Abstract

Technological leaps have led to shifts in paradigm which nowadays known and named as "industrial revolutions". The mechanization field is where the so-called 1st industrial revolution took place, the intensive use of electrical energy led to the second industrial revolution, and the widespread of digitalization led to the 3rd one. On the basis of an advanced digitalization within manufacturing plants, combining the Internet technologies and future-oriented technologies in the field of "smart" objects (machines and products) seems to be in the way of resulting a new fundamental paradigm shift in industrial production.

A great challenge is represented by the Industry 4.0 for businesses in general and for SMEs in particular. The study at hand will observe and document SMEs´ awareness, readiness and capability to meet this challenge.

A Manufacturing Execution System (MES) is a system that companies use as a way of measuring and controlling production activities. As the base of installed MES grows significantly and due to the growth pace of the market, more vendors and implementation partners are entering the market. Organizations that intend to successfully implement a MES solution need to be informed and educated in a well manner about the intricacies of software implementations. Organizations need to ensure that they are in full control of the process of implementation and not at the mercy of the software vendors and implementation partners for success.

The main objective of this thesis is to investigate the implementation process of Manufacturing Execution System by SMEs by studying a real case study of a company in Italy and documenting all the steps and problem encountered during the process to be a reference for other companies planning to take this step in the near future. Finally, analysing the data which can be extracted after implementing the system and studying to which extent this data can be used for optimization to draw a conclusion.

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Chapter(1) Introduction

1.1 Industry 4.0:

Nowadays industrial production is driven by the fierce global competition and the need for fast adaptation of production to the dynamic ever changing market request. The only way to meet these requirements is by advancing radically in the current manufacturing technology. The approach which seems promising enough is Industry 4.0 which is based on the integration of business and manufacturing processes, as well as the integration of all actors in the value chain (suppliers and customers). Addressing the technical aspects of these requirements by application of generic concepts of the cyber physical systems (CPS) and industrial internet of things (IoT). The Industry 4.0 execution system is therefore based on connecting CPS building blocks. These blocks are embedded systems with decentralized control and advanced connectivity that gather and exchange real-time information which has the role to identify, locate, track, monitor and optimize the production processes. Moreover, an extensive software support based on decentralized and adapted versions of Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) is required for a seamless integration of manufacturing and business processes. An additional important aspect is how to handle this big amount of data collected from the processes, machines and products. Typically the data is stored in a cloud storage. It requires an extensive analytics that lead the data in its raw form to the useful information and, finally to the concrete actions that support an adaptive and continuous self-optimizing industrial production process. The transition is important for the countries as it affects the country position in the global market so some governments led some initiatives to support the transition. Industry 4.0, as the first such initiative and is considered an inspiration for other initiatives was initiated in Germany. Similar concepts that were introduced in other countries are presented in the continuation. The Industrial Internet concept has been brought up in North America by the General Electric company by late 2012. Its integration is seen as tight one between physical and digital worlds that combines big data analytics with the Internet of Things. The concept assumes a much wide-ranging application area as the Industry 4.0 and covers power generation, distribution, healthcare, manufacturing, public sector, transportation and mining [1]. Within the Industrial Internet consortium that was founded by General Electrics and some other companies [1], it has been estimated that 46% of the global economy can benefit from the Industrial Internet. In France, the core of French industrial policy is set to be served by the introduction of the concept 'Industrie du futur'. It is based on cooperation of industry and science and built on five pillars: (1) cutting edge technologies including additive manufacturing, virtual plant, IoT, and augmented reality, (2) supporting the French companies, especially small to middle ones, to adapt to new technologies, (3) extensive employees' training, (4) strengthening international cooperation around industrial standards and (5) promotion of French industry of the future [2]. Next similar initiative 'Made in China 2025' was introduced in 2015 [3]. It was initiated by the China's Ministry of Industry and Information Technology in cooperation with many experts from the China Academy of Engineering. The main goal of this initiative is to upgrade Chinese industry comprehensively by directly drawing an inspiration from Germany's concept (Industry 4.0) and adapt it to the needs of China. The transformed manufacturing should be innovation-driven. Also other elements like sustainable development and green energy are considered. Ten priority sectors were identified starting from information technology, robotics and automated machine tools. The long term goals are to reform China manufacturing industry, to move from the high number of low-cost products to high-quality products and to take over Germany and Japan dominance in manufacturing until 2035, in order to evolve into the industry world superpower until 2049.

The paper is structured as follows, first an introduction about the 4th industrial revolution and the Italian government support regarding the matter. Then a brief introduction about Manufacturing Execution System and a chapter of literature review. Followed by introducing the case study company and its process data collection now. A chapter of the challenges that face Mista and other SMEs during implementing such projects. Finally a chapter of the research and findings discussing the two portals used to interface with the MES, kind of data collected and the form of presenting the data which all serve in drawing a conclusion at the end.

1.1.1 Italian government supporting the transition:

The Industry 4.0 National plan was presented for the first time in late September 2016 in Milan in the presence of the former prime minister Matteo Renzi and the Minister of Economic Development Carlo Calenda. The 2017 budget act underlined the significant importance of the new industrial policy, bringing it back to the heart of the political agenda. In February 2017 plan was launched to place horizontal measures which can be easily accessed by all enterprises with the objective of boosting investments in new technologies, research and development, and revitalise the competitiveness of Italian companies. Simultaneously, some complementary measures were introduced in order to support I4.0. The private investment to support I4.0 were triggered by the introduction of some measures such as Ultra Broadband Plan (to ensure adequate network infrastructure), collaboration for the definition of IoT standard communication protocols and other, especially venture capital and private equity. I4.0 was inspired by similar national strategies in Germany (Platform Industrie 4.0), France (Alliance Industrie du Future) and the Netherlands (Smart Industry), taking into consideration the international and national economic environment, up-to-date series of macroeconomic data and the dynamic nature of the industrial sector.

Companies operating in Italy will benefit from the great opportunity resulting from the adoption of the national Industry 4.0 plan for industrial technological and digital transformation by the Italian government. The plan aims to raise tax incentives for investments in goods and technologies connecting physical and digital systems, in order to conduct complex analysis (Big Data) and adapt manufacturing systems in real time. The 2017 Budget Law introduces new tax incentives and rises existing incentives for companies that invest in technological and digital transformation in compliance with the Industry 4.0 model, hyper-depreciation on tangible operating assets and super-depreciation on intangible operating assets, a new Sabatini Act, tax credits for R&D, facilitations for SMEs and innovative start-ups, etc.

1.2 Manufacturing Execution System:

Manufacturing Execution System, commonly known as and referred to as MES, is an information system that connects, monitors and controls manufacturing systems and data flows that occur on a shop or factory floor. The overall goal of MES is to ensure that manufacturing operations are executed efficiently and improves output of production. Many issues that are plaguing the manufacturing environment can be solved by Manufacturing execution system. Collection and provision of real time data can be numerously beneficial. Recently the landscape for MES growth have been paved by advances in data management and computing technology. Due to the high competition in markets in the past two decades this spotted the light on the advantages provided by the system.

MES provides enhanced resource management, integration and visibility in addition to document and product control, which ultimately deliver higher throughput and quality. Such benefits place the adopting company in a solid and competitive position, and as such continue to provoke the rapid adoption of MES.

How does a company transfer its existing manufacturing environment to interface with MES and govern the several stages of the process implementation? The lacking in information surrounding the issue has prolonged the integration of manufacturing execution system into the average small to medium sized companies. For addressing the issue, not just MES must be understood, but also all other factors influencing the implementation such as:

- Type and architecture of software/hardware
- People and machines which are involved
- Specifics desired for reporting and functionality

The shop floor nowadays is highly complex and its environment is continuously varying. Taking into account this level of variation for scheduling which typically beyond the scope of the planning systems-MRP, Master Scheduling and others. MES considers and controls the highly critical details of a typical plant shop floor.

Main variation causes on the shop floor includes:

- Machine breakdowns
- Absenteeism of labour
- Shifting setup times
- Times of cleaning and maintenance
- Changes in delivery dates
- Quality problems
- Alternative work plans
- Alternative parts list
- Transport Availability
- Availability of quality resources
- Changes to minimize setups, processes times,..

