mentre il rame viene scartato). Il pezzo non arriva al cliente	8	Errore di distrazione	2	Check del controllo qualità in fase 170 (misura delle resistenze)	1	16	Operazione deve essere svolta dall'operatore di linea. Attraverso l'etichetta prodotto il check viene svolto dal responsabile di linea.	Operatore di linea	8	2	2	32
Controllo timbro	Analisi valida sia per la timbratura del codice cliente in testa al pacco che per la timbratura finale	Timbro errato o non leggibile	I pezzi con timbro sbagliato devono essere rilavorati. Il pezzo può arrivare al cliente	5	Errore di distrazione o altre cause di illeggibilità	4	Check del controllo qualità in fase 210 e a fondo linea	2	40	Operazione deve essere svolta dal responsabile di di linea. Implementazione di un sistema Poka Yoke per limitare gli errori. Rimane comunque il check a fondo linea	Responsabile di linea	5	5	3	75
Verifica dei parametri impostati in aggraffatrice		Errore nel richiamare il programma sbagliato o dei parametri impostati nel programma stesso	I pezzi lavorati con il programma sbagliato vengono rilavorati. Il pezzo non arriva al cliente	4	Errore di distrazione	2	Check del controllo qualità in fase 219	1	8	Operazione deve essere svolta dall'operatore di linea. Attraverso l'etichetta prodotto il check viene svolto dal responsabile di linea.	Operatore di linea	4	2	2	16

Table 24 – Quality FMEA

The only critical task could be the copper barrel check, if it will be shifted, the RPN dropped to 96.

Each stator is characterized by a specific type of copper wire identified by a couple of values: the number of sections and the wire’s diameter.

When a new product must be processed, an operator places the specific copper barrel near the related Statomat machine. The operator should always check if the barrel is correct, but sometimes this not happen. If the placed copper wire barrel is wrong, the entire process must be stopped and all the stator produced up to that moment scrapped. When this type of error occurs, I've noticed that it is impossible to trace the operator who performed the task and this is wrong for two reason: first, knowing that it is not possible to trace the name, operator perform the task with less attention; second, if we do not know who make the mistake, we can't understand why it happened. So, in the "development countermeasures" phase, it is useful to make some specific considerations.

Once tasks identified, it is important to fix three basic concepts: material, information and control/responsibility. "Material" stands for the material that the operator will use for the maintenance interventions or the quality check. "Information" are the specifications to know. "Control/Responsibility" is related to the person in charge for a specific task from which the sense of responsibility results.

The excel table below summarize these concepts for maintenance interventions and quality checks considered.

MAINTENANCE				
Mansione	**Procedure**	**Materiali**	**Informazione**	**Controllo**
Cambiare il puntale del bucatore	Necessary	Il puntale è nell'armadio delle presse. E' necessaria la brugola AT n° 3	Sull'etichetta Heijunka	Resp. di linea
Montaggio anello (in iso. H 2° strato) per H pacco >= 160	Necessary	Gli anelli (Per 190 e 198) sono a bordo linea. Sono necessarie le chiavi n° 3 e 5	Sull'etichetta Heijunka	Resp. di linea
Regolazione della pressata	Necessary	\	Sull'etichetta Heijunka	Resp. di linea
Montare blocchetto DataMatrix	Necessary	Il blocchetto è nell'armadio delle presse. E' necessaria la chiave n° 3	Sull'etichetta Heijunka	Resp. di linea
Cambio periodico delle spazzole	Necessary	Le spazzole sono in un cassetto a bordo linea. Sono necessrie le chiavi n° 20/22 e 5	L'operatore decide il momento in cui cambiare le spazzole	Resp. di linea
Programmi	Necessary	\	Sull'etichetta Heijunka	Resp. di linea

Table 25 – Maintenance material, info and resp.

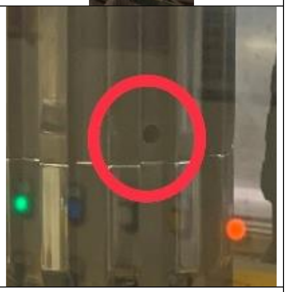
QUALITY CHECKS				
Mansione	**Procedure**	**Materiali**	**Informazione**	**Controllo**
Verifica funzionale macchina aggraffatura pacchi (con Master)	Unnecessary	Master	Master corretto da inserire (190 e 198) e tolleranze	\
Verifica dei parametri impostati in aggraffatrice pacco	Unnecessary	\	Sull'etichetta Heijunka	Resp. di linea
Controllare che il fusto di rame corrisponda a quello previsto per la lavorazione	Unnecessary	\	Sull'etichetta Heijunka	Resp. di linea
Verifica dei parametri impostati in bobinatrice	Unnecessary	\	Sull'etichetta Heijunka	Resp. di linea
Controllo timbro (Timbratura del codice cliente in testa al pacco & Timbratura finale)	Unnecessary	\	Sull'etichetta Heijunka	Resp. di linea
Verifica dei parametri impostati in aggraffatrice	Unnecessary	\	Sull'etichetta Heijunka	Resp. di linea

Table 26 – Quality material, info and resp.

From table 25, it can be noticed that procedures are necessary. So, the last self-control control countermeasure development step is the procedures formalization. For the maintenance tasks, in addition to an initial teaching period between the mechanic and the line-operator, another useful tool could be the detailed procedure printed and available for consultation. Mechanics shown me "physically" the procedure for those tasks will be shifted. The procedure "Tips chance" is reported as an example below. Other nine procedures with the same form were realized. They are all reported in the attachments.

CAMBIO DEL PUNTALE (BUCATORE)

OPERAZIONI	IMMAGINI
Il 1° e 2° puntale si trovano nell'armadio A48. Il 3° si trova nell'armadio A59	
Prelevare dall'armadio il puntale corretto I puntali si differenziano in base all'inclinazione della lama Il puntale con l'inclinazione prevista per la lavorazione è segnato sull'etichetta della commessa L'inclinazione è scritta sul puntale, come si può vedere dall'immagine a fianco	
Portare il selettore "MAN – AUT" su "MAN"	
Tenere premuto "SBLOCCO MAGNETI CANCELLO ANTERIORE" per qualche secondo e aprire le porte	

Posizionare il ferro di sicurezza	
Allentare le due viti sulle estremità opposte del puntale (cerchio in rosso nell'immagine a fianco) utilizzando una brugola a T n° 3 Ricordarsi di tenere sempre una mano sotto il puntale, per non farlo cadere	
Estrarre il puntale	
Inserire il puntale previsto per la lavorazione corrente posizionando l'incastro in maniera congrua con il segno presente sul puntale (Cerchiato in rosso nell'immagine a fianco) Il verso della lama del puntale deve essere sempre parallelo alle due matasse di rame dello statore Avvitare le due viti sulle estremità opposte del puntale in modo da fissarlo	
Richiudere le porte	

Premere "INSERZIONE COMANDI"	
Se la macchina non è in fase tenere premuto il pulsante di "RIPRISTINO" della macchina finché la luce non rimane fissa (Se la luce lampeggia significa che la macchina non è ancora in fase)	
Riportare il selettore "MAN – AUT" su "AUT"	
Premere "START CICLO"	
Riportare il puntale smontato nell'armadio corretto	

Figure 19 – Tips change procedure

Set up scheduling KPI showed that, on average, 15% of set up time is “overtime”. The set up scheduling countermeasures primary aim must be the set up time reduction. The reason related to the high level of products average set up time and standard deviation is the production plan. The planner modifies the MPR scheduling only for some client constraint. No one production parameter is considered.

The idea is to develop a set up scheduling tool. It mathematically replicates one of the daily line-supervisor task, the product scheduling optimization. The line-supervisor considers four different parameters, the following: sheet diameter, pack hight, product family and copper wires. The mathematical transposition benefits of this task are twofold. On the on hand, the scheduling tool is parametrizable, it can consider all the production parameters of the 605-Line. On the other hand, it is possible to extend the analysis to any time horizon. The first step for the set up scheduling tool creation was the analysis of all the set up operations. For each of them, it was important understand on which parameter they depend on and the specific processing time. In the table below, all the set up operations are listed, with the two important characteristics just mentioned.

Fase	Descrizione Fase	Operazione	Dipendenza	Tempo [s]
10	Preparazione pacco	Impostazione altezza sulla macchina	In base all'altezza pacco	60
		Cambiare campana, piattello e pinze	In base al diametro del lamierino	420
20	Isolamento pacco	Cambiare il Mylar	In base all'altezza Mylar	300
30	Bobinatura 1° strato	Impostazione prg. Winder e prg. RWE	Dipende dal modello	60
		Sistemazione del fusto di rame	Dipende da ø e n° sez	120
		Impostazione altezza sulla macchina	In base all'altezza pacco	60
40	Spelatura,montaggio cannucce e sist.capi 1° strato	Impostazione prg. Spelatura	"IN SERIE" o "IN PARALLELO"	30
		Impostazione prg. Sollevatore	"INCLUSA" o "ESCLUSA"	30
50	Bucatura e allargatura 1°strato	Cambiare il puntale del bucatore. L'allargatore non cambia mai	Il puntale del bucatore cambia in base all'inclinazione	180
60	Montaggio isolanti H 1° strato	\	\	0
70	Bobinatura 2° strato	Impostazione prg. Winder e prg. RWE	Dipende dal modello	60
		Sistemazione del fusto di rame	Dipende da ø e n° sez	120
		Impostazione altezza sulla macchina	In base all'altezza pacco	60
80	Spelatura,montaggio cannucce e sist.capi 2° strato	Impostazione prg. Spelatura	"IN SERIE" o "IN PARALLELO"	30
		Impostazione prg. Sollevatore	"INCLUSA" o "ESCLUSA"	30
90	Bucatura e allargatura 2°strato	Cambiare il puntale del bucatore. L'allargatore non cambia mai	Il puntale del bucatore cambia in base all'inclinazione	180
100	Montaggio isolanti H 2° strato	Montare l'anello	Se l'altezza supera i 160 cm bisogna montare l'anello	60
110	Bobinatura 3° strato	Impostazione prg. Winder e prg. RWE	Dipende dal modello	60
		Sistemazione del fusto di rame	Dipende da ø e n° sez	120
		Impostazione altezza sulla macchina	In base all'altezza pacco	60
120	Spelatura,montaggio cannucce e sist.capi 3° strato	Impostazione prg. Spelatura	"IN SERIE" o "IN PARALLELO"	30
		Impostazione prg. Sollevatore	"INCLUSA" o "ESCLUSA"	30
130	Bucatura 3°strato	Cambiare il puntale del bucatore	Il puntale del bucatore cambia in base all'inclinazione	180

140	Rotazione Pallet	Impostare il selettore su "INCLUSA" o "ESCLUSA"	"INCLUSA" o "ESCLUSA"	30
160	Pressatura per formatura matasse	Cambiare piattello superiore	Il piattello cambia in base alla famiglia di prodotto	300
		Regolazione della pressata superiore	Cinque modalità: 0, 1, 2, 3 o 4	60
		Cambiare piattello inferiore	Il piattello cambia in base alla famiglia di prodotto	300
		Regolazione della pressata inferiore	Tre modalità: 0, 1 o 2	60
190	Aggraffatura termistori	Impostare il selettore su "INCLUSA" o "ESCLUSA"	"INCLUSA" o "ESCLUSA"	30
		Cambio delle graffette	Se il selettore è su "INCLUSA" possono esserci due tipologie di graffette: 1,30 e 1,60	180
210	Timbratura codice cliente in testa pacco	Impostare il selettore su "INCLUSA" o "ESCLUSA"	"INCLUSA" o "ESCLUSA"	30
219	Aggraffatura connessioni	Impostare il prg. Aggraffatrice	Dipende dal modello	60
		In base all'accoppiamento Grnd. Attrezz. - Svil. Graff. devono essere cambiate le componenti	Cinque tipologie di accoppiamenti: 3-15; 2-17; 2-20; 1-20; 1-23. Se rimane lo stesso accoppiamento, non bisogna cambiare	480
255	Sistemazione gruppo conduttori e marcatura cluster	Impostare il prg. Marcatura	Dipende dal modello	60
		Sostituzione del blocchetto	Dipende dal modello	60
260	Pressatura di formatura finale	Cambiare piattello superiore	Il piattello cambia in base alla famiglia di prodotto	300
		Regolazione della pressata superiore	Cinque modalità: 0, 1, 2, 3 o 4	60
		Cambiare piattello inferiore	Il piattello cambia in base alla famiglia di prodotto	300
		Regolazione della pressata inferiore	Quattro modalità: 0, 1, 2 o 3	60
		Tassello "SI" o "NO"	"SI" o "NO"	30
		Posizionamento selettore in base al diametro del lamierino	In base al diametro del lamierino	30
280	Cucitura matasse	Impostazione del prg. della macchina	Dipende dal modello	60
		Impostazione dell'altezza	In base all'altezza pacco	60
		Cambiare tasselli dei Flat sulla base del diametro	In base al diametro del lamierino	300
		Sostituzione spago in base all'altezza	In base all'altezza pacco (se superiore a 140)	480
300	Collaudo elettrico e timbratura finale	Timbratura "INCLUSA" o "ESCLUSA"	"INCLUSA" o "ESCLUSA"	30
340	Incarcassamento e saldatura carcassa (solo per 198)	Impostazione del prg. della macchina	Dipende dal modello	60
		Cambiare i distanziali di callettamento e saldatura	Dipende dal valore del distanziale	720
		Cambiare la chiavetta	Due tipologie di chiavette. Tutte le famiglie usano la stessa tranne una	180
		Cambiare il perno di saldatura	"GRANDE" o "PICCOLO" in posizione 1,2 o 3. Dipende dal valore del distanziale	300
		Cambiare la campana di protezione	Due tipologie di campana. Tutte le famiglie usano la stessa tranne una	120

Table 27 – Mech. set up interventions

Those one in yellow are the "heavier" in term of processing time. A database for "yellow" parameters was defined.