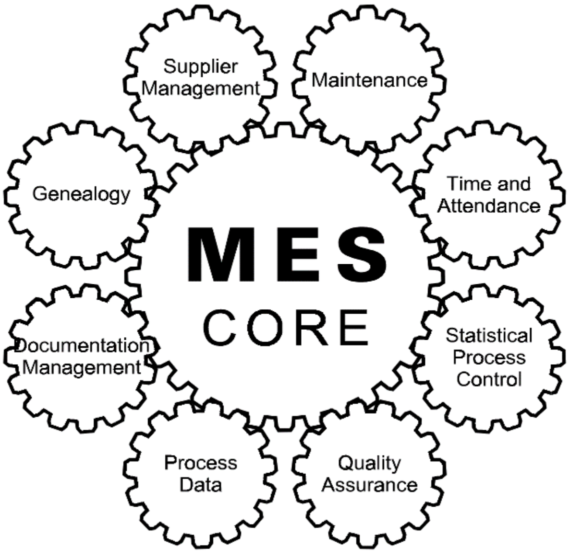


Figure 1 : The Core of MES [1]

Therefore it is imperative placing the right tools and critical information in the hands of front line personnel in the factory or shop floor in order to produce the products in the most possible optimal manner. A good manufacturing execution system operates on a real time basis which comes handy for the schedulers for immediate reaction to any variance on the shop floor. The MES allows immediate response, helping in faster decisions in issues such as costing over-runs, poor quality and late deliveries. It is virtually the heartbeat for all things happening on the shop floor.

1.2.1MES History:

The term itself was first invented in the beginning of the 90's. At its core, the system serves effort trying to offer the highest shop floor control and visibility through a real time data collection and analysis. The interface between the management and the factory floor in the real core strength of MES. Information transfer is emphasized by MES between the two layers, the production one and the business one. MES also increases the optimization of the production process of the whole enterprise through the integration of information. The conveyance of information in real time provides the management with up to date information which helps in making fully informed decisions. To study the full utility of MES a connected enterprise resource planning (ERP) system is essential and must be supposed. Briefly, the ERP system will enable the interaction of MES with other functions within a company, and completes the allocation of information to a company wide audience. The implementation quality and in-depth integration of the MES will dictate the level of functionality to be attained.

Chapter (2) LITERATURE REVIEW

Relevant capabilities that provide an efficient and flexible manufacturing system appear to be possessed by Computer Integrated Manufacturing (CIM), it has the capability of producing high quality products at low costs, and shorter lead times [4]. MES are a part of CIM which supports the information connection between production planning and production process control [5], and are seen as an intermediary between high level planning by ERP and operational level manufacture of the physical goods. The National Institute of Standards [6] defines MES as a collection of hardware/software components enabling management and optimization of the production activities from order launch to finished goods. The MES scope includes (not limited to)[6]:

- Resource allocation & tracking
- Scheduling
- Data Collection
- Labour Management
- Quality Management
- Process Management
- Managing Maintenance
- Tracking of products

There is a high degree of agreement on the benefits of MES in literature. MES has lowered the cost of production in several discreet manufacturing industries [5]. Plants using MES are found to easily acquire the ability to reduce costs more dramatically compared to the plants not using MES [7], improving the return on operational assets, on time delivery, inventory turns, gross margin and performance of cash flow [8]. These benefits are not only limited to profitability issues, but it extends to include matters such as productivity improvement, enhancements in process and personnel development [7]. MES may also help in improving resources planning and allocation [9], and allows for supervision of process execution using real time and precise data [8], making it possible for a prompt identification of any abnormal, deviant or critical situations in the production process [10]. In essence, the benefits of MES can be summed up as codifying best practice, empowering employees and reinforcement ability of management systems as environments change [11]. Suppliers of MES support these conclusions in their promotional material suggesting that MES has the ability to improve efficiencies and utilization, timeliness and accuracy of information, scrap and labour overheads reduction via real time monitoring of machines, reporting, live scheduling, identification of any abnormalities in the processes and automatic data acquisition and interrogation. The advantages of MES ranging from improving operational to financial performance have been acknowledged in this literature review. It stands for the companies in identifying opportunities for improvement and in presenting a suitable justification to invest in MES. These systems can be justified based upon fulfilling purely financial wise, strategic wise or operational wise aims, by using faith alone [12], or a combination of these. The most frequent and basic problem accompanying the justification of a new manufacturing technologies is that their advantages lie not in the areas of cost reduction, but rather in more nebulous and strategic areas such as shortening in lead times, simplifying scheduling, and more consistent quality [13].

Chapter (3) Case Study

3.1 Mista S.p.A:

During writing the thesis, the study was made in Mista S.p.A during a three months of internship with the following duties :

- Follow the implementation of the MES project.
- Collection and analysis of data generated by the system.
- Proposals for optimization and improvement.

The internship helped me a lot in this dissertation as it gave me the opportunity to study the hypothesis and to have a practical real life case study. In a company which considered to be under the SMEs category.

3.1.1 The story of Mista:

In 1971,Mista was founded in Turin. The year in which it began its activity producing for Cavis, a Fiat-induced company. During this period it was involved in radiofrequency welding of the water bags of the window washer (heat sealing). The process includes a gluing phase with hot-melt (or hot melt adhesive) which is a thermoplastic material that when applied to the liquid state adheres to surface at the moment of cooling, a shearing phase by means of trances applied on plastic and a finally the finishing of the wheel arches (what separates the body from the wheel) by using thermoforming.

By 1972 the first metal shear was built, and in those years Mista developed the shearing department. Simultaneously, the first headlight mouldings were starting to be produced, then Mista was separated from Stampla. Mista specializing in moulds, blanking and welding of silver contacts and small metal parts. And Stampla specializing in plastic moulding, particularly producing headlights with manual moulding that required the regular presence of an operator on board of the press.

During the 80s and 90s Mista developed the production of stamped electrical contacts with welded or riveted silver pads. These products are used in the components for home appliances. It is used in a widely range of components from thermostats for refrigerators and boilers, to pressure switches, switches, valves and pumps.

Moreover, after the acquisition of Fire, which is specialized in the production of relays manufactured fully by hand, by 1982, Mista began producing electromechanical components. It initiated by producing relays and then later it expanded to the production of switches especially for the automotive sector. In 1986 the headquarter in Turin was moved to Cortiglione and as early as 1987 the shearing department worked at full capacity and was largely automated.

The Automatization of the production of relays started from 1987 and it wasn't completed until 1996, when the relocation of the activity of relay production to the Feme industry took place (known today as Carlo Gavazzi), whose production was transferred to Tunisia for some years, before being absorbed by Stampla, which finally entirely abandoned that activity due to entering into the market of oriental industries that made it nearly impossible for the company to maintain competitiveness in that sector.

The production was made up of manual assembly and testing. There were machines, on which the assemblies were placed, which aimed to reduce the workload on the line operator, up to manual co-moulding in which only the metal inserts were to be loaded and then the machine printed.

During the 90s the Stampla began producing the moulding of technical plastic articles to serve the automotive sector and by 2000 it began the first assembly productions in Tunisia through a subcontractor.

After the acquisition of Stars in 2002 (Thermoplastic injection press department of Valeo), it raised the possibility of strengthening the thermoplastic moulding and co-moulding sector both in Tunisia and Cortiglione. Stampla and Mista finally merged and became a single company in 2013.

Nowadays, Mista produces electrical contacts, stamped and welded parts, thermoplastic products for the most significant manufacturers of car components, appliances for household and low power electricity.

All products and processes are developed in Italy and then realized in the production sites of Cortiglione in Italy and Menzel Bouzelfa in Tunisia. Up to now almost all machines are manual with automatic testing. The first fully automated machine has been running for about four years now.

3.1.2 Mista Today:

Manufacturing at the company is totally based on make-to-order process. Mista's products now are electrical contacts, stamped and welded parts, thermoplastics for the most significant manufacturers of car components, electrical appliances and low-power electricity. Currently, the work force is about 500 people divided between the Italian headquarters of Cortiglione (AT), where about 150 people work, and the Tunisian one of Menzel Bouzelfa, where about 350 people work.

3.1.3 Italian headquarters of Cortiglione (AT):

The head quarter in Cortiglione consists of a plastic moulding department, a stamping department for small parts, tooling department, a warehouse for metallic materials and a one for plastics raw material and resins, laboratories for carrying out checks on raw material and parts produced and finally the offices. The following Fig. Shows the layout of the plant in Italy.

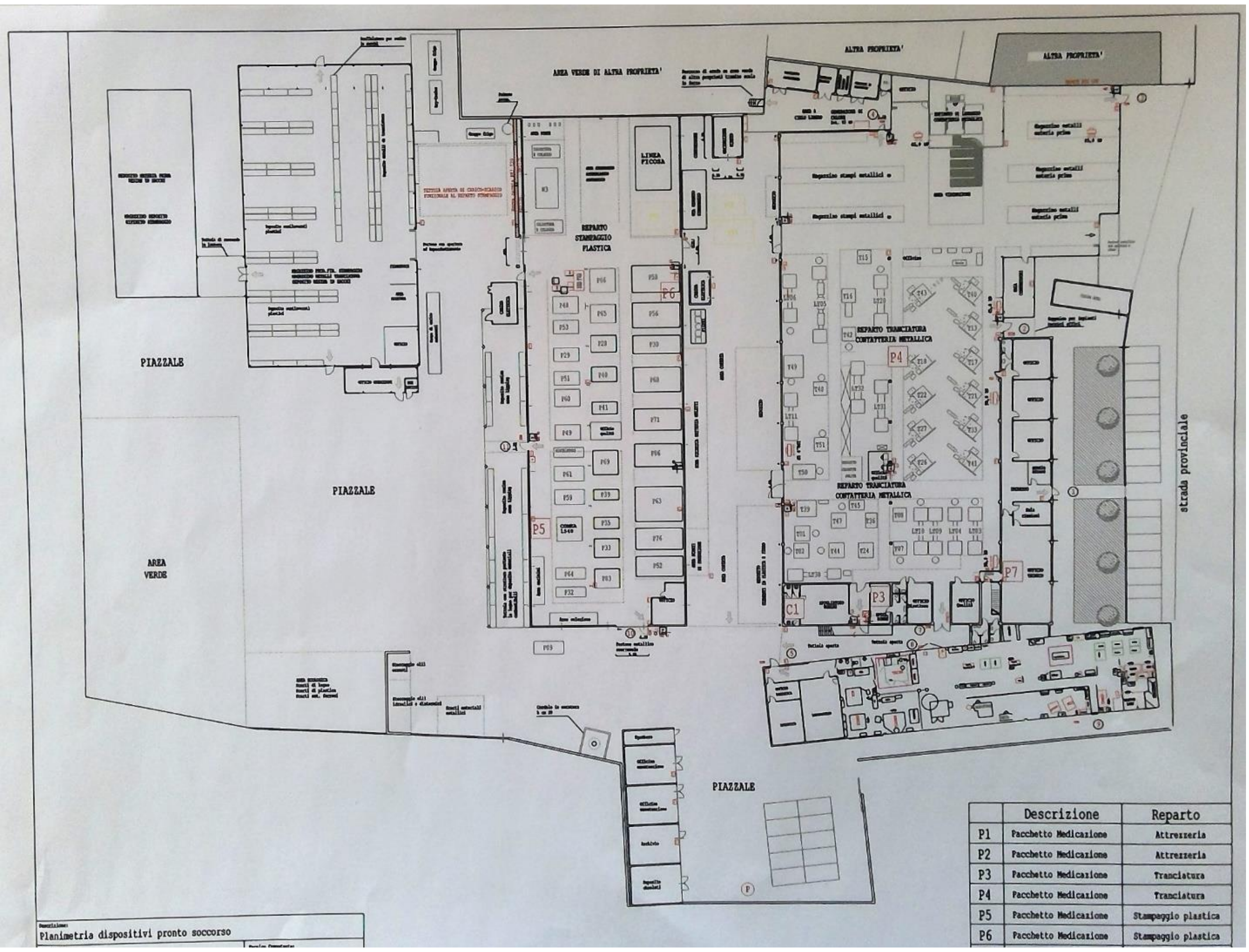


Figure 2: Headquarters Layout (Cortiglione,Asti)

The thermoplastic moulding department as indicated by P5 and P6 in the 2 consists of 31 horizontal injection presses ranging from 50 to 350 tons, two automatic assembly and testing lines and vertical machines for inserting the moulds. These assembly lines are automated and modern, for the other presses in Table 1, the distinction between old and new presses is emphasised because the old one has the ability to only show basic information such as electrical I / O impulses

Location	Number of press	Moulding Shop	Model	Screw Diameter (mm)	Number of presses	Generation
Mista - Italy	59	ARBURG 100T	370M 1000-250	35	1	Old
Mista - Italy	61	ARBURG 100T	420M 1000-350	35	1	Old
Mista - Italy	49	ARBURG 100T	420C 1000-250	35	1	Old
Mista - Italy	60	ARBURG 100T	420C 1000-250	35	1	New
Mista - Italy	76	ARBURG 1200T	1300-210	40	1	Old
Mista - Italy	55	ARBURG 1200T	1300-210	40	1	Old
Mista - Italy	40, 69	ARBURG 150T	470C 1500-400	40	2	New
Mista - Italy	41	ARBURG 150T	470C 1500-400	35	1	New
Mista - Italy	30	ARBURG 160T	470C 1600-675	50	1	New
Mista - Italy	52	ARBURG 200T	470C 2000-675	55	1	Old
Mista - Italy	71	ARBURG 320T	720S 3200-2100	70	1	New
Mista - Italy	68	ARBURG 320T	720S 3200-1300	60	1	New
Mista - Italy	64	ARBURG 35T	270S 350-70	22	1	New
Mista - Italy	32, 35	ARBURG 50T	320C 500-100	25	2	New
Mista - Italy	65, 66	ARBURG 50T	320C 500-1700	25	2	New
Mista - Italy	28	ARBURG 60T	320C 600-250	30	1	New
Mista - Italy	78	ARBURG 70T	370U 700-290	40	1	New
Mista - Italy	39	ARBURG 100T	420C 1000-290	35	1	New
Mista - Italy	33	ARBURG 100T	420C 1000-350	25	1	New
Mista - Italy	49	ARBURG 75T	320M 750-90-210	30	1	Old
Mista - Italy	84	ARBURG 80T	1200T-800-150	30	1	New
Mista - Italy	48	ARBURG BIMAT 100T	420M 1000-100/250	35-30	1	Old
Mista - Italy	63	ARBURG BIMAT 160T	520S 1600-290	25-30	1	New
Mista - Italy	75	ARBURG BIMAT 200T	570S 2200-290	25-30	1	Assembly line
Mista - Italy	82	ENGEL 120 T	Victory	40	1	Assembly line
Mista - Italy	83	ENGEL 120 T	Victory	45?	1	New
Mista - Italy	56, 58	ENGEL 300 T	ES 1300-300	60	2	Old, Old
Mista - Italy	87	ENGEL 300 T	VC 1350-300	60	1	New
Mista - Italy	53	ENGEL 85 T	ES 380/85	35	1	Old

Table 1: Press Details (Italy's Moulding Department)

The metal stamping and welding department consists of 42 stamping and welding lines equipped with 51 presses as shown in Fig 2 indicated by P4. The presses are Ompsa, SanGiacomo, Bruderer, Yamada, Balconi. In which ranging from 25 to 100 tons. Some of them, shown in Table 2, are interconnected by Brankamp control equipment. The production annualy exceeds 500 million pieces. The tooling department is mainly used for the maintenance, testing and construction of moulds.