Materiale	Diametro lamierino (190 o 198)	INSER H PACCO	ALTEZZA MYLAR	Famiglia	n° sez x Ø	n° sez x Ø	1° PRESSA		2° PRESSA	
							PIATTELLO SUP	PIATTELLO INF	PIATTELLO SUP	PIATTELLO INF
49126070000	190	129	155	SPECTER SERIE	2 x 1	2 x 0,938	A04	A01	11A	…
49126080000	190	129	155	SPECTER PARALLELO	2 x 1	2 x 0,938	A04	A01	11A	…
49126090000	190	129	155	SPECTER PARALLELO	1 x 1,06	2 x 1	A04	A01	11A	…
49126100000	190	129	155	SPECTER SERIE	0 x 0	3 x 1	A04	A01	11A	…
49126110000	190	129	155	SPECTER SERIE	1 x 0	4 x 1	A04	A01	11A	…
49126120000	190	118	142	SPECTER SERIE	1 x 1,09	2 x 1,06	A04	A01	11A	…
49126130000	190	118	142	SPECTER PARALLELO	1 x 1,09	2 x 1,06	A04	A01	11A	…
49126140000	190	118	142	SPECTER SERIE	1 x 1,06	4 x 1,09	A04	A01	11A	…
49126150000	190	118	142	SPECTER SERIE	1 x 0,97	2 x 0,95	A04	A01	11A	…
…	…	…	…	…	…	…	…	…	…	…

Table 28 – Set up parameter database

Then, for each parameter, a specific weight must be identified. I've defined the different weights in collaboration with the line-supervisor and the mechanics. Totally, fourteen parameters were fixed.

Parameter	Weight
Lamierino	20
H pacco	14
Famiglia	12
1° filo rame	8
2° filo rame	8
Piattello 1	7
Piattello 2	7
Piattello 3	7
Piattello 4	7
Distanziali	6
Accopp. aggraff.	4
Puntale 1	2
Puntale 2	2
Puntale 3	2

Table 29 – Param. weight

When a set up is performed, each parameter can be: "same" or "different". There will be non-compatible products in which most parameters differ and compatible product that allows an easy set up with a visible time reduction.

The next step is the scheduling tool procedure formalization. It is presented below.

SCHEDULING TOOL PROCEDURES

1) A Product-Code is processing

2) Taking into account any time horizon, other n Product-Codes must be scheduled

3) We consider all possible mathematically existing combinations (production plans) that are: n * (n - 1) * (n - 2) * ... * 1 = n!

4) The algorithm assigns to each production plan set up a number (there will get n values for each production plan called "non-compatibility" factor or "NOK")

5) The "NOK" factor is calculated in this way: Set Up are characterized by a series of parameters that can be the same or different. If a parameter changes, the algorithm assigns the value "1", otherwise "0". Once all the parameters have been considered, the algorithm multiplies each of them by their weight. There are 128 different types of Set Up, from the one where no one parameterm changes ("NOK" equal to 0) to the one where all the parameters different ("NOK equal to 100")

6) Summing all the "NOK" for each production plan, we obtain the "non-efficiency plan" or "DEL" factor (in total we will have as many "DEL" factors as there are production plans, then: n * (n - 1) * (n - 2) * ... * 1 = n!

7) The Plan with the minor "DEL" is the one that reduces set up time and complexity for the n products that must be scheduled

Figure 20 – Tool procedure


The algorithm was developed also through a flow chart

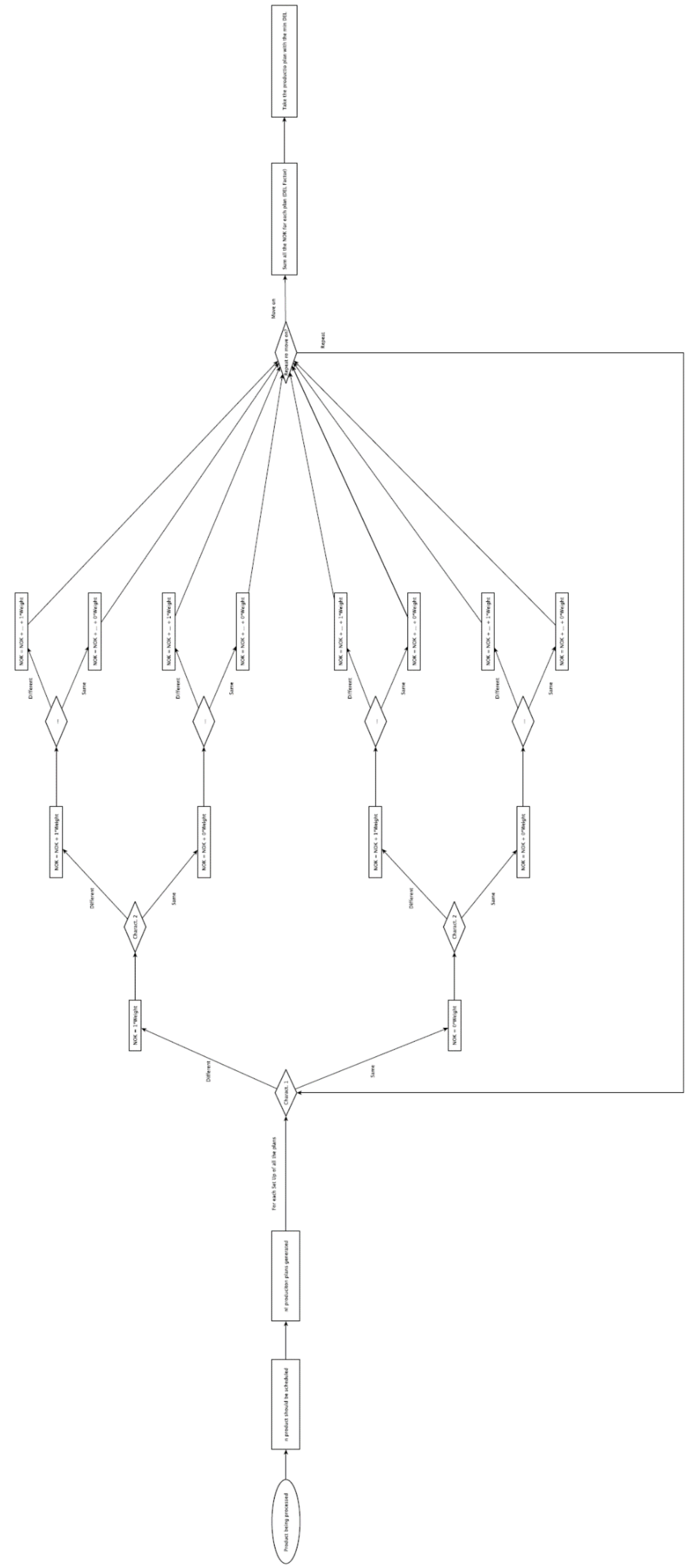


Figure 21 – Flow chart

As mentioned in the step 7 of the scheduling tool procedure, the output of the algorithm is the best possible production plan. It minimizes the set up time and the number of machine interventions.

7.2. Countermeasures Cost-Benefit analysis

Countermeasures Cost – Benefit analysis is divided in two steps. First, it is focused on the implementation cost and time evaluation of each countermeasures. Second, it esteems all the possible benefits. The cost – benefit analysis can be used as a countermeasures' "feasibility" dashboard, highlighting hypothetical not convenient scenarios.

For the Heijunka box, we got in touch directly with one of the Sisme's supplier, 4lean (http://www.4lean.net/)

The price was around 500 € and the time esteemed for the implementation was 15/20 hours. Heijunka box benefits are referred to the annual downtime reduction due to the human errors elimination. Human errors occur on average once a week and they have an impact on downtimes equal to 8 minutes. Considering fifty working weeks in a year, the annual downtime reduction thanks to the Heijunka box is 400 minutes (6,67 hours). The downtime reduction can also be exploited economically. Discussing with the head of S&OP, we decided to exploiting the line-operator overtime saved. The overtime cost per hour is 22,5 €/h. The average number of line-operators who are currently working on 605-line is 10. Multiplying the annual downtime reduction, the overtime cost and the avg. number of line-operator, the annual economical saving related to the Heijunka box is 1500€.

The second countermeasures listed is the tool-holder with electric maintenance interventions basic instruments. This countermeasure allows to avoid the time wasted by the operators who walk the way from the electric maintenance HQ to the 605-Line two or three times to collect instruments necessary for the interventions. The tool-holder price is 300 € and the countermeasure implementation time is around 5 hours.

The downtime reduction evaluation was computed subtracting form the electric maintenance intervention annual time (number of electric maintenance interventions per year multiplied for the average intervention time) the time without wastes. The number of electric maintenance interventions in a year are 54 and the average time for an intervention is equal to 22,19 minutes.

The annual downtime reduction related to the elimination of the walking time along the electric maintenance HQ and the 605-Line way is 7,2 hours. As for the human errors case, this value can be translated in economic terms.

Multiplying the annual downtime reduction, the overtime costs and the number of line-operators, the annual economical saving related to the tool-holder with basic electric maintenance instruments is 1620 €.

The self-control countermeasure aims to shift the 55% of the mechanic set up interventions and the 26% of quality checks in the check list to the line-operator. Time esteemed for "Self-Control" implementation is 30 hours. Benefit related to this countermeasure are two. On the on hand, the line-operators self-control process reduces downtime eliminating overlapping situations in which mechanics are forced to postpone one activity between maintenance intervention or set up. On the other, it leaves more time to mechanics and quality operators to focus on other more important activities.

For each batch, probability of overlapping between mechanical intervention and set up is 50%. On average, the downtime impact related to postpone one of the two tasks is 5 minutes. So, the annual downtime reduction due to the "overlap" elimination is 1110 minutes. Multiplying the downtime reduction, the overtime costs and the avg. number of line-operators, the economical saving is 4163 €.

In the table below, all the mechanic set up activities are listed.

Fase	Operazione	Tempo [min]	Occurrence	Time*Occ.
10	Impostazione altezza sulla macchina	1	100%	1
	Cambiare campana, piattello e pinze	7	20%	1,4
20	Cambiare il Mylar	6	60%	3,6
30	Impostazione prg. Winder e prg. RWE	1	100%	1
	Impostazione altezza sulla macchina	1	100%	1
50	Cambiare il puntale del bucatore. L'allargatore non cambia mai	4	50%	2
70	Impostazione prg. Winder e prg. RWE	1	100%	1
	Impostazione altezza sulla macchina	1	100%	1
90	Cambiare il puntale del bucatore. L'allargatore non cambia mai	4	50%	2
100	Montare l'anello	2	20%	0,4
110	Impostazione prg. Winder e prg. RWE	1	100%	1
	Impostazione altezza sulla macchina	1	100%	1
130	Cambiare il puntale del bucatore	4	50%	2
160	Cambiare piattello superiore	6	50%	3
	Regolazione della pressata superiore	2	50%	1
	Cambiare piattello inferiore	6	50%	3
	Regolazione della pressata inferiore	2	50%	1
	Cambio delle graffette	3	20%	0,6
219	Impostare il prg. Aggraffatrice	1	100%	1
	In base all'accoppiamento Grnd. Attrezz. - Svil. Graff. devono essere cambiate le componenti	8	30%	2,4
	Sostituzione del blocchetto	2	20%	0,4
260	Cambiare piattello superiore	6	50%	3
	Regolazione della pressata superiore	2	50%	1
	Cambiare piattello inferiore	6	50%	3
	Regolazione della pressata inferiore	2	50%	1
280	Impostazione del prg. della macchina	1	100%	1
	Impostazione dell'altezza	1	100%	1
340	Impostazione del prg. della macchina	1	100%	1
	Cambiare i distanziali di callettamento e saldatura	12	50%	6
	Cambiare la chiavetta	3	10%	0,3
	Cambiare il perno di saldatura	4	50%	2
	Cambiare la campana di protezione	2	10%	0,2

Table 30 – Mech. “shifted” tasks

Mechanic set up activities that will be shifted are highlighted in red. In order to consider the right time spent by mechanic involved with the set up, the processing time of each activities were multiplied by its occurrence. The actual mechanic set up involvement time is on average 50,3 minutes (0,84 hours). The self-control process shifts the 52% of this time to line-operators, 26 minutes (0,45 hours). 605-line provides on average 444 set up. Multiplying 0,45 [h] * 444 [set up] * 22,5 [€/h] the economical saving is 4629 €.