Location	Supplier	Press	Max speed (up to)	Number of presses	Generation
Mista - Italy	Legnani	60 T	300	2	Old
Mista - Italy	S. Giacomo	40 T	150	21	Old
Mista - Italy	Yamada*	40 T	1200	1	New
Mista - Italy	Colombo Agostino	40 T	200	3	Old
Mista - Italy	Colombo Agostino	95 T		1	Old
Mista - Italy	Balconi	80 T	300	1	Old
Mista - Italy	Balconi*	60 T	300	1	Old
Mista - Italy	Balconi*	100 T	300	1	Old
Mista - Italy	Balconi	25 T	150	1	Old
Mista - Italy	Bruderer*	50 T	1500	1	Old
Mista - Italy	Bruderer*	60 T	1000	2	Old
Mista - Italy	Ompsa*	40 T	500	7	Old
Mista - Italy	Ompsa*	40 T	350	1	Old
Mista - Italy	Ompsa*	50 T	500	3	Old
Mista - Italy	Ompsa*	63 T	500	1	Old
Mista - Italy	Bullcom	40 T	250	4	Old

Table 2: Press Details (Italy's Stamping Departement)

In Cortiglione's mould shop, the customers are provided a long experience in the design, production and maintenance of equipment for stamping and electric welding, as well as the design and production of injection moulds for moulding and also thermoplastic co-moulding.

Location	Department	Manufacturer	Machine	Quantity
Mista - Italy	Tooling Shop	Sodick A325	Electrowire erosion	1
Mista - Italy	Tooling Shop	Agie Charmilles Chellenger	Electrowire erosion	1
Mista - Italy	Tooling Shop	Agie Charmilles Robofil 6000	Electrowire erosion	1
Mista - Italy	Tooling Shop	Deckel Maho FP3NC	CNC milling machine	1
Mista - Italy	Tooling Shop	Deckel Maho V75Linear	CNC milling machine	1
Mista - Italy	Tooling Shop	Stan	manual milling machine	1
Mista - Italy	Tooling Shop	Rambaudi V3	manual milling machine	1
Mista - Italy	Tooling Shop	CR611	automatic microdrilling machine	1
Mista - Italy	Tooling Shop	Fine Sodick	manual microdrilling machine	1
Mista - Italy	Tooling Shop	Kent KGS25	grinding machine	1
Mista - Italy	Tooling Shop	KGS410	grinding machine	1
Mista - Italy	Tooling Shop	Jones & Shipman 0540	grinding machine	1
Mista - Italy	Tooling Shop	Agie Charmilles Roboform 400	edm machine	1
Mista - Italy	Tooling Shop	Agie Charmilles Form 20	edm machine	1
Mista - Italy	Tooling Shop	Millutensil 3V251	mould testing machine	1
Mista - Italy	Tooling Shop	OR Laser BU120	laser welding machine	1

Table 3: Equipment Details (Italy's Tooling Department)

The workshop is equipped with many steel processing equipment such as:

- CNC 2 x CNC machining centre
- Wire EDM x 3
- Plunge EDM
- Planar coordinate grinding x 3
- 3D CNC coordinate measuring machine
- Test press for moulds

Different mechanical tests and tests to be carried out on raw materials and components takes place in the laboratories which are equipped with cutting edge technologies. Finally, the offices are divided into technical, sales and purchasing office as shown in 2 and indicated by P7.

3.1.4 Tunisian Plant:

In Tunisia, the factory consists of a moulding department with presses underlined in the table below. Also laboratories, raw materials and semi-finished warehouses and offices.

The moulding department contains 28 injection moulding presses between 50 and 320 tons as shown in Table 4, and in addition to the presses there are vertical injection presses, ultrasonic welding machines and lines for testing and assembly of electromechanical products .

Press Number	Serial	Supplier	Model	Screw diameter(mm)	Generation
Presse N°80	226060	ARBURG	720S 3200-1300	60	New 2013
Presse N°77	226028	ARBURG	720S 3200-1300	60	New 2013
Presse N°72	221581	ARBURG	720S 3200-1300	60	New 2012
Presse N°6	203880	ARBURG	720S 3200-1300	60	New 2007
Presse N°20	165814	ARBURG	520C 2000-675	55	Old 1996
Presse N°18	161546	ARBURG	470C 1600-625	50	Old 1995
Presse N°19	185390	ARBURG	630S 2500-1300	70	Old 2001
Presse N°34	196155	*ARBURG*	420C 1000-350	35	Old 2004
Presse N°43	196157	ARBURG	420C 1000-350	40	Old 2004
Presse N°33	205063	ARBURG	420C 1000-290	35	New 2007
Presse N°17	214581	ARBURG	420C 1000-290	35	New 2010
Presse N°88	232504	ARBURG	470S 1100-400	40	New 2015
Presse N°87	231310	*ARBURG*	420C 1000-290	35	New 2015
Presse N°40	208968	*ARBURG*	370S 700-290	25	New 2008
Presse N°79	165554	*ARBURG*	420M1100-100/250	30	Old 1996
Presse N°67	212565	ARBURG	1200T 800-350		New 2010
Presse N°73	221564	ARBURG	1200T 1000-400	25	New 2012
Presse N°74	165851	ARBURG	1200T 1300-210	40	Old 1996
Presse N°42	164728	*ARBURG*	1200T 1300-210	40	Old 1995
Presse N°81	166312	ARBURG	1200T 1300-210	40	Old 1996
Presse N°41	207264	ARBURG	1200T 1300-350	40	New 2007
Presse N°85	229838	ARBURG	320C 500-170	30	New 2015
Presse N°45	212449	ARBURG	320C 500-170	30	New 2010
Presse N°39	209589	ARBURG	320C 500-170	30	New 2008
Presse N°38	204400	ARBURG	320C 500-170	30	New 2007
Presse N°37	209730	ARBURG	320C 500-100	25	New 2008
Presse N°36	193994	ARBURG	320C 500-100	25	Old 2004
Presse N°25	196151	ARBURG	320C 500-100	25	Old 2004

Table 4: Press Details (Tunisia Moulding Department)

Moreover, on the site of Menzel Bouzelfa in Tunisia there is a department for pad printing. The department consists of 5 pad printing machines in which 3 of them with 2 colours, 1 with 4 colours, and one for large pad printing (up to 500 mm). The department is also equipped with heated ovens for drying the components.

In equipment, same as Cortiglione site, there are machines for testing, producing and maintaining the moulds.

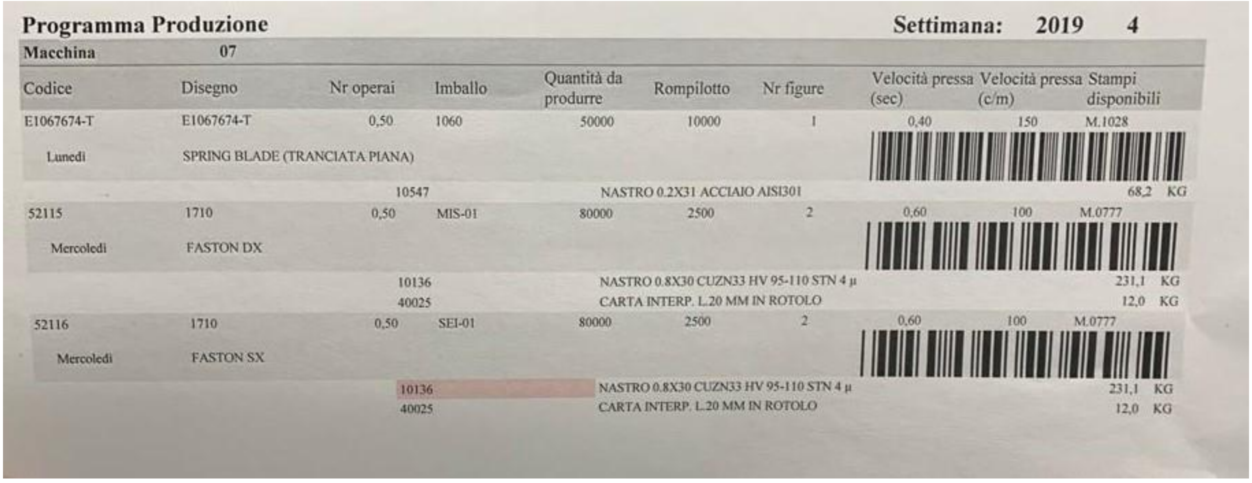
3.2 Process Data collection:

It is fundamental to know how the company manage the data collection before implementing MES. In this section there will be a detailed clarification of every step of documenting the process starting from initiating the work order until the quality control and accepting the final product. The company now still uses paper work for every step with different templates throughout the process resulting in a massive data on papers with no actual beneficial analysis of the management over the data for both short term and long term tackling of problems, preventing them or implementing any improvements.

3.2.1 Initiating a work order:

The program of production for a specific duration which can be monthly, weekly or daily depending on the case is printed and presented beside the machine for the operator with different kind of information. All this data is extracted from the management system used by the company which is the SIGIP. The data is different depending on the type of the machine and also the department's floor. So there are different information for the injection moulding department and the stamping department. The following figure shows the production program for pressing machine no. 7 in the stamping department with information such as:

- The code of the order
- design
- number of operators needed
- the quantity to be produced
- packaging
- No. Of figures
- The Press velocity
- The raw material needed from the warehouse with their description and unit as No. of parts or the mass in Kg.



Programma Produzione — **Settimana: 2019 4**

Macchina 07

Codice	Disegno	Nr operai	Imballo	Quantità da produrre	Rompilotto	Nr figure	Velocità pressa (sec)	Velocità pressa (c/m)	Stampi disponibili
E1067674-T	E1067674-T	0,50	1060	50000	10000	1	0,40	150	M.1028
Lunedi	SPRING BLADE (TRANCIATA PIANA)								
		10547		NASTRO 0.2X31 ACCIAIO AISI301					68,2 KG
52115	1710	0,50	MIS-01	80000	2500	2	0,60	100	M.0777
Mercoledi	FASTON DX								
		10136		NASTRO 0.8X30 CUZN33 HV 95-110 STN 4 µ					231,1 KG
		40025		CARTA INTERP. L.20 MM IN ROTOLO					12,0 KG
52116	1710	0,50	SEI-01	80000	2500	2	0,60	100	M.0777
Mercoledi	FASTON SX								
		10136		NASTRO 0.8X30 CUZN33 HV 95-110 STN 4 µ					231,1 KG
		40025		CARTA INTERP. L.20 MM IN ROTOLO					12,0 KG

Figure 3: Production Program Template (Example of Work Orders Queued)

3.2.2 Production monitoring:

The process consists of recording and filling manually some templates in a specific times and when there is any deviation from the process. Moreover, a sample is taken every interval of time depending on the machine and the case, established by the management system (SIGIP) during which the line operator controls the piece by performing visual and other checks with the help of complementary tools to evaluate whether it is conforming or not. Fig.4 shows the

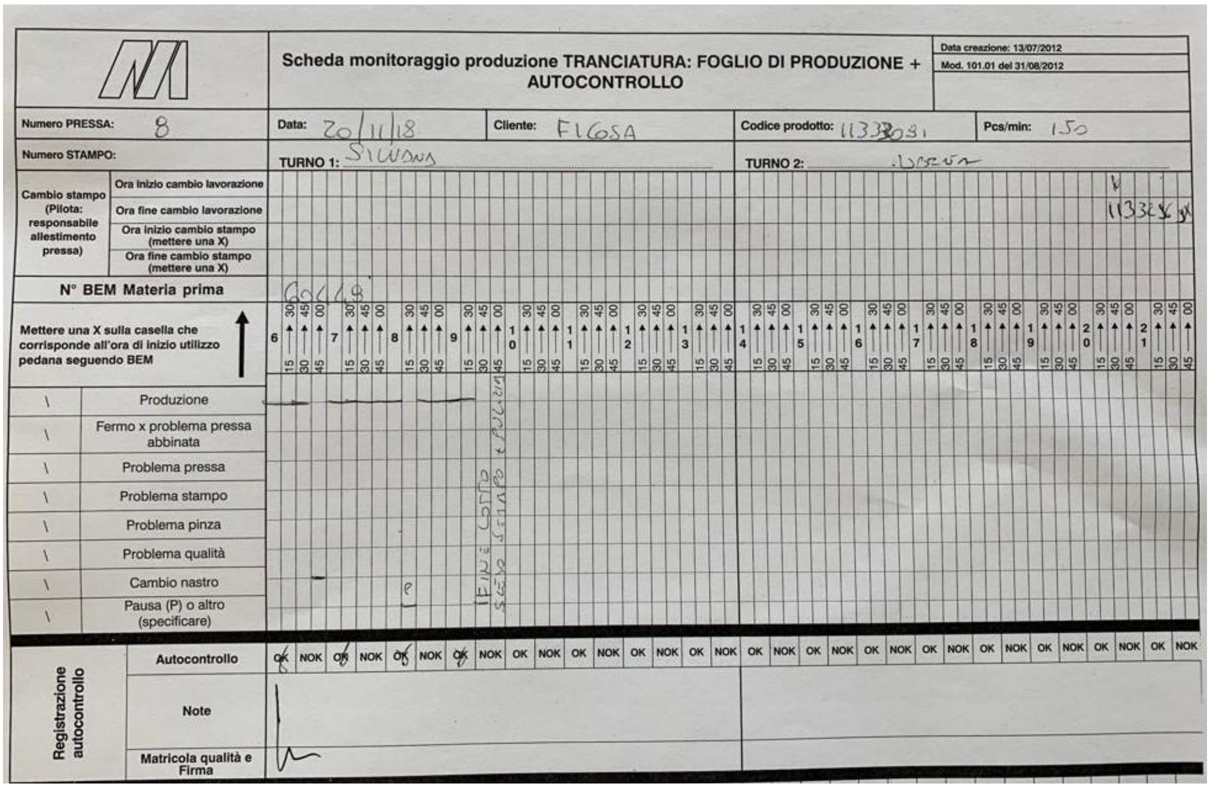


Figure 4: Production Card Template

template which is located beside the machine to be filled manually by the operator and then each section of the template will be clarified.

Following on the monitoring sheet, The production monitoring card is uniquely identified by the press number and the date of production.

	Scheda monitoraggio produzione: FOGLIO DI PRODUZIONE + AUTOCONTROLLO				Data creazione: 13/07/2012 Mod. 101.01 del 31/08/2012 **Codice resina:**
Numero PRESSA:	**Data:**	**Cliente:**	**Codice prodotto:**	**Identificazione stampo:**	**Numero impronte stampo:**

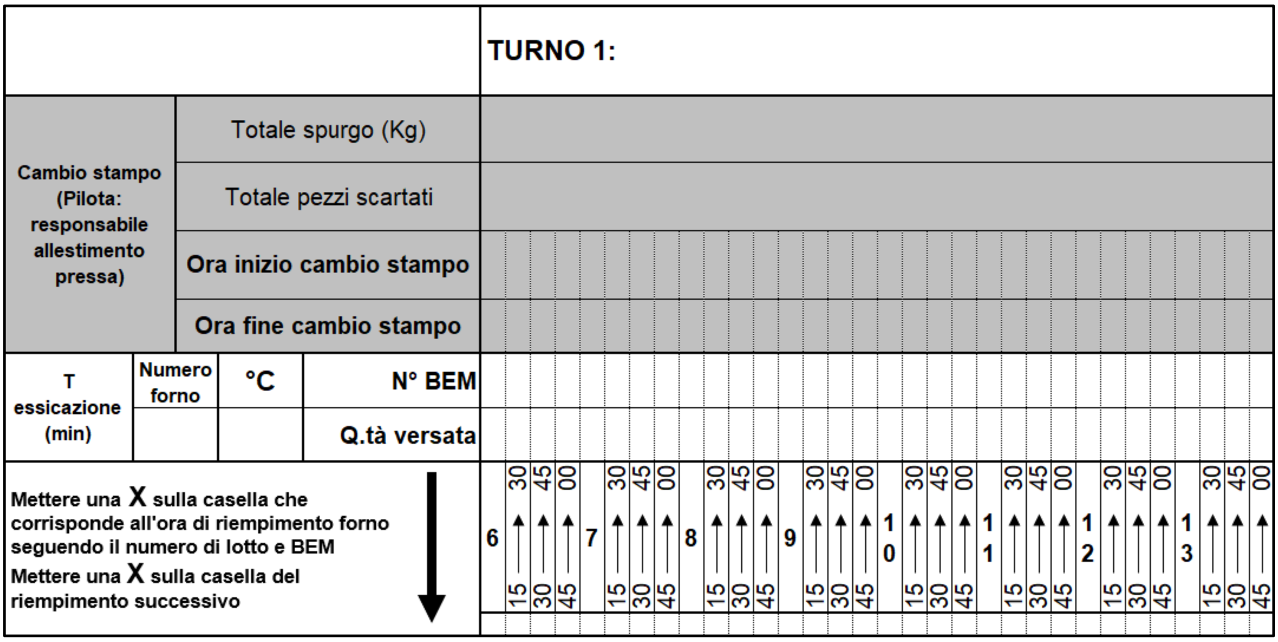
Figure 5: Production Card – Sub 1

On the right, in Fig.5, there is the field to be filled which relative to the number of cavities that is an indication of how many output will be produced for each print by the press.