The same for quality checks.

FASE	QUALITY CHECK	Tempo [min]
10	Verifica funzionale macchina aggraffatura pacchi (con Master)	3
	Verifica dei parametri impostati in macchina aggraffatura pacchi	1
30	Verifica dei parametri impostati in bobinatrice (n° spire, codice modello), Ø filo rame e n° sezioni, presenza marchio "G2"	4
40	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	1,5
60	Controllo visuale dello statore e del suo corretto isolamento	1,5
70	Verifica dei parametri impostati in bobinatrice (n° spire, codice modello), Ø filo rame e n° sezioni, presenza marchio "G2"	4
80	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	1,5
100	Controllo visuale dello statore e del suo corretto isolamento	1,5
110	Verifica dei parametri impostati in bobinatrice (n° spire, codice modello), Ø filo rame e n° sezioni, presenza marchio "G2"	4
120	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	1,5
170	Misura delle resistenze mediante tester (riportarle a 25°C) e dell'altezza pacco e delle quote flat (dove previsto) mediante calibro a corsoio; registrare i valori in SPC. Controllo visuale dello statore	10
180	Verifica del posizionamento dei termistori (come da disegno)	2
190	Verifica dell'altezza delle graffette (termistori) & Effettuare le prove di trazione e registrare i valori in SPC	3
210	Controllo timbratura codice compressore (dove previsto)	1
219	Verifica dei parametri impostati in aggraffatrice	1
	Verifica altezza delle graffette e l'assenza di bave & Effettuare la prova di trazione manuale e registrare i valori in SPC.	3
250	Verifica del corretto posizionamento dei cappucci isolanti	1
255	Verifica del corretto set-up dell'apparecchiatura e della posizione del Datamatrix	2
	Controllo della posizione di protettore, uscita conduttori e loro lunghezza	1
	Verifica del corretto inserimento dei faston su protettore tipo UBUKATA DFXX o Sensata tipo 32/33 HM (dove previsto)	1,5
300	Verifica funzionale apparecchiatura controllo elettrico A3 & Verifica dei parametri impostati in apparecchiatura A3 e del circuito di terra/presenza pezzo (aggiungere 0,1 mA)	-
	Controllo visuale generale dello statore	2
340	Controllo visuale generale statore & Verifica del codice della carcassa, quota incarcassamento, posizione radiale e visuale saldature (dove previsto)	3

Table 31 – Quality "shifted" tasks

Quality operator involvement time processing all the checks in the check list is 54 minutes (0,9 hours). The self-control process shifts the 20% of this time to line-operators, 14 minutes (0,23 hours). Check list is carried out every set up, so, 444 times.

As for mechanics, multiplying 0,23 [h] * 444 [set up] *22,5 [€/h] the economical saving is 2331 €. Total economical saving related to self-control countermeasures is 11122 €.

The set up scheduling tool is realized by a computer programmer external to Sisme. The implementation time is around 40 hours and the estimate amounts to 3000 €.

Set up scheduling tool benefit consists in 33,85% set up time reduction, with the 32,35% of the interventions avoided.

These percentages derive from a simulation in which a real 605-line production plan is compared with an optimized one, output of the algorithm.

In the Excel tables below, all the simulation steps are shown.

First of all, the time horizon must be decided. In this simulation, two weeks, from 30th august to 10th September, has been taken as case study. This below is the real 605-line's plan.

Piano Reale		
MODELLO 49	ARTICOLO	DATA
49130490000	B13049	31/08/2020
49129850020	B12985/20	31/08/2020
49131300020	B13130/20	31/08/2020
49139050000	B13905	31/08/2020
49133310000	B13331	01/09/2020
49127340000	B12734	01/09/2020
49134210000	B13421	01/09/2020
49127360000	B12736	02/09/2020
49131600000	B13160	02/09/2020
49129120020	B12912/20	02/09/2020
49128740000	B12874	03/09/2020
49128760000	B12876	03/09/2020
49131230000	B13123	03/09/2020
49131310020	B13131/20	03/09/2020
49126820010	B12682/10	03/09/2020
49126070000	B12607	03/09/2020
49139050000	B13905	07/09/2020
49123150010	B12315/10	08/09/2020
49129840020	B12984/20	08/09/2020
49129030000	B12903	09/09/2020
49141530000	B14153	09/09/2020
49139090000	B13909	10/09/2020

Table 32 – Real 605-line plan

Then, the algorithm generates the n! possible combinations of the different plans.

Combinazioni	1		2		…	n	
Codice	MODELLO	ARTICOLO	MODELLO	ARTICOLO		MODELLO	ARTICOLO
0	49130490000	B13049	49130490000	B13049		49130490000	B13049
1	49129850020	B12985/20	49131300020	B13130/20		49131300020	B13130/20
2	49131300020	B13130/20	49129850020	B12985/20		49129850020	B12985/20
3	49139050000	B13905	49139050000	B13905		49139050000	B13905
4	49133310000	B13331	49133310000	B13331		49133310000	B13331
5	49127340000	B12734	49127340000	B12734		49127340000	B12734
6	49134210000	B13421	49134210000	B13421		49134210000	B13421
7	49127360000	B12736	49127360000	B12736		49127360000	B12736
8	49131600000	B13160	49131600000	B13160		49131600000	B13160
9	49129120020	B12912/20	49129120020	B12912/20		49129120020	B12912/20
10	49128740000	B12874	49128740000	B12874		49128740000	B12874
11	49128760000	B12876	49128760000	B12876		49128760000	B12876
12	49131230000	B13123	49131230000	B13123		49131230000	B13123
13	49131310020	B13131/20	49131310020	B13131/20		49131310020	B13131/20
14	49126820010	B12682/10	49126820010	B12682/10		49126820010	B12682/10
15	49126070000	B12607	49126070000	B12607		49126070000	B12607
16	49139050000	B13905	49139050000	B13905		49139050000	B13905
17	49123150010	B12315/10	49123150010	B12315/10		49123150010	B12315/10
18	49129840020	B12984/20	49129840020	B12984/20		49129840020	B12984/20
19	49129030000	B12903	49129030000	B12903		49129030000	B12903
20	49141530000	B14153	49141530000	B14153		49139090000	B13909
21	49139090000	B13909	49139090000	B13909		49141530000	B14153

Table 33 – Combinations

The algorithm assigns for each set up of the n! production plan the “NOK” factor. Sum of all the “NOK” for a specific production plan is the “DEL” factor.

Combinazioni	1	2	…	n
NOK 1	51	90		44
NOK 2	49	18		87
NOK 3	59	110		115
NOK 4	120	61		78
NOK 5	16	49		67
NOK 6	3	50		50
NOK 7	61	67		67
NOK 8	61	3		42
NOK 9	102	70		89
NOK 10	18	69		39
NOK 11	85	110		75
NOK 12	63	25		110
NOK 13	36	3		10
NOK 14	94	120		98
NOK 15	74	15		44
NOK 16	79	70		110
NOK 17	36	75		9
NOK 18	119	106		42
NOK 19	89	85		6
NOK 20	38	66		66
NOK 21	6	78		91
DELATE	**1259**	**1340**		**1339**

Table 34 – “NOK” and “DEL”

The production plan with the minor "DEL" is the one that reduces set up time and the number of interventions.

Combinazioni	Ottimo
NOK 1	31
NOK 2	26
NOK 3	13
NOK 4	67
NOK 5	5
NOK 6	58
NOK 7	79
NOK 8	44
NOK 9	30
NOK 10	45
NOK 11	67
NOK 12	50
NOK 13	51
NOK 14	69
NOK 15	75
NOK 16	44
NOK 17	89
NOK 18	96
NOK 19	38
NOK 20	50
NOK 21	53
DELATE	**1080**

Table 34 – Best "DEL"

Set up time confrontation shows 65 minutes time reduction (33,85%).

Piano Reale		
MODELLO 49	**ARTICOLO**	**Set Up**
49130490000	B13049	-
49129850020	B12985/20	6
49131300020	B13130/20	8
49139050000	B13905	10
49133310000	B13331	8
49127340000	B12734	12
49134210000	B13421	8
49127360000	B12736	10
49131600000	B13160	10
49129120020	B12912/20	8
49128740000	B12874	10
49128760000	B12876	10
49131230000	B13123	10
49131310020	B13131/20	10
49126820010	B12682/10	4
49126070000	B12607	10
49139050000	B13905	8
49123150010	B12315/10	10
49129840020	B12984/20	3
49129030000	B12903	15
49141530000	B14153	10
49139090000	B13909	12
192		

Piano Ottimo		
MODELLO 49	**ARTICOLO**	**Set Up**
49130490000	B13049	-
49131310020	B13131/20	6
49126820010	B12682/10	4
49129850020	B12985/20	5
49129840020	B12984/20	3
49123150010	B12315/10	4
49131300020	B13130/20	5
49139050000	B13905	10
49139050000	B13905	0
49139090000	B13909	8
49126070000	B12607	8
49133310000	B13331	5
49131230000	B13123	5
49128760000	B12876	10
49141530000	B14153	8
49128740000	B12874	8
49131600000	B13160	8
49129120020	B12912/20	6
49129030000	B12903	6
49127360000	B12736	8
49127340000	B12734	4
49134210000	B13421	6
127		

Table 35 – Set up time confrontation

For each set up, the different parameters considered can be the same or different. If a parameter change, a machine intervention is required, otherwise not. The real 605-line production plan require 102 set up interventions on machines. The optimized plan 69 thirty-three less (the 32,35%).