The work carried out, and therefore the data collected in the moulding department do not always match with the stamping department as shown in Fig.4 as an example, it is clear that the number of mould cavities does not exist in stamping process, therefore it is not required in the production monitoring card for that department.

Each working day on the production monitoring card is divided into two or more shifts assigned to a line operator, signing the sheet at the end of the shift is required.

Furthermore, as shown in Fig.6 the daily timeline divided into 15 minute intervals. In fact, it is necessary to indicate the start and end time of the mould change if it happens.



	TURNO 1:
Cambio stampo (Pilota: responsabile allestimento pressa) — Totale spurgo (Kg)	
Totale pezzi scartati	
Ora inizio cambio stampo	
Ora fine cambio stampo	
T essicazione (min) — Numero forno — °C — N° BEM	
Q.tà versata	
Mettere una X sulla casella che corrisponde all'ora di riempimento forno seguendo il numero di lotto e BEM. Mettere una X sulla casella del riempimento successivo	6: 15–30, 30–45, 45–00; 7: 15–30, 30–45, 45–00; 8: 15–30, 30–45, 45–00; 9: 15–30, 30–45, 45–00; 10: 15–30, 30–45, 45–00; 11: 15–30, 30–45, 45–00; 12: 15–30, 30–45, 45–00; 13: 15–30, 30–45, 45–00

Figure 6: Production Card - Sub 2

For traceability issues it is essential to indicate the raw material as BEM number shown in the above figure which is an alphanumeric code that identifies uniquely the bag of the raw materials used, which can be plastic resin or metal strip located near the press. Entering the code, it will be made known to posterity for any possible backward checks, from which bag the press is supplied with raw material. However it is not completely sufficient in tracing the production chain because the BEM code is certainly not a single lot of raw material. Another row to be filled is dedicated to the number of discards which is calculated by adding the scrap made by the alarm press visible on the press monitor and the number of parts identified as non-conforming by the quality control. The quality control section will be explained in details later.

One section in the card is dedicated for the finished part drying process, the person in charge must insert some information about the process which are the time taken by the press to complete the operation, the temperature at which it was carried out and oven number.

One of the rows is "Total Spurgo" which is the quantity of material to be removed during the processing, used for guaranteeing the shape of the piece which is will be inserted in kilograms. It is automatically discarded by automatic systems installed on the press that separate it from the output product.

Moreover in the stamping department there are more flexibility because there is the ability to perform different types of machining using the same machine, the line operator will have to enter starting and ending time to document change of work, because in this case it is necessary to set up the press for the purpose.

In order to document and monitor the production process, it is important to record the time in which the production is running and the times it stops and the reason behind stopping or interrupting the process. As shown in Fig xxx, the operator will have to mark the moments when the machine was working. Otherwise, there is a list of the most frequent causes of machine downtime, in this case they must be marked with a broken line in correspondence with the timeline, in order to know every detail on the work that is executing.

Machine downtime causes in the moulding department and in the stamping department do not coincide, the main causes for process interruption that are found in the stamping department among which to choose are:

- Stop due to combined press problem
- Press problem
- Mould problem
- Welding Problem
- Quality problem
- Changing the tape of raw material

As shown in Fig xxx there is only slight differences in this section of the production card between the two departments. The difference appears in interrupting the production in the stamping department due to the change of the tape of raw material which makes the presence of an operator indispensable..

Mettere una **X** sulla casella che corrisponde all'ora di riempimento forno seguendo il numero di lotto e BEM Mettere una **X** sulla casella del riempimento successivo ↓		6	15 → 30	30 → 45	45 → 00	7	15 → 30	30 → 45	45 → 00	8	15 → 30	30 → 45	45 → 00	9	15 → 30	30 → 45	45 → 00	10	15 → 30	30 → 45	45 → 00	11	15 → 30	30 → 45	45 → 00	12	15 → 30	30 → 45	45 → 00	13	15 → 30	30 → 45	45 → 00
\	Produzione																																
\	Fermo pressa pianificato																																
\	Pb pressa, stampo, ecc.																																
\	Problema Qualità																																
\	Cambio produzione																																
\	Mancanza personale																																
\	Manca MP / inserti / imballi																																
\	Pausa o altro (specificare)																																

Figure 7: Production Card – Sub 3 (State of The Machine)

Continuing through the rest of the document there is a section for the quality control as shown in Fig.8, there are various methods for controlling. The control can be visual, contact, or carried out with the use of third party tools. They are recorded on the basis of an hourly program known to the operator who will check number of pieces verifying their conformity, if compliant they will be registered as "OK" and if not then "NOK".

For compliance verification, each press is equipped with a dossier called the defects atlas, which contains the tests to be carried out on the piece and a trace of historical defects found previously. Mostly, the operator asks for the opinion of the department manager if he identifies an anomaly which is not listed. You can also enter notes, for a new defect that was never found previously or other details that you think should be provided. Finally, to verify the quality of the piece, the signature of the quality manager of the shift is placed. Moreover, there is a specific area where the temperature of the mould should be recorded.

Registrazione autocontrollo	**Numero impronte controllate**				
	Test	OK NOK	OK NOK	OK NOK	OK NOK
	Note				
	Firma operatore				
	Firma qualità				
Registrazione temperatura stampo (se richiesta)	**Parte Fissa**				
	Parte Mobile				

Figure 8: Production Card - Sub 4

In the second page of the production card the type of defect which is detected and identified during sampling should be recorded. The card lists the most frequent ones as shown in Fig.xxxxx which do not match exactly the anomalies found in the stamping department. Moreover, the card in the stamping department lists the following causes for non-conforming:

- Rupture / chipping;
- spots;
- Out of quota;
- Scrap marking;
- Other (to be specified).

The sorts of imperfections that can be found are much lower than those of the moulding department, because stamping process is obviously much less complex than moulding.

	6.30	8.30	10.30	12.30	14.30	16.30
Incompletezza						
Rottura						
Bava						
Macchie						
Bruciature						
Risucchi						
Bolle						
Caduti						
Ideo NC						
Circuito deformato						
Pin corto o deformato						
Allarme macchina						
Scarto collaudo generico						
Altro (specificare)						

Figure 9: Production Card - Sub 4 (Causes of Scrap)

Recognizing the number of pieces produced by the machine is possible on board of each press. Also it has the ability show the number of pieces produced during a possible alarm state of the machine, which are automatically labelled as production waste. As shown in Fig. Xxxxxx, it is necessary to enter the number of pieces produced and among them the number of the conforms, in order to recognize the progress of production. The number that appears on the machine, if it falls into the "Old" category, is the number of prints it has made, so it must be multiplied by the number of shapes it produces. Both as regards the alarms and the production, the number of printed in the oldest presses is shown, therefore a multiplication and subtraction operation must be performed to obtain the conforms:

No. Of conforming parts = [No. printed * No. Figure]-[No. (printed in alarm) * No. Figure]

Moreover, it should be taken into account that the number obtained from the formula does not correspond to the real number of compliant parts, as several quality checks are carried out on the piece to detect anomalies that the machine alone would not distinguish.

<table>
<tr><td rowspan="3">PEZZI NON CONFORMI:</td><td rowspan="2">Contatore pressa</td><td>Contatore INIZIO</td><td></td><td>Contatore FINE</td><td></td></tr>
<tr><td></td><td></td><td>Operatore</td><td></td></tr>
<tr><td>Totale pezzi conformi</td><td colspan="4"></td></tr>
<tr><td colspan="2">Note</td><td colspan="4"></td></tr>
</table>

Figure 10:Production card – sub 5

A row to be filled in Fig.xxxxxx is "Total Pezzi Conformi" which is the number of compliant detected by the machine and reduced by the differences identified by the quality control check made by the operator. Declaring the piece produced to be suspended from the appearance of the anomaly even before the detection by the operator is the strategy followed. So all the production will be temporarily subtracted from the progress of the order, to be rechecked by an employee and maybe reinserted later on. So the duty of the operator related to this issue is as follows:

1. Note the defect
2. Check the other sampled parts from the machine as a test. Count the pieces produced from the moment of detection of anomaly on the odd piece.
3. Involve the head of department if deemed necessary
4. Updating the number of compliant pieces
5. Write any notes in the space provided to allow a comprehensible process for third parties.

It is necessary to document any tampering with the machine parameters due to initiatives by the employee or a request. There is a special space at the bottom of the page, as shown in Fig.xxxxxxx to insert various changes made as deemed necessary by those responsible, or resulting from an alarm or any encountered problem during the shift. The signature is to be affixed for assigning responsibilities.

Informazioni per il capo turno e azioni realizzate	
Nome e firma dell'operatore	

Figure 11: Production card – sub 5

For Defects recognition, there is a card that contains all the test methods to be carried out on the piece. The worker is required to execute various operations for quality control, which may also involve the use of auxiliary equipment positioned for this purpose on board the machine.

At the top part of the document as shown in Fig.xxxxxxxx identifies the piece to be checked, by means of customer code and drawing from which it will be necessary to display the required dimensions.

DOSSIER DI PRODUZIONE

Documento: **SCHEDA METODI DI COLLAUDO**

Prodotto: Support commutateur - Stampo a fig. 2

RIFERIMENTI:	Nome società Cliente		
Area produttiva	Mista	Esp. Mod: J del 07/01/2015	
Reparto appartenenza:	Stampaggio o Tranciatura		
Prodotti:	Nuovi		Modificati
Vettura di destinazione	J92		
Disegni cliente:	**Codice che identifica il disegno**		

Figure 12: Testing Methods Sheet - Sub 1

Scrolling along the rest of the document you will find the operations to be performed in details, which can be of various kinds, denoting different parameters. To be in handy for the operator, preferably a highlighted checks to be performed that turn or that day as shown in Fig.xxxxxxxxx, essentially, which will not have to complete the whole card, but only some operations considered the most relevant, in order to optimize the exploitation of time and resources.

For each control the following is specified as shown in the below figure:

- The technical characteristic to be checked.
- The size and relative tolerance.
- The document or instruction to refer to.
- The means to be used for the control and the frequency with which the characteristic will have to be checked.

SCHEDA METODI DI COLLAUDO								
N°	CARATTERISTICHE DA CONTROLLARE	CLASSE Q	RIFERIMENTI	DESCRIZIONE MEZZO	FREQ.	ENTE	CARTA REGISTR.	PIANO DI REAZIONE
1	Quota (F-12) Ø 39,4 mm +0,2/-0	FF	ISTRUZIONE OPER. 020/17	TAMP. P/NP M.879	BIL \ BCL	Q	081	AEFL
					1 st \ 24 ore	Q	101	ADEFL
					1 st \ 2 ore	L	101	ABDEFIL
2	Quota (J-8) Ø 64,1 mm +0,25/-0	FF	ISTRUZIONE OPER. 020/17	TAMP. P/NP M.880	BIL \ BCL	Q	081	AEFL
					1 st \ 24 ore	Q	101	ADEFL
					1 st \ 2 ore	L	101	ABDEFIL
3	Quota (J-7) 27,3 mm ± 0,1	IFF	ISTRUZIONE OPER. 020/17	TAMP. P/NP M.881	BIL \ BCL	Q	081	AEFL
	(Misurata su L2=0)				1 st \ 24 ore	Q	101	ADEFL
					1 st \ 2 ore	L	101	ABDEFIL
4	Quota (I-15) 11,8 mm +0,2/-0,05	FF	ISTRUZIONE OPER. 020/17	DIMA M.901NP	BIL \ BCL	Q	081	AEFL
					1 st \ 24 ore	Q	101	ADEFL

Figure 13: Testing Methods Sheet - Sub 2

Moreover, as shown in Fig.xxxxxxxxxx it does not always refer to quotas to be measured with equipment supplied, sometimes it is only required to have a visual check with the images present in the atlas of the defects , available on board the press.

17	Assenza deformazione, bave e incompletezze (vedi istr. Operativa dedicata)	-	ATLANTE DIF.	VISIVO PER COMPARAZ.	BIL \ BCL	Q	081	AEFIL
					1 st \ 24 ore	Q	101	ABDEFIL
					1 st \ 2 ore	L	101	ABDEFIL
18	Verifica corretto utilizzo materiale : PP FV30% STAMAX 30YM240 Cod. 680290	-	E1064284	visivo	BIL \ BCL	Q	081	AE
					1 st \ 24 ore	Q	101	AEL
19	Peso	-	TABELLA PESI	BILANCIA	BIL	Q	081	AEF
20	Verifica corretta registrazione sk ok demarrage	-	081	visivo	BIL	Q	081	AEFL

Figure 14: Testing Methods Sheet - Sub 3

Following this process, there will be an employee, in charge of collecting these data to transfer them to the management system (SIGIP). He/she moves through the department, with a mobile station, prepared with a laptop and a scale, with the ability to computerize useful data and collecting others. The operator has the task of weighing each single piece sampled, with a precision scale with triple decimal. Once the weight of the product is obtained, it will be inserted on an X-R Control card which is present on the laptop relative to that precise object code. It will then check the status, whether in control or not, and in the event of an anomaly, it will be directed to the departmental manager for decision making.

The laptop is essential, as well as to fill the control card, also to enter data on SIGIP, to be processed. In fact, the person in charge will insert the production progress, the manager, and all the information deducible from the production sheet.

Moreover, if an anomaly is recognized as different from all the others, the employee will take care to take a picture to insert it, first in the management system, and then, in the defects, placed on the machine.

All these data will then be entered in the management software, SIGIP, at the end of the production day and then displayed with a delay of at least one day.

Chapter (4) Challenges

4.1 Process of Choosing the Supplier

The Following is just a brief explanation of how Mista was trying to choose its MES supplier from about a year ago before it chooses INNOVO Tech which designs and develops innovative software products for manufacturing companies, in particular solutions for automating the collection of production data from the simple and basic replacement of the paper report to the whole management of the factory. Innovo's MES systems find a practical application in the production companies of different sorts and categories such as: mechanical, molding, machines, electrical, food and pharmaceutical.

The INNOVO company is characterized by its firm internal competences, which are solutions flexibility, continuous attention towards the evolution in technology of its software products (SPHERA), the modern hardware and it is known also for the continuity in the support service offered.

During the process of choosing the best supplier to Mista, it was essential to transform the objectives into requirements. First dividing the requirements into two main macro categories, functional requirements and interface requirements. The functional requirements concerning the software side of the system, which covers the functionalities and the services that it is able to offer. This is in particular the production data collection, through a hardware installed on the machine, or manually inserting of the same through a barcode. The interface requirements consist of the accessibility of the system and its usability. To fulfill these requirements it is necessary to offer an easy user experience that is easily understandable and intuitive in use.

Therefore it is necessary that the system is correct, complete and consistent. This means that the system must be able to represent in an adequate way all the functions of interest to the company without any inconsistencies. Once the main requirements of the newly information system have been defined to meet the needs of the company, it is required to choose whether to buy or to implement the system. In another words, to exploit the resources internally to develop the MES or purchase a solution provided by a specialist in the field.