REAL PLAN

Materiale	MODELLO	Diametro lamierino (190 o 198)	INSER H PACCO	Famiglia	n° sez x Ø	n° sez x Ø	1° PRESSA		2° PRESSA		Incarcassatrice				Aggraffatura connessioni (3-15, 2-17, 2-20, 1-20, 1-23		Bucatura 1° strato	Bucatura 2° strato	Bucatura 3° strato
							PIATTELLO SUP	PIATTELLO INF	PIATTELLO SUP	PIATTELLO INF	DISTANZIALI CALETT.	DISTANZIALI SALDAT.	PERNO SALDAT.	POS. PERNO SALDAT.	GRANDEZZA ATTREZZATURA	SVILUPPO GRAFFETTA	PUNTALE	PUNTALE	PUNTALE
49130490000	DANFOSS STAT.190 DA IMPR.	190	89,5	PERFORMER SERIE	0 x 0	4 x 1,06	A04	A01	11A	12A					2	20	45°	75°	75°
49129850020	DANFOSS STAT.190 DA IMPR.	190	89,5	PERFORMER SERIE			A03	A01	10A	12A					3	15	45°	75°	70°
49131300020	DANFOSS STAT.190 DA IMPR.	190	70,5	PERFORMER SERIE			A03	A01	10A	12A					2	17	45°	75°	75°
49139050000	EMERSON STAT.190 2P 142 LCS DA IMPR.	190	142	EMERSON LCS HP 142 SERIE	1 x 1,06	3 x 1,02	A04	A01	11A	12A					2	20	45°	75°	85°
49133310000	GEABOCK STAT.190 2P 102 DA IMPR.	190	102,2	GEABOCK	0 x 0	3 x 1,02	A04	A01	11A	12A					2	17	45°	75°	75°
49127340000	DANFOSS STAT.198 2P 142 PERF.4 DA IMPR.	198	142	PERFORMER SERIE	2 x 1	3 x 1,02	A05	A01	11A	12A	180,75	69,6	GRANDE	1	1	20	45°	75°	75°
49134210000	DANFOSS STAT.198 2P 142 PERF.1 DA IMPR.	198	142	PERFORMER SERIE	3 x 1,02	1 x 1,06	A05	A01	11A	12A	-/184,25	-/73,1	GRANDE	1	2	20	45°	75°	70°
49127360000	DANFOSS STAT.198 2P 160 PERF.4 DA IMPR.	198	160	PERFORMER SERIE	2 x 1,09	3 x 1,06	A05	A01	11A	12A	180,75	69,6	GRANDE	1	1	20	45°	75°	75°
49131600000	ST.BTZ 198 DA IMPREGNARE	198	114	BITZER 198	1 x 1,02	2 x 1,06	A05	A01	11A	12A	225	113,6	PICCOLO	3	2	20	45°	75°	70°
49129120020	DANFOSS STAT.198 PF1 DA IMPR.	198	114	PERFORMER SERIE			A05	A01	11A	12A	197,25	85,8	GRANDE	2	2	17	45°	75°	70°
49128740000	ST.BTZ 198 DA IMPREGNARE	198	83,2	BITZER 198	1 x 1,09	1 x 1,06	A05	A01	11A	12A	202,2	90,8	PICCOLO	3	2	17	45°	75°	70°
49128760000	ST.BTZ 198 DA IMPREGNARE	198	108,6	BITZER 198	1 x 1,02	2 x 1	A05	A01	11A	12A	176,55	65,4	PICCOLO	3	2	20	45°	70°	75°
49131230000	ST. BTZ 190 DA IMPREGNARE	190	108,6	BITZER 190	1 x 0,95	2 x 1	A04	A01	11A	12A					2	17	45°	70°	75°
49131310020	DANFOSS STAT.190 DA IMPR.	190	89,5	PERFORMER SERIE			A03	A01	10A	12A					2	20	45°	75°	75°
49126820010	DANFOSS STAT.190 DA IMPR.	190	89,5	PERFORMER SERIE			A03	A01	10A	12A					2	17	45°	75°	70°
49126070000	EMERSON STAT.190 2P 129 SPECTER DA IMPR	190	129	SPECTER SERIE	2 x 1	2 x 0,938	A04	A01	11A	12A					2	20	45°	75°	75°
49139050000	EMERSON STAT.190 2P 142 LCS DA IMPR.	190	142	EMERSON LCS HP 142 SERIE	1 x 1,06	3 x 1,02	A04	A01	11A	12A					2	20	45°	75°	85°
49123150010	DANFOSS STAT.190 DA IMPR.	190	70,5	PERFORMER SERIE			A03	A01	10A	12A					3	15	45°	75°	75°
49129840020	DANFOSS STAT.190 DA IMPR.	190	70,5	PERFORMER SERIE			A03	A01	10A	12A					3	15	45°	75°	70°
49129030000	DANFOSS STAT.198 2P 129 PERF.1 DA IMPR.	198	129	PERFORMER PARALLELO	2 x 0,95	2 x 1	A05	A01	11A	12A	197,25	85,8	GRANDE	2	1	20	45°	75°	70°
49141530000	BITZER STAT.198 2P 171 GSD8	198	171	BITZER 198	2 x 1,09	2 x 1,06	A05	A01	11A	12A	169,75	58,1	GRANDE	1	1	20	45°	70°	75°
49139090000	EMERSON STAT.190 2P 160 LCS	190	160	EMERSON LCS HP 142 SERIE	1 x 1,12	3 x 1,09	A04	A01	11A	12A					1	20	60°	75°	75°
102		4	15	\	\		9	0	6	0	9	9	5	6	8	13	1	3	14

OPTIMAL PLAN

Materiale	MODELLO	Diametro lamierino (190 o 198)	INSER H PACCO	Famiglia	n° sez x Ø	n° sez x Ø	1° PRESSA		2° PRESSA		Incarcassatrice				Aggraffatura connessioni (3-15, 2-17, 2-20, 1-20, 1-23		Bucatura 1° strato	Bucatura 2° strato	Bucatura 3° strato
							PIATTELLO SUP	PIATTELLO INF	PIATTELLO SUP	PIATTELLO INF	DISTANZIALI CALETT.	DISTANZIALI SALDAT.	PERNO SALDAT.	POS. PERNO SALDAT.	GRANDEZZA ATTREZZATURA	SVILUPPO GRAFFETTA	PUNTALE	PUNTALE	PUNTALE
49130490000	DANFOSS STAT.190 DA IMPR.	190	89,5	PERFORMER SERIE	0 x 0	4 x 1,06	A04	A01	11A	12A					2	20	45°	75°	75°
49131310020	DANFOSS STAT.190 DA IMPR.	190	89,5	PERFORMER SERIE			A03	A01	10A	12A					2	20	45°	75°	75°
49126820010	DANFOSS STAT.190 DA IMPR.	190	89,5	PERFORMER SERIE			A03	A01	10A	12A					2	17	45°	75°	70°
49129850020	DANFOSS STAT.190 DA IMPR.	190	89,5	PERFORMER SERIE			A03	A01	10A	12A					3	15	45°	75°	70°
49129840020	DANFOSS STAT.190 DA IMPR.	190	70,5	PERFORMER SERIE			A03	A01	10A	12A					3	15	45°	75°	70°
49123150010	DANFOSS STAT.190 DA IMPR.	190	70,5	PERFORMER SERIE			A03	A01	10A	12A					3	15	45°	75°	75°
49131300020	DANFOSS STAT.190 DA IMPR.	190	70,5	PERFORMER SERIE			A03	A01	10A	12A					2	17	45°	75°	75°
49139050000	EMERSON STAT.190 2P 142 LCS DA IMPR.	190	142	EMERSON LCS HP 142 SERIE	1 x 1,06	3 x 1,02	A04	A01	11A	12A					2	20	45°	75°	85°
49139050000	EMERSON STAT.190 2P 142 LCS DA IMPR.	190	142	EMERSON LCS HP 142 SERIE	1 x 1,06	3 x 1,02	A04	A01	11A	12A					2	20	45°	75°	85°
49139090000	EMERSON STAT.190 2P 160 LCS	190	160	EMERSON LCS HP 142 SERIE	1 x 1,12	3 x 1,09	A04	A01	11A	12A					1	20	60°	75°	75°
49126070000	EMERSON STAT.190 2P 129 SPECTER DA IMPR	190	129	SPECTER SERIE	2 x 1	2 x 0,938	A04	A01	11A	12A					2	20	45°	75°	75°
49133310000	GEABOCK STAT.190 2P 102 DA IMPR.	190	102,2	GEABOCK	0 x 0	3 x 1,02	A04	A01	11A	12A					2	17	45°	75°	75°
49131230000	ST. BTZ 190 DA IMPREGNARE	190	108,6	BITZER 190	1 x 0,95	2 x 1	A04	A01	11A	12A					2	17	45°	70°	75°
49128760000	ST.BTZ 198 DA IMPREGNARE	198	108,6	BITZER 198	1 x 1,02	2 x 1	A05	A01	11A	12A	176,55	65,4	PICCOLO	3	2	20	45°	70°	75°
49141530000	BITZER STAT.198 2P 171 GSD8	198	171	BITZER 198	2 x 1,09	2 x 1,06	A05	A01	11A	12A	169,75	58,1	GRANDE	1	1	20	45°	70°	75°
49128740000	ST.BTZ 198 DA IMPREGNARE	198	83,2	BITZER 198	1 x 1,09	1 x 1,06	A05	A01	11A	12A	202,2	90,8	PICCOLO	3	2	17	45°	75°	70°
49131600000	ST.BTZ 198 DA IMPREGNARE	198	114	BITZER 198	1 x 1,02	2 x 1,06	A05	A01	11A	12A	225	113,6	PICCOLO	3	2	20	45°	75°	70°
49129120020	DANFOSS STAT.198 PF1 DA IMPR.	198	114	PERFORMER SERIE			A05	A01	11A	12A	197,25	85,8	GRANDE	2	2	17	45°	75°	70°
49129030000	DANFOSS STAT.198 2P 129 PERF.1 DA IMPR.	198	129	PERFORMER PARALLELO	2 x 0,95	2 x 1	A05	A01	11A	12A	197,25	85,8	GRANDE	2	1	20	45°	75°	70°
49127360000	DANFOSS STAT.198 2P 160 PERF.4 DA IMPR.	198	160	PERFORMER SERIE	2 x 1,09	3 x 1,06	A05	A01	11A	12A	180,75	69,6	GRANDE	1	1	20	45°	75°	75°
49127340000	DANFOSS STAT.198 2P 142 PERF.4 DA IMPR.	198	142	PERFORMER SERIE	2 x 1	3 x 1,02	A05	A01	11A	12A	180,75	69,6	GRANDE	1	1	20	45°	75°	75°
49134210000	DANFOSS STAT.198 2P 142 PERF.1 DA IMPR.	198	142	PERFORMER SERIE	3 x 1,02	1 x 1,06	A05	A01	11A	12A	-/184,25	-/73,1	GRANDE	1	2	20	45°	75°	70°
69		1	12	\	\		3	0	2	0	7	7	3	5	8	10	2	2	7

Table 36 – Set up interventions confrontation

The set up interventions are highlighted in red.

Multiplying the “weekly” set up time reduction (32,5 minutes) for 50 weeks in a year, the annual downtime reduction related to the scheduling production plan optimization is 1625 minutes. To determine the economical saving of the countermeasure, it is also crucial to take into consideration how the 32,35% of set up interventions avoided impact on 605-line workers. Set up involvement is approximately divided in this way:

- Line – supervisor | 10%
- Quality operator | 20%
- Mechanic | 30%
- Line – operators | 40%

Set up on average covers 2 hours of the 8 available working hours in a day. Multiplying the annual amount of set up hours, the specific involvement of each 605-line figures, the overtime cost and the percentage of interventions avoided, the annual economical saving is 17595 €.

Total economical saving of the set up scheduling tool countermeasures is 23689 €.

In the table below, the countermeasures cost-benefit analysis is summarised.

Countermeasure	Cost	Benefit	Annual Downtime Reduction [min]	Annual Saving [€/y]	Tot. Cost	Tot. Saving [€]	Delta
Heijunka Box	5/10 hours & 500 €	Human errors elimination	400	1500	3800	37931	34131
Wasted time in el. Interv.	5 hours & 300 €	Wasted Time elimination	432	1620			
Self-Control	30 hours	Overlap "elimination" and 55% mech. Involvment set up time and 26% quality checks time reduction	1110	11122			
Set Up Scheduling Tool	40 hours & 3000 €	33,8% Set Up Time reduction and 32,3% inetreventions avoided	1625	23689			

Table 37 – Count. cost-benefit analysis

The total cost of the different countermeasures amounts to 3800 €. The total economical saving is 37931 €.

Countermeasures Implementation

The "countermeasure implementation" phase consists in put into practice the theoretical analysis of the "development Countermeasure".

The Heikunka box first step was the uploading on SAP of the Excel database with the order cards information. Some of them were already on SAP (like the BOM) while the majority still had to be uploaded. During this phase I've collaborated with the IT manager who performed this task.

Then, we had to work on the SAP printing program. This step took time because the aim was the creation of something parametrizable and, therefore, easily replicable. In other words, once defined the SAP printing program, any type of card should be created. Cards can be related to different lines, but they derive from the same printing program in which suitable items will be selected.

As mentioned in the "Development countermeasures" phase for each box there will be two cards, one for production and one for mechanics.

This is the Sap print for “Production order cards”.

PRODUZIONE

SISME	Ordine: / 000000		Codice materiale: 49131900000	
	Definizione prodotto: ST. BTZ 190 DA IMPREGNARE		Numero dell'ordine: 1101302	Quantità dell'ordine: 100 NR
Responsabile MRP: 605 Resp. 605	Famiglia: AH	Tipo di ordine: PP01 Ordine di	Inizio: 27.11.2020	Fine: 30.11.2020
Stato: RIL. MADM STMP CALP EDCO RSCO		Divisione: PL00 Sisme IT	Versione produzione: -	Data di creazione: 27.11.2020
Informazioni sul progetto: STAMPIGLIATURA ETICHETTA NOMEX				

Classificazione

		LAMIERINO	
		ALTEZZA MYLAR	134 MM
		INSER H PACCO	
		n° sez x Ø	
		n° sez x Ø	
0030	Bobinatura primo strato	PRG WINDER	
0031	Bobinatura primo strato	PRG RWE	
0040	Spelat. E sist. 1 strato	PRG. SOLLEVATORE	
0040	Spelat. E sist. 1 strato	PRG SPELATURA	
0070	Bobinatura 2°strato	PRG WINDER	
0071	Bobinatura 2°strato	PRG RWE	
0080	Spelat. E sist. 2 strato	PRG. SOLLEVATORE	
0080	Spelat. E sist. 2 strato	PRG SPELATURA	
0100	Montaggio H 2° strato	ANELLO	
0110	Bobinatura 3°strato	PRG WINDER	
0111	Bobinatura 3°strato	PRG RWE	
0120	Spelat. E sist. strato	PRG. SOLLEVATORE	
0120	Spelat. E sist. 3 strato	PRG SPELATURA	
0140	Rotazione Pallet	INCL / ESCL	
0190	Aggraffatura termistori	SELETTORE	
0190	Aggraffatura termistori	GRAFFETTA	1
0210	Timbratura	SELETTORE	
0219	Aggraffatura connessioni	PRG	184
0219	Aggraffatura connessioni	PRG	184
0255	Marcatura Cluster	CLUSTER	
0255	Marcatura Cluster	PRG MARCATURA	
0260	Pressatura formatura finale	TASSELLO	
0260	Pressatura formatura finale	POS SELETTORE	
0280	Cucitura	GUIDE PACCO	
0280	Cucitura	PROGRAMMA	12
0300	Collaudo el. e timbratura	TIMBRATURA FIANCO	
0340	Incarcassamento e saldatura	PROGRAMMA	13

Componenti

Pos.-Nr.		Materiale	Q.tà		Ubicazione
0000	15604000000	NAST.X TRASF.TERMICO	2,800	M	1A0
0000	16509380000	FILO RAME 0.938 mm	348	KG	
0000	16510000000	FILO RAME 1.00 mm	132	KG	
0000	18301800790	NASTRO NOMEX X ETICH	0,040	KG	5B3*
0000	18703500150	MYLAR PRESSAFILO	4,160	KG	C-7-6*
0000	18703501340	NASTRO MYLAR	10,050	KG	C-3*
0000	20128770010	CARCS.BITZ.83-90-108	100	NR	IS1
0000	20218950010	LAM.STAT. 198 2P	1.445,070	KG	
0000	20219150010	LAM.STAT. 198 2P BATT.	15,800	KG	
0000	20327220030	ISOL.H 108,6	200	NR	2A1
0000	20328420030	ISOL.H 108.6	200	NR	2A1
0000	20329360030	ISOL.H 108,9	200	NR	2A1
0000	20330200030	ISOL.H 108,6	200	NR	2A1
0000	20406840000	SPAGO X ERMETICI	2.210	M	4B1*
0000	20415300030	ISOL. DI SALDATURA	200	NR	6B3*
0000	20416510010	TUBETTO ISOL. INCROCI	300	NR	6B5*/SK
0000	20416510040	TUBETTO ISOL. INCROCI	200	NR	6B5*
0000	20416510110	TUBETTO ISOL. INCROCI	100	NR	6B5*
0000	20417160090	TUBO DI PROTEZIONE	100	NR	TV2
0000	20417180050	ISOLANTE DI SALDATURA	400	NR	TV2*
0000	20418100030	RIVET.XDEFLET.BITZ2P	200	NR	2A3*
0000	20418420010	LACCIO X ERMETICO	100	NR	6A5*
0000	20418690010	PIATT.AGGRAFF.CONDUT	8,100	M	4A1*
0000	20418830000	DEFLETTORE X BITZ.2P	100	NR	1A3*
0000	20419210010	TERMIST.TRIPLO 100 C	100	NR	2A3
0000	20419500070	ETICH.NOMEX	100	NR	
0000	30406460030	PIAT.AGRAF.PAC10X0,9	7,020	KG	
0000	30418770010	CONNETTORE	200	NR	7B3*
0000	40335360050	GRUPPO COND.ASS.	100	NR	4B1*

Figure 22 – Production card print

The card is printed on an A4 size paper. On top there are some information related to the line: the Order Code, the Product Code and the beginning and the end batch dates. Below this information, there is the Bill of Material and then all the production process parameters. The most important are presented first (sheet diameter, pack hight, Myler hight, family and the copper wire). It was important insert the production phase because, for example, the phase 30 line-operator does not waste time looking for the information he needs, among the other.

The same is for the mechanic cards. The SAP print is presented below.

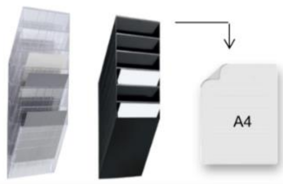
MANUTENZIONE

SISME	Ordine: / 000000		Codice materiale 49131900000	
	Definizione prodotto ST. BTZ 190 DA IMPREGNARE		Numero dell'ordine 1101302	Quantità dell'ordine 100 NR
Responsabile MRP 605 Resp. 605	Famiglia AH	Tipo di ordine PP01 Ordine di	Inizio 27.11.2020	Fine 30.11.2020
Stato RIL. MADM STMP CALP EDCO RSCO		Divisione PL00 Sisme IT	Versione produzione -	Data di creazione 27.11.2020

0111	Bobinatura 3°strato	PRG RWE	
0120	Spelat. E sist. strato	PRG. SOLLEVATORE	
0120	Spelat. E sist. 3 strato	PRG SPELATURA	
0130	Bucatura 3° strato	PUNTALE	75
0140	Rotazione Pallet	INCL / ESCL	
0160	Pressatura form. Matasse	PIATTELLO INF	
0160	Pressatura form. Matasse	REG PRESSATA INF	0
0160	Pressatura form. Matasse	PIATTELLO SUP	
0160	Pressatura form. Matasse	REG PRESSATA SUP	0
0190	Aggraffatura termistori	SELETTORE	
0190	Aggraffatura termistori	GRAFFETTA	1
0210	Timbratura	SELETTORE	
0219	Aggraffatura connessioni	GRAND. ATTREZ.	2
0219	Aggraffatura connessioni	GRAND. ATTREZ.	2
0219	Aggraffatura connessioni	SVILUPPO GRAFFETTA	20
0219	Aggraffatura connessioni	SVILUPPO GRAFFETTA	20
0219	Aggraffatura connessioni	PRG	184
0219	Aggraffatura connessioni	PRG	184
0255	Marcatura Cluster	CLUSTER	
0255	Marcatura Cluster	PRG MARCATURA	
0260	Pressatura formatura finale	POS SELETTORE	
0260	Pressatura formatura finale	PIATTELLO INF	
0260	Pressatura formatura finale	REG PRESSATA INF	0
0260	Pressatura formatura finale	TASSELLO	
0260	Pressatura formatura finale	REG PRESSATA SUP	0
0260	Pressatura formatura finale	PIATTELLO SUP	
0280	Cucitura	PROGRAMMA	12
0280	Cucitura	GUIDE PACCO	
0300	Collaudo el. e timbratura	TIMBRATURA FIANCO	
0340	Incarcassamento e saldatura	CAMPANA DI PROT.	
0340	Incarcassamento e saldatura	CHIAVETTA	
0340	Incarcassamento e saldatura	DISTANZIALI CALETT.	177
0340	Incarcassamento e saldatura	DISTANZIALI SALDAT.	65
0340	Incarcassamento e saldatura	PERNO SALDAT.	
0340	Incarcassamento e saldatura	POS. PERNO SALDAT.	3
0340	Incarcassamento e saldatura	PROGRAMMA	13

Figure 23 – Mech. card print

This below, is the Heijunka box bought from 4lean.



Acrylic document pocket slim Porta documentos em acrílico / Porta documenti acrilico /Porta documentos acrílico/ Porte document acrylique		
Reference Referência/Articolo Referencia/Référence	Dimensions (H*W*D) Dimensões / Dimensioni / Dimensiones / Dimensions	Colours Cores/Colore Colores/Couleur
B-VB649*	690*240*135 mm	T ☐ P ■

The tool-holder with the basic instrument for electric maintenance interventions was the fastest countermeasures to implement. It takes about five hours and the cost for the tool-holder was 300 €.

Firstly, in collaboration with the electric maintenance operators, we have created a list of the most frequent interventions. It came also from the observation phase of the first weeks.

- Profibas change | Frequency: Two times a day
- Electric machine reset | Frequency: Once a day
- Micro sensors change | Frequency: Once a week
- Broken component replacement | Frequency: Twice a month

Once we have defined the most frequent interventions, the operators decided the instruments to put on the tool-holder. Finally, it was placed near the 605-line in the up-right corner.

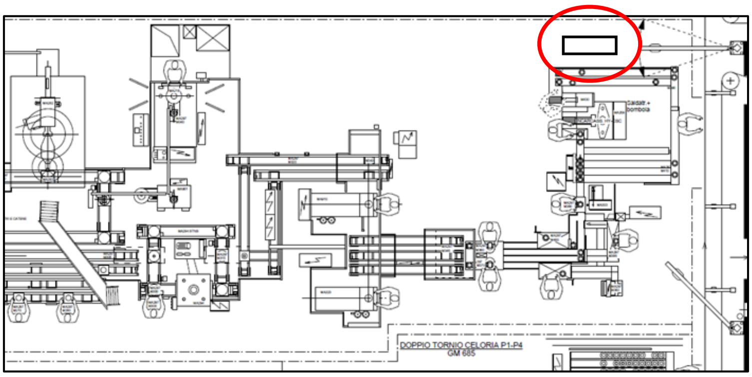


Figure 24 – Tool-holder location

The Self-Control countermeasure implementation was quite easy, but with some tricky issues. The first implementation step was the decision about which operators have to perform the shifted task. We have decided to separate between “easy” tasks and “not for all” tasks. “Easy” tasks can be carried out by everyone. In the contrary, “Not for all” task need to be assigned to a specific figure. As the name suggest, the operator must be chosen carefully. Specific security notes and technical instruments are needed to carry out these specific tasks.

So, in collaboration with the quality manager, the maintenance manager and the line supervisor, we created a list with the most suitable 605-line operators. This step was particularly important, we had to modify the operator “Competence matrix”. Shifting a task from mechanic or quality operator to line-operator means increase both his skills and his responsibilities. This was the massage we wanted to spread. One of the self-control countermeasures issues emerged regarded the line-operators feedback. There could be the possibility they intended the self-control project as additional work, instead it is exactly the opposite. The self-control aims to balance in a better way the workload. The line-supervisor organized a meeting in which he explained to the operators all the details. Then, the different procedures (showed in the “developing countermeasure “ phase) were placed in their specific station and, during the first weeks, at the mechanics were asked to assist the operator in performing the new “shifted” tasks.

Regarding the NVA quality checks, they were eliminated from the check list. The only consideration regards the copper coil control. We introduce the “Controllo del rame” module. The operator who works at the specific welding machine has the task to fill it. He must report the Product Code processed, the dates, the name of the operator who performed the copper coil change, and the type of copper used.

RAME - 1° BOBINATRICE

Fase: 30

Check: Verifica dei parametri impostati in bobinatrice (n° spire, codice modello), diametro del filo, n° sezioni e presenza del marchio “G2”

Frequenza: Ad ogni cambio modello e ogni volta che finisce il fustino di rame

DATA	ORA	OPERATORE	FILO 1	FILO 2

Figure 25 – “Rame” module

The setup scheduling tool was the longer countermeasure to implement. As for the Heijunka box, the first implementation step was the Excel data uploading on SAP. Then, after a consultation with an external computer programming, he told us the development time, around 40/50 hours and the price, 3000 €.

We organized meeting in which all the specification related to the algorithm were explained to the computer programmer. We provided him the tool procedure, the flow chart and the excel table with all the different parameters weights.

Until now, the set up scheduling tool realization is still in progress. The graphical interface we should get will look like the one presented below.

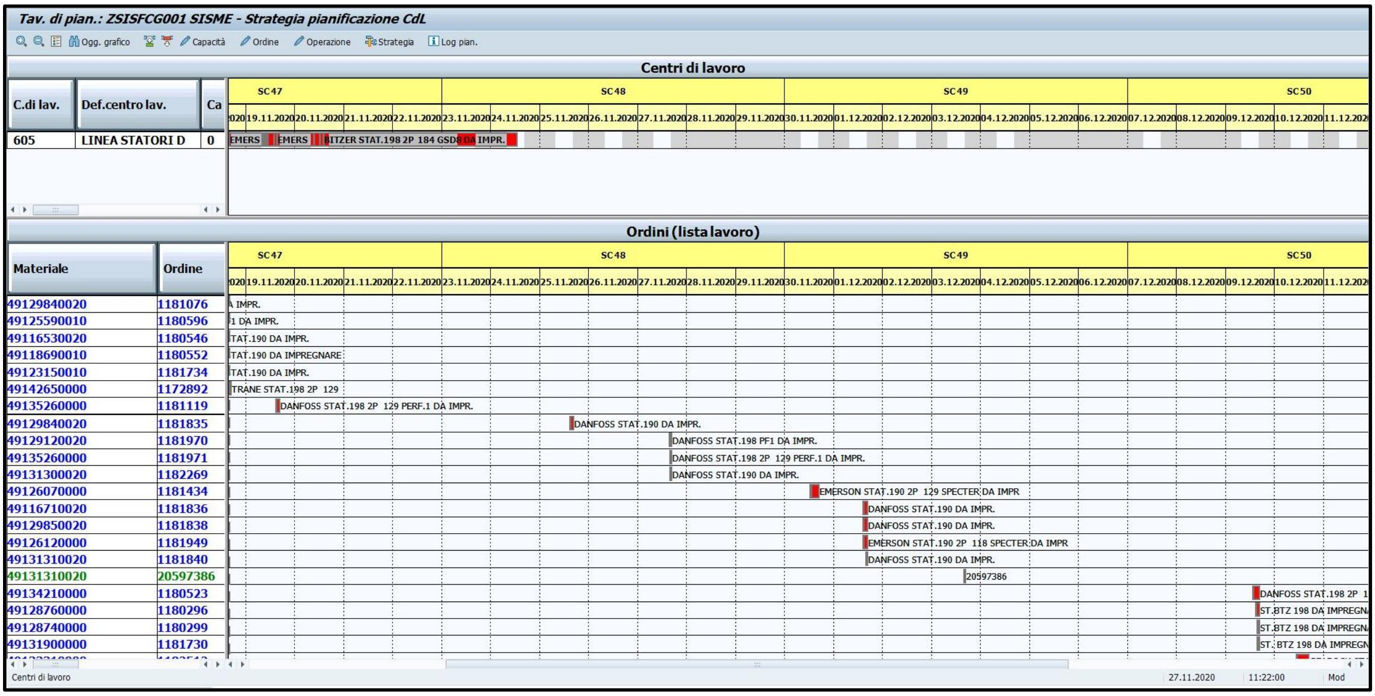


Figure 26 – Algorithm output

The output will show the optimal production plan on the left part, where each product will be identified by the product code and the order code. In the centre there will be product batches temporally allocated. Each batch will be characterized by a “start date” and an “end date” consistent with the processing time of the specific batch.

Monitor Results

In this phase of the A3 model is necessary to present the project results achieved and to compare them with the ones previously set in the "target setting" phase.

The first goal of the project was the downtime reduction. I set the "time-based" target on the 605-line availability.

In order to check if the "must have" target availability was achieved, I have monitored the "605-line Master file". It is the same file presented in the in the "problem background" phase.

MODELLO	ARTICOLO	NOME	DATA	Ta	UPTIME	DOWNTIME	VOLUME (OUTPUT)	Manutenzione Guasti	Set Up	Problemi Tecnici
49126080000	B12608		44151	120	115	5	46		5	
49133300000	B13330		44151	60	54	6	24		6	
49129120020	B12912/20		44151	30	0	30	12	20		10
49129090000	B12909		44152	50	45	5	18		5	
49127360000	B12736		44152	50	45	5	18		5	
49139050000	B13905		44152	300	292	8	105		8	
49139050000	B13905		44153	135	120	15	54	15		
49139120005	B13912/5		44153	45	40	5	18		5	
49119290010	B11929/10		44153	50	45	5	23		5	
49126820010	B12682/10		44153	45	40	5	20		5	
49116710020	B11671/20		44153	205	200	5	92		5	
49118690010	B11869/10		44154	300	300	0	138			
49125590010	B12559/10		44154	180	175	5	64		5	
49125590010	B12559/10		44155	75	65	10	30	10		
49123150010	B12315/10		44155	160	155	5	69		5	
49116530020	B11653/20		44155	245	230	15	94	10	5	
49131230000	B13123		44158	100	100	0	80			
49139050000	B13905		44158	270	265	5	199		5	
49139090000	B13909		44158	270	245	25	109	25		
49131310020	B13131/20		44159	105	100	5	45		5	
49129850020	B12985/20		44159	105	99	6	40		6	
49129850020	B12985/20		44159	150	145	5	52			5
49130490000	B13049		44160	60	55	5	23		5	
49116710020	B11671/20		44160	135	131	4	48		4	
49116530020	B11653/20		44160	135	129	6	46		6	
49131300020	B13130/20		44160	80	60	20	23	20		
49129840020	B12984/20		44161	210	205	5	69		5	

Table 38 – "605-line Master file" last two weeks

Downtimes value related to each batch are highlighted in yellow.

These values referring to two weeks, that go from the 16th of November to the 27th. These are the first two weeks in which countermeasures were applied. In order to get the availability, the same OEE calculation showed in the “problem breakdown” phase was done.

The time available is 3670 minutes, downtime is equal to 215 minutes and the uptime is 3455 minutes. So, the availability value related to these two weeks is 94,14%.

The “must have” target availability was equal to 94%, the “nice to have” 95%. Project “must have” goal is completely achieved. Some considerations on the “nice to have” can be made. Unfortunately, the set up scheduling tools countermeasure has required long time and it was not possible fully implement it. But, according with the estimations regarding the annual downtime reduction elaborated in the countermeasures cost – benefit analysis, I can state that when the set up algorithm will be ready, 605-line will register even more positive data and also the “nice to have” target could be achievable.

The second target set was the “operational-based”. The “must have” target was the quality checks (in the check list) reduction from 23 checks to 20. In “nice to have” scenario, checks should be 17. Through the self-control countermeasure, we were able to eliminate the six NVA quality checks from the check list. So, in this case, the “nice to have” target was achieved. In the next page the “new” reduced quality check list is shown (the “old” version is in the attachments.

REGISTRAZIONE DEI CONTROLLI DI PROCESSO LINEA 605 Ø 190/198

ANNO 20..

In caso di non conformità rispetto quanto riportato sulle cheek list, l'ispettore della Qualità dovrà attivare le seguenti azioni:
1) avvisare il responsabile di Qualità e Produzione

2) circoscrivere e segnalare con appositi cartelli di colore rosso tutto il materiale ritenuto a rischio (quando la non conformità coinvolge il prodotto)

3) sostituire eventuali apparecchiature in avaria e/o chiedere l'intervento della manutenzione per una eventuale riparazione in loco. In questo caso, il responsabile della Qualità dovrà richiamare il prodotto controllato con l'apparecchiatura starata e ripetere tutti i controlli.
Ogni non conformità dovrà essere controfirmata dal responsabile di produzione.
Sarà cura dei responsabili di Qualità e Produzione, individuare le più opportune azioni correttive per l'eliminazione di tutte le non conformità.

MODELLO
ISPETTORE
DATA
TURNO

MESE ______________

Note: i master per effettuare le varie verifiche elencate sono disponibili presso il Box della Qualità.

Fase	DESCRIZIONE CHECK	Riferimento	Frequenza	Note e notifica non conformità	Data e firma responsabile
40	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	IS-LV 01/39	ad ogni cambio mod. o inizio turno		
60	Controllo visuale dello statore e del suo corretto isolamento	IS-LV 01/28	ad ogni cambio mod. e minimo 1 volta a turno		
80	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	IS-LV 01/39	ad ogni cambio mod. o inizio turno		
100	Controllo visuale dello statore e del suo corretto isolamento	IS-LV 01/28	ad ogni cambio mod. e minimo 1 volta a turno		
120	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	IS-LV 01/39	ad ogni cambio mod. o inizio turno		
170	Misura delle resistenze mediante tester (riportarle a 25°C) e dell' altezza pacco e delle quote flat (dove previsto) mediante calibro a corsoio; registrare i valori in SPC. Controllo visuale dello statore	dis. ass.statore, IS-LV 01/28	3 pz. per ogni modello		
180	Verifica del posizionamento dei termistori	dis. ass.statore, IS-LV 01/43	ad ogni cambio mod. e minimo 1 volta a turno		
190	Verifica dell' altezza delle graffette, effettuare le prove di trazione; registrare i valori in SPC	IS-LV 01/49	3 aggraffature ad ogni cambio sezione		
219	Verifica dei parametri impostati in aggraffatrice e dell' altezza delle graffette e l' assenza di bave; registrare i valori in SPC. Effettuare la prova di trazione manuale	libro macchina, IS LV 01/45	3 pz. per ogni modello o inizio turno		
230	Verifica del corretto posizionamento dei cappucci isolanti e dei termistori	IS-LV 01/41	ad ogni cambio mod. o inizio turno		
250	Controllo della posizione di protettore, uscita conduttori e loro lunghezza	dis. ass.statore	3 pz. per ogni modello		
255	Verifica del corretto set-up dell' apparecchiatura e della posizione del Datamatrix.	DDI SP.CO.020	ad ogni cambio mod. o inizio turno		
295	Verifica del corretto inserimenti dei faston su protettore tipo UBUKATA DFXX o Sensata tipo 32/33 HM (dove previsto)	dis. ass.statore	3 pz. per ogni modello ed almeno 2 volte turno		
300	Verifica funzionale apparecchiatura controllo elettrico A3	master	una volta nelle 48 ore		
300	Verifica dei parametri impostati in apparecchiatura A3 e del circuito di terra/presenza pezzo (aggiungere 0,1 mA)	scheda di collaudo statore	ad ogni cambio mod.		
300	Controllo visuale generale statore	DDI e IS-LV 01/28	3 pz. per ogni modello		
340	Verifica del codice della carcassa, quota incarcassamento, posizione radiale e visuale saldature (dove previsto)	DDI	3 pz. per ogni modello		

rif. IS-CQ 015/1

Figure 27 – "New" quality check list

Standardize & Share Success

In the “standardize and share success” phase the question is: “How can I replicate the procedure?”.

One of the long-term objective of the project is the replication of the same “lean” approach used for the 605-line also with other similar line. Certainly, one of the most suitable line is the 695-line, analogous to the 605-line, in which stator with a 160 millimetres diameter are produced.

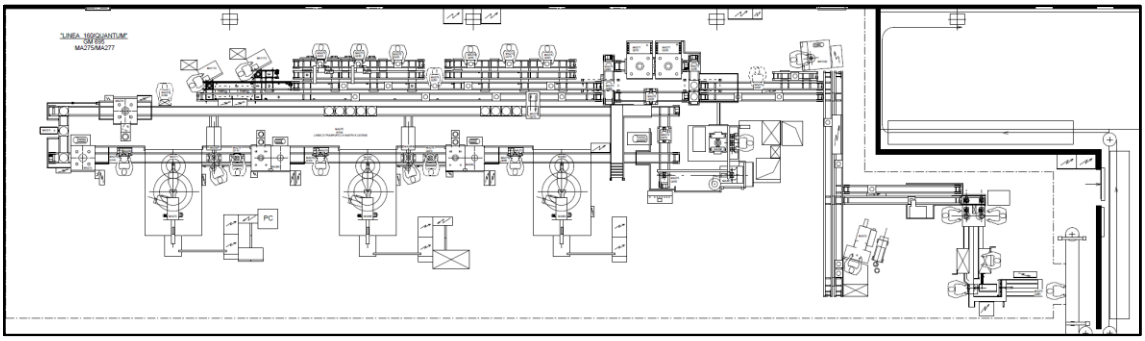


Figure 28 – 695-line layout

For this reason, developing some of the 605-line countermeasures, we tried to make them parametrizable in order to facilitate the replicability, changing only the parameters value, but maintaining the basic structure of the countermeasures intact. These are the cases of Heijunka box and set up scheduling tool.

As mentioned in the “countermeasures implementation” phase, the IT manager, who performed the realization of the SAP, created a flexible tool in which there is the possibility to add or remove items easily. Any kind of order card stamps can be created and, once the most suitable is defined, it can be saved in order to launch the “Heijunka box” program automatically.

The same for the set up scheduling tools. We tried to create an algorithm based on a “true or false” logic, in our case “same or different”. In this way, in order to find the “NOK” factor for each set up, the procedure followed by the algorithm is always the same. The more the parameters change in a set up, the more the “NOK” factor is hight and consequently the “DEL” factor related to the production plan.

To apply the tools to another line, therefore, it will not be necessary start over, but simply create the table with the set up parameters and their related weights for the new line considered and the basic structure of the algorithm will remain unchanged.

The self-control countermeasure is not based on an SAP parametrizable database, but we tried to follow a development and implementation process as standardized as possible. If we want to replicate the “self-control” with another line, there is a list of basic steps to follow, from the FMEA to find the possible tasks with low RPN values to the meetings in which we identified the most suitable line-operators to perform the new “shifted” tasks.

My Experience

“Continuous professional growth”. This is the best slogan for my Sisme experience. As one of the main lean requisites “kaizen” (“continuous improvement”) my IMLab project in Sisme can be described as a continuous personal professional growth.

Compared to my previous IMLab experience, in which with my teammates we worked only in the administrative HQ of the Company, Sisme offered me the possibility to get in touch directly with the industrial manufacturing field. The project involved the production department for almost the 60% of time and this point increased my professional skills as industrial management engineer exponentially.

But that’s not the half of it. The support that I received from the first day was fundamental. A special thank goes to Alfonso, the head of Sisme’s operations department, that make easy my involvement the daily Sisme’s routine. I become gradually familiar with a lot of different people, some of which become essential for the project development.

Progressively during the course of the project, I had the opportunity to help out concretely on 605-line production process. For this reason, despite the project focus was based on the “self-control”, I tried to develop and implement also other type of countermeasures (like the Heijunka box and the set up scheduling tool). About that, another thank goes to the IT department and especially to Antonio who cooperated at the SAP environment realization.

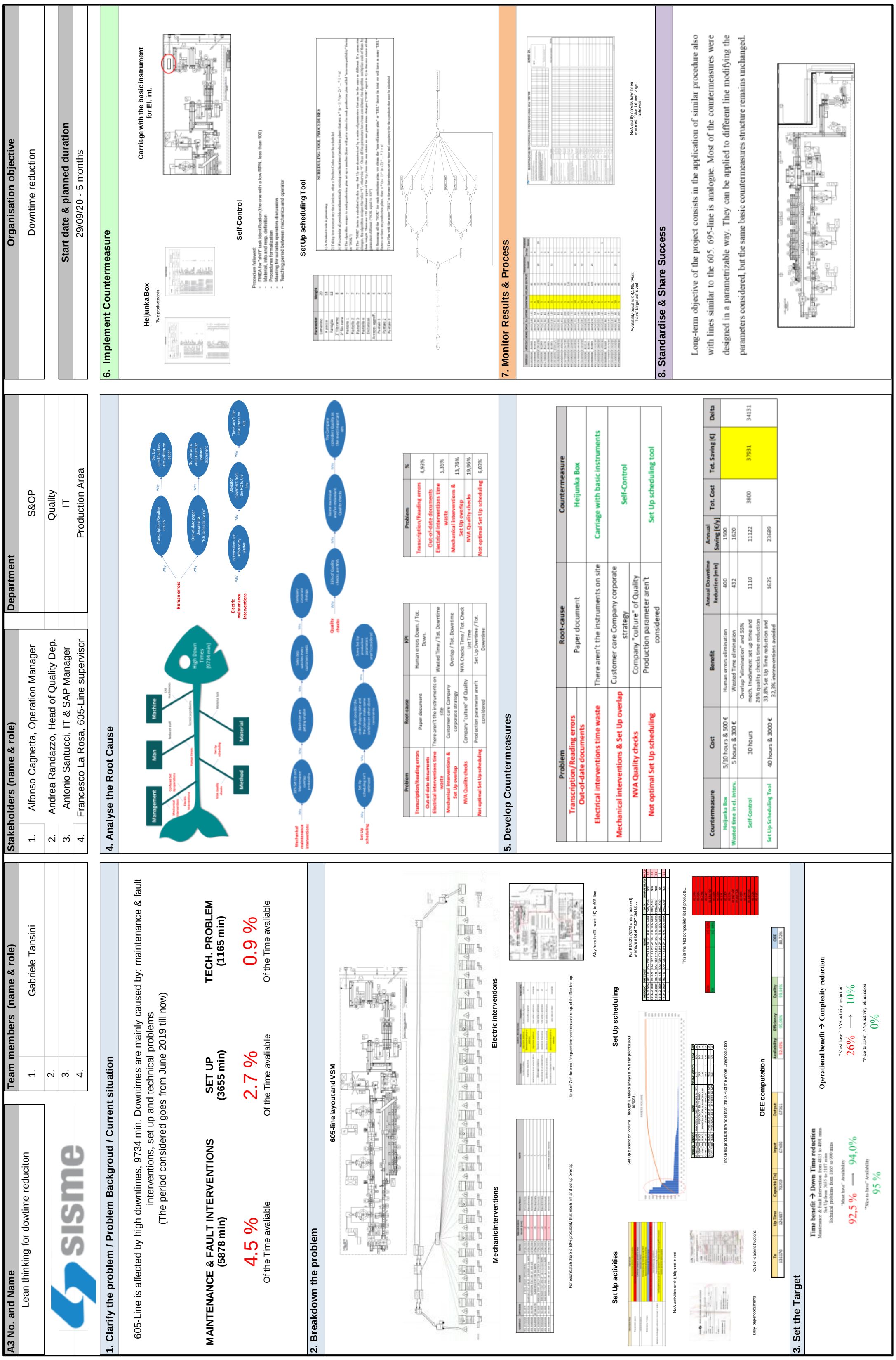
No action was taken without the incredible willingness of all the 605-line operators who followed countermeasures in a such precise and effective way.

Finally, a thank also go to the IMlab Polimi team, in particular to Professor Alberto Portioli Staudacher and my methodological tutor Alessia Valvo who helped me during the whole course of the project.

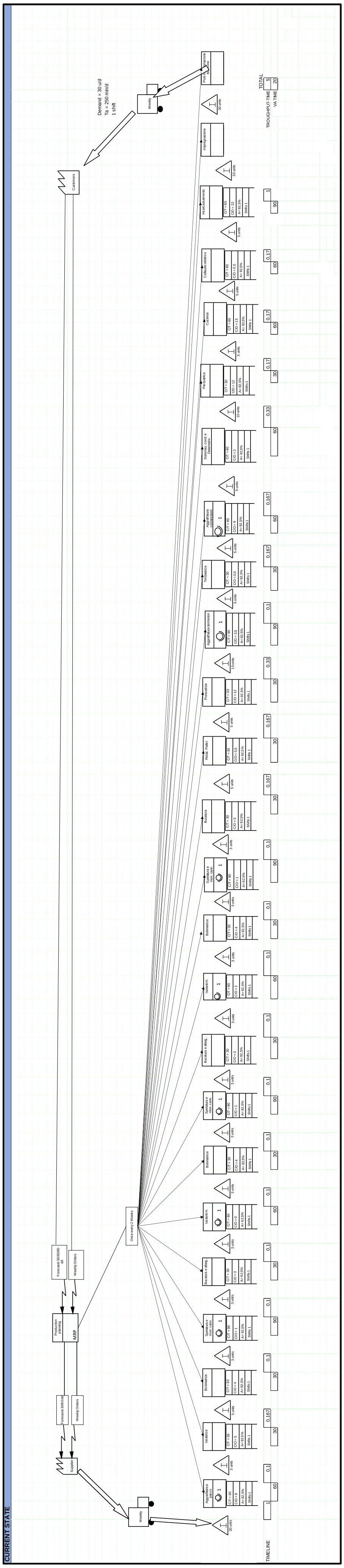
Now that I’m at the end of the thesis, I can state that the experience was extremely positive from my personal point of view and I hope also the Company is satisfied in the project results obtained.


Attachments

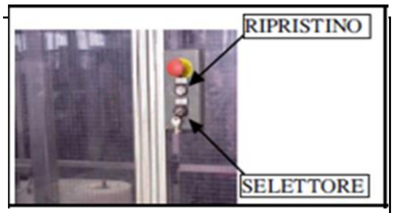
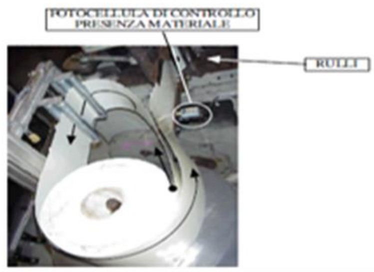
12.1. A3

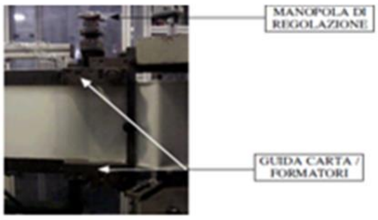
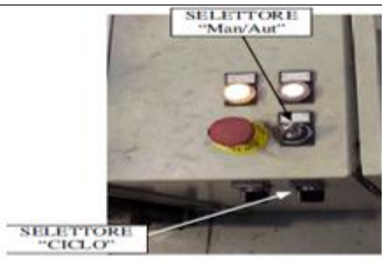


12.2. VSM



12.3. Self-Control Procedure

CAMBIO DEL MYLER	
OPERAZIONI	**IMMAGINI**
Ruotare il selettore in posizione "**1**", aprire il cancello per accedere all'interno della macchina	
Accedere all' interno della macchina e tagliare il Mylar inserito	
Sfilare la carta rimanente dai rulli di trascinamento	
Togliere il rotolo di materiale rimanente dal supporto esterno	
Caricare un nuovo rotolo di materiale isolante sul piatto	
Rifilare con le forbici l'estremità del mylar	
Infilare il Mylar nel corretto percorso di passaggio fra i rulli e la fotocellula di fine carta	

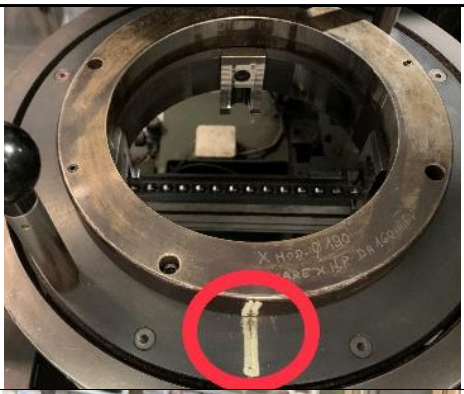
Piegare leggermente i bordi dell'isolante onde preformarlo per guidarlo nella sagomatura del bordino	
Regolare il guida carta per l'altezza da lavorare, ruotando la manopola di regolazione	
Infilare l'isolante sotto l'astina di tenuta e guidarlo nei formatori	
Dopo la formatura del bordino tagliare la parte in eccesso	
Selezionare l'isolatrice in manuale ruotando il selettore "**Man/Aut**" su "**Man**" e il selettore "**Ciclo**" su "**Impulso**"	
Sollevare il piatto portapezzo	

Alimentare la carta il più vicino possibile al guida carta sulla lama di taglio	
Inserire la carta nel guida carta e contemporaneamente premere ad impulsi il pulsante "**Avviamento**"	
Effettuare dei cicli di tegolatura fino ad avere degli isolanti di cava omogenei	

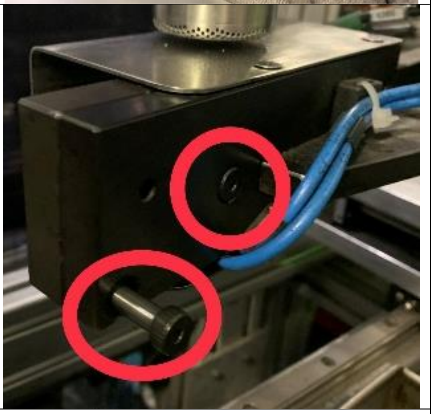
MONTAGGIO ANELLO (IN ISO. H 2° STRATO)

per altezza pacco > 160

OPERAZIONI	IMMAGINI
Se uno statore ha un'altezza pacco superiore ai 160 millimetri, nella postazione degli iso. H del 2° strato deve essere montato un anello	
L'anello si trova su un tavolo dietro la postazione Ci sono due tipologie di anello, uno per gli statori da 190 e uno per quelli da 198 La tipologia è segnata sull'anello (Cerchiata in rosso nell'immagine a fianco)	
Portare il selettore "MANUALE – AUTOMATICO" su "MANUALE"	
Portare il selettore "SPORTELLO" su "RIPOSO"	
Il cancellino si aprirà in maniera automatica	
Portare il selettore "MOVIMENTO ORIZZONTALE" su "LAVORO"	

Posizionare l'anello in maniera coerente con il segno presente su di esso (Cerchiato in rosso nell'immagine a fianco)	
Avvitare due viti con la brugola a T n°3 (più piccola) e le altre due con la brugola a T n° 5 (più grande)	
Se la macchina non è in fase tenere premuto il pulsante di "RIPRISTINO" della macchina finché la luce non rimane fissa (Se la luce lampeggia significa che la macchina non è ancora in fase)	
Portare il selettore "MANUALE – AUTOMATICO" su "AUTOMATICO"	
Premere "START CICLO"	
Svolgere le stesse operazioni nel momento in cui l'anello deve essere smontato	

MONTAGGIO BLOCCHETTO DATAMATRIX

OPERAZIONI	IMMAGINI
I blocchetti del Datamatrix sono tenuti nell'armadio A59	
Il blocchetto corretto da utilizzare per la lavorazione corrente è segnato sull'etichetta della commessa Il codice identificativo è inciso direttamente sul blocchetto	
Svitare le due viti (cerchiate in rosso nell'immagine a fianco) senza toglierle completamente utilizzando una brugola a T n° 3	
Estrarre il blocchetto	

Posizionare il blocchetto previsto per la lavorazione corrente come nella foto a fianco	
Avvitare le due viti svitate in precedenza	
Portare il blocchetto estratto nell'armadio A59	

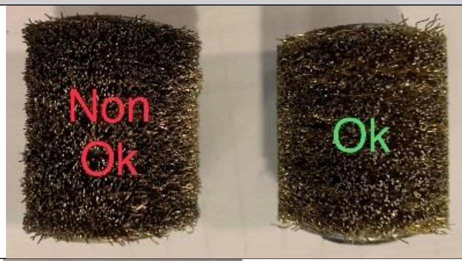
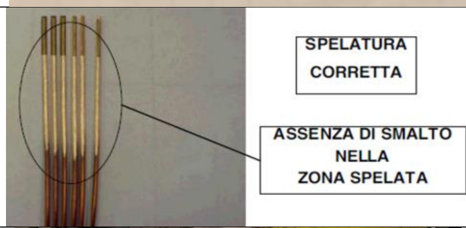
REGOLAZIONE DELLA PRESSATA

OPERAZIONI	IMMAGINI
Posizionare il selettore di rotazione del pallet su “ESCL” o “INCL” in base a ciò che c’è scritto sull’etichetta della commessa	
Portare il selettore “MAN – AUT” su “MAN”	
Tenere premuto “SBLOCCO MAGNETI CANCELLO ANTERIORE” per qualche secondo e aprire le porte	

Inserire la barra di sicurezza tra le traverse della pressa	
Il corretto valore della pressata da impostare è segnato sull’etichetta della commessa	
Girare il blocco finché il valore corretto della pressata non è allineato con il riferimento Ogni scatto di posizione è accompagnato da un rumore metallico di incastro Il riferimento è cerchiato in rosso nell’immagine a fianco	 
I valori sono quelli in giallo per la pressata superiore, in bianco (nella parte superiore del blocco) per quella inferiore	 
Richiudere le porte	
Premere “INSERZIONE COMANDI”	

Se la macchina non è in fase tenere premuto il pulsante di “RIPRISTINO” della macchina finché la luce non rimane fissa (Se la luce lampeggia significa che la macchina non è ancora in fase)	
Portare il selettore “MAN – AUT” su “AUT”	
Premere “START CICLO”	
Verifica della lavorazione per il primo pezzo (testate matasse non rovinate, fili schiacciati, dimensioni ed ingombri testata)	

CAMBIO DELLE SPAZZOLE SPELAFILI

OPERAZIONI	IMMAGINI
Le spazzole spelafili ti trovano in un cassetto vicino alla zona della postazione Le spazzole devono essere sostituire quando arrivano ad essere come nell’immagine a fianco e la quota è al massimo	
Valutare visivamente la qualità della spelatura	
Sostituire per prima la spazzola superiore, utilizzando una chiave n° 20/22 e una brugola a T n°5 Estrarre mandrino e spazzola per facilitarsi l’operazione di separare le due componenti	
Inserire nel mandrino la nuova spazzola nel verso indicato da un puntino bianco (segnato nell’immagine a fianco)	

Rimettere l'assieme mandrino – spazzola in posizione e riavvitare il tutto	
Per sostituire la spazzola inferiore posizionare il selettore "MAN – AUT" sopra il quadrante digitale a sinistra della postazione su "MAN" Premere "ESC" Premere la freccia in su Premere "SHIFT" Con le frecce in su o in giù cercare "SPELATURA INFERIORE" Premere "ENTER"	
Premere contemporaneamente i tasti "MOVIMENTI MANUALI" e "AUX MOVIMENTI MANUALI"	
A questo punto l'insieme mandrino – spazzola si alzerà leggermente in maniera automatica Ora è possibile sostituire la spazzola. Eseguire le stesse operazioni svolte per la spazzola superiore	
Premere contemporaneamente i due tasti di "RIPRISTINO" finché lo sportello non si chiude e poi non si riapre. A questo punto la macchina è in fase	

Ora devono essere azzerate le quote Con le frecce in su o in giù cercare "QUOTE SPAZZOLE" Premere contemporaneamente "F1 + SHIFT" Digitare "1" Premere "ENTER"	

12.4. Quality Check list

REGISTRAZIONE DEI CONTROLLI DI PROCESSO LINEA 605 ø 190/198

ANNO 20..

In caso di non conformità rispetto quanto riportato sulle check list, l'ispettore della Qualità dovrà attivare le seguenti azioni:

1) avvisare il responsabile di Qualità e Produzione

2) circoscrivere e segnalare con appositi cartelli di colore rosso tutto il materiale ritenuto a rischio (quando la non conformità coinvolge il prodotto)

3) sostituire eventuali apparecchiature in avaria e/o chiedere l'intervento della manutenzione per una eventuale riparazione in loco. In questo caso, il responsabile della Qualità dovrà richiamare il prodotto controllato con l'apparecchiatura starata e ripetere tutti i controlli.
Ogni non conformità dovrà essere controfirmata dal responsabile di produzione.

Sarà cura dei responsabili di Qualità e Produzione, individuare le più opportune azioni correttive per l'eliminazione di tutte le non conformità.

MODELLO
ISPETTORE
DATA
TURNO

MESE ____________

Nota: i master per effettuare le varie verifiche elencate sono disponibili presso il Box della Qualità.

Fase	DESCRIZIONE CHECK	Riferimento	Frequenza	Note e notifica non conformità	Data e firma responsabile
10	Verifica funzionale macchina aggraffatura pacchi	master	una volta nelle 24 ore		
10	Verifica dei parametri impostati in macchina aggraffatura pacchi	dis. ass.statore	ad ogni cambio mod.		
30	Verifica dei parametri impostati in bobinatrice (n° spire, codice modello), ø filo rame e n° sezioni, presenza marchio "G2"	dis. ass.statore	ad ogni cambio mod. o inizio turno		
40	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	IS-LV 01/39	ad ogni cambio mod. o inizio turno		
60	Controllo visuale dello statore e del suo corretto isolamento	IS-LV 01/28	ad ogni cambio mod. e minimo 1 volta a turno		
70	Verifica dei parametri impostati in bobinatrice (n° spire, codice modello), ø filo rame e n° sezioni, presenza marchio "G2"	dis. ass.statore	ad ogni cambio mod. o inizio turno		
80	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	IS-LV 01/39	ad ogni cambio mod. o inizio turno		
100	Controllo visuale dello statore e del suo corretto isolamento	IS-LV 01/28	ad ogni cambio mod. e minimo 1 volta a turno		
110	Verifica dei parametri impostati in bobinatrice (n° spire, codice modello), ø filo rame e n° sezioni, presenza marchio "G2"	dis. ass.statore	ad ogni cambio mod. o inizio turno		
120	Verifica dello stato di usura delle spazzole e delle matasse (assenza di incisioni o schiacciature)	IS-LV 01/39	ad ogni cambio mod. o inizio turno		
170	Misura delle resistenze mediante tester (riportarle a 25°C) e dell' altezza pacco e delle quote flat (dove previsto) mediante calibro a corsoio; registrare i valori in SPC. Controllo visuale dello statore	dis. ass.statore, IS-LV 01/28	3 pz. per ogni modello		
180	Verifica del posizionamento dei termistori	dis. ass.statore, IS-LV 01/43	ad ogni cambio mod. e minimo 1 volta a turno		
190	Verifica dell' altezza delle graffette, effettuare le prove di trazione; registrare i valori in SPC	IS-LV 01/49	3 aggraffature ad ogni cambio sezione		
210	Controllo timbratura codice compressore (dove previsto)	dis. ass.statore o DDI	ad ogni cambio mod. o inizio turno		
219	Verifica dei parametri impostati in aggraffatrice, dell' altezza delle graffette e l' assenza di bave; registrare i valori in SPC. Effettuare la prova di trazione manuale	libro macchina, IS-LV 01/45	3 pz. per ogni modello o inizio turno		
230	Verifica del corretto posizionamento dei cappucci isolanti e dei termistori	IS-LV 01/41	ad ogni cambio mod. o inizio turno		
250	Controllo della posizione di protettore, uscita conduttori e loro lunghezza	dis. ass.statore	3 pz. per ogni modello		
255	Verifica del corretto set-up dell' apparecchiatura e della posizione del Datamatrix.	DDI SP.CO.020	ad ogni cambio mod. o inizio turno		
295	Verifica del corretto inserimenti del faston su protettore tipo UBUKATA DFXX o Sensata tipo 32/33 HM (dove previsto)	dis. ass.statore	3 pz. per ogni modello ed almeno 2 volte turno		
300	Verifica funzionale apparecchiatura controllo elettrico A3	master	una volta nelle 48 ore		
300	Verifica dei parametri impostati in apparecchiatura A3 e del circuito di terra/presenza pezzo (aggiungere 0,1 mA)	scheda di collaudo statore	ad ogni cambio mod.		
300	Controllo visuale generale statore	DDI e IS-LV 01/28	3 pz. per ogni modello		
340	Verifica del codice della carcassa, quota incarcassamento, posizione radiale e visuale saldature (dove previsto)	DDI	3 pz. per ogni modello		

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12.5. Project Gantt

	A3 Steps	Attività	Responsabile	Data inizio	Data fine	05-ott	06/10-08/10	2/10-16/1	9/10-23/1	26/10-30/10	2/11-06/1	9/11-13/1	6/11-20/1	3/11-27/1	0/11-04/1	7/12-11/1	4/12-18/1	1/12-24/1	4/01-08/0	1/01-15/0	8/01-22/0	5/01-29/0	29-gen
Plan	*Problem statement*	Kick-Off e apertura dei lavori	*Gabriele - Alfonso Cagnetta*	05-ott	05-ott																		
		Studio della situazione Attuale - Linea 605	*Gabriele - Alfonso Cagnetta*	06-ott	08-ott																		
	Problem Breakdown	Mappatura del processo - Linea 605	*Gabriele*	12-ott	16-ott																		
		Data Collection Tempi - Linea 605	*Gabriele- Operatori*	14-ott	22-ott																		
		Data Collection Attività - Linea 605	*Gabriele- Operatori*	14-ott	22-ott																		
	Setting the Target	Definizione del target	*Gabriele - Alfonso Cagnetta - Tutor Metodologico*	22-ott	23-ott																		
	Root Causes Analysis	Studio delle cause radice	*Gabriele*	26-ott	30-ott																		
	Check intermedio e raccolta feedback	Presentazione intermedia Progetto	*Gabriele - Sisme - Tutor Metodologico - Federica Costa*	Data da definire																			
	Develop Contermeasures	Ideazione/Sviluppo contromisure	*abriele - Operatori - Alfonso Cagnetta - Tutor Metodologic*	02-nov	06-nov																		
		Contromisure - Cause Radice - Benefici	*Gabriele - Tutor Metodologico*	05-nov	06-nov																		
Do	*Implement Countermasure*	Sviluppo piano di implemetazione	*Gabriele - Alfonso Cagnetta*	09-nov	11-nov																		
		Implementazione Quick win Solution	*Gabriele - Operatori*	09-nov	04-dic																		
		misurazione Quick Win Solution	*Gabriele - Operatori*	19-nov / 30-nov	19-nov / 30-nov																		
		Follow Up - Quick Win Solution	*Gabriele - Alfonso Cagnetta - Tutor Metodologico*	20-nov / 07-dic	20-nov / 07-dic																		
		Implementazione Nice to have Solution	*Gabriele - Operatori*	30-nov	08-gen																		
Check	*Monitor Result and Process*	Monitoraggio risultati	*Gabriele - Operatori*	11-gen	15-gen																		
		Fine-tuning contromisure	*Gabriele - Operatori*	18-gen	22-gen																		
Act	*Standardise and share success*	definizione piano Continouos Improvement	*Gabriele*	25-gen	29-gen																		
		chiusura dei lavori/condivisione dei risultati	*Gabriele - Sisme - Tutor Metodologico - Federica Costa*	Data da definire																			

List of Figures and Tables

13.1. List of Figures

13.2. List of Tables

References

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