An economic and a strategic variant should form the decision. It is necessary to have a balanced budgets and resources to be used, but at the same time taking into account the company's goal, what is needed to be focused on and areas of interest. Developing a software internally is challenging today, for example in Tunisia a device has been developed internally that can interconnect some machines but it is not competitive on the market in a particular way. Developing software internally would imply a very high fixed cost for necessary skills acquiring, also it is considered time consuming and it require the availability of massive resources. Following this analysis it was therefore considered necessary to look for solutions provided by those in charge and purchasing the system seemed the right decision after analyzing the situation. Different possibilities were ranging:

- Proprietary solutions of machine manufacturers. On one hand Mista would deal with already known suppliers so therefore trusted. But on the other hand the aspect that could be negative is that the MES doesn’t coincide with the core business of the company, and consequently the product could do not fully meet the needs of the customer. (Engel, , Arburg ALS, Brankamp)

- ERP supplier solutions. But anyway the ERP provider could very easily create a bridge of communication between MES and SIGIP, without the need to be specialized in the implementation of the information system and therefore could provide a product which may not be competitive enough. (Sorma)

- The producers of MES. They have working prototypes and therefore have the ability to provide a service and a product that can meet the requirements of the company, but they do not know the company compared to those of other options and may encounter problems in the customization of the system. (Brick di Reply, Atomos, Jpiano by AEC Soluzioni)

- Solutions developed by manufacturing companies. These are considered by those who have already competence in the manufacturing sector, but also in the IT sector and software development. There will be the risk of the presence of bugs in the system as the knowledge of the specific moulding and stamping sector could make the choice attractive. (SmartFAB, Rold)

- Manufacturers of interface between machines (Plc, numerical controllers). Mista also took into consideration those who manufacture PLCs and numerical controllers, which therefore own the know-how of technologies for the communication between machines and MES , even if the latter could not fall within the supplier's scope and therefore may be subjected to imperfections and shortcomings . (Alleantia)

Realizing the selection was reached after following different steps. Once the requirements have been defined, the searching process between the suppliers begun in order to improve the requirements. The online research was therefore intended primarily to find out how the market was working, what suppliers were offering, and what other Mista-like companies had implemented. At this point there was the possibility to select some suppliers on the basis of some references, official website's offers, geographical location, number of installations, experience in the sector and years of activity.

For the companies that have been selected on the basis of the criteria explained above, it was then followed by contact through telephone. Specific documentation has been sent, identifying the characteristics at the present time of the company and the requirements that were required to be met through the installation of the MES and a meeting was requested for a direct comparison to have more information about the offer and to get response to any clarification needed by Mista.
The meeting was intended to fill the requirements matrix through an interview. The rows of the matrix are:

a. Knowing in real time whether the machine is working or not and for how long
b. Identifying the reason of machine stop:
    - set up
    - alarm status
    - lack of MP
    - programmed stop
    - unplanned stop
c. Number of good and defective parts counted in alarm or by line operators

d. Type of any identified defect
e. User-friendly interface
f. Customizable interface
g. Knowledge of responsibilities:
   - line operator if qualified
   - Department head
   - Quality Manager
h. Traceability of production responsibilities:
   - press code
   - date and time of production
   - piece code
i. KPI Calculation:
   - OEE (Overall Equipment Effectiveness)
   - Time left at the end of production
j. Programming machine parameters from the MES
k. Acquisition of machine parameters for the production of the piece from the press to the MES to compare it with the starting ones and alarms
l. Use of Big Data for the purpose of:
   - monitoring the improvement of production quality
   - process performance improvement
m. Registration of quality checks
n. MP traceability
o. Collecting status information in tooling
p. Multilingual
q. Scheduler availability
r. Flexibility in software development
s. Pre-existing system completeness
t. Experience in the sector
u. Non-proprietary hardware
v. Purchase of software license
w. Compatibility with multiple operating systems
x. Knowledge of Euromap 63
y. Knowledge of OPC-UA
z. SIGIP knowledge

Then a matrix filling criterion was based on assigning the value 1 for the satisfied requirement and 0 if not. Moreover, every requirement has been assigned absolute importance and subsequently a relative importance. The scale of the importance assigned ranges from 1-5 in which:

1. Irrelevant
2. Not Important
3. Important
4. Very Important
5. Fundamental

As a result of the meeting, the interlocutor has learned in more depth the needs of the company, filled the matrix and a detailed economic proposal has been requested.
In the first place, investing much effort was not needed to analyse the packages that were offered and then rank them on the basis of the prices without considering other factors.

In the offers that were presented, each supplier included both the price of the software and the hardware taking into consideration the personnel cost and the post and pre-installation services. Finally the MES system has been divided into functions. The functions on which it is expected to act are: production management, traceability of raw materials, maintenance management and quality control.

4.2 SMEs Challenges of Implementation :

In this chapter the challenges that can face small and medium enterprises during the transition phase to industry 4.0 will be discussed and also a detailed explanation of what faced Mista S.p.A during MES implementation as a step toward industry 4.0 will be recorded here as a reference for other companies with similar size and circumstances before starting the process of implementation.

The degree to which Industry 4.0 applications are speeded, depends mainly on size of enterprise [14]. Companies which are large enough and produce in high volumes are characterized by being highly capital intensive . Continuous optimisation of highly automated production is a permanent element of process management. The proportion of manual and hybrid activities is much higher In SMEs. They produce rather for niche markets and often their degree of specialization is relatively high. In contrast, large companies will realise much higher efficiency gains from the use of Industry 4.0 technologies compared to SMEs. The range of technological options is increasing so small and medium sized industrial enterprises will have to take advantage of developments towards networked production. Otherwise their will be a threat to their international competitiveness. In this context the main challenges that small and medium sized enterprises have to meet are the development of an appropriate strategy, a cost benefit analysis of the relevant technologies and uniform standard.

4.2.1 Deficiency of a digital strategy alongside scarcity of resources:

Consistent data and its availability is an significant condition on the way to Industry 4.0. Along Value creation chain the information must be consistently available both vertically and horizontally. On one hand, vertical integration in the sense of the integration of various IT systems into a seamless solution, thus achieving compatibility between various IT applications, processes and data of the company's functional areas such as production, procurement and sales. On the other hand, the horizontal integration is the way of connecting various process stages between which there are flows of materials, energy and information [15]. One example to illustrate it is the Enterprise Resource Planning system, which takes care of material related issues, scheduling and capacity planning of order processing and is connected to a Manufacturing Execution System (MES) in the company's software architecture. This handles short-term, detailed planning and control of production orders. Boosted efficiency and shortened throughput times are reachable as a result of such coordination between the various levels of the hierarchy by means of complementary IT [16].

The set of IT systems, machinery and processes at most of small or medium sized enterprises tend to have been acquired over time, the machines and equipment come from various manufacturers and are of different vintages. As a result, retrofitting automation software in order to achieve compatibility is expensive [15]. An even more critical challenge for many small and medium sized enterprises is likely to be is bringing about data flow to adjacent internal and external areas for enabling exchange of production data in both horizontal and vertical forms. Horizontally with suppliers and customers and vertically for sales, planning, services or controlling.

For SMEs this challenge is particularly great because they have less resources and know how than large companies [17]. The Managers themselves will have to go through the task of assessing various Industry 4.0 technologies in respect to their technological maturity and business potential, because SMEs often do not have their own IT department. These variances is the reason why small and medium sized enterprises are often encountered by difficulties in selecting the right solution and complain of a lack of user transparency.

The SMEs management always view networking production with some caution, this fact is illustrated by the IT Innovation Readiness Index produced annually since 2013. This shows that the senior managements of manufacturing SMEs are more cautious about the issue of Industry 4.0 than production managers who were surveyed [18]. This reserve on the part of business management is disturbing to the extent that the implementation of Industry 4.0 is an extensive task that usually has to be considerably planned and introduced at this level. The task comprises of reworking processes and company organisation at almost all levels by restructuring them, the adaptation of workers qualifications and strategic reflections with regard to the development of new business models and the initiation of new markets. Without involving the management and their impetus toward the dissemination of Industry 4.0, it will be kept within narrow limits. Forty percent of SMEs have no inclusive and clear strategy for Industry 4.0 implementation, while among larger companies the percentage is only twenty which shows that this limitation is a characteristic of SMEs [19].

4.2.2 Lack of standards and poor data security:

The hesitations that small and medium sized enterprises have regarding the switch to new Industry 4.0 technologies and moving forward with the integration of the various IT systems can also be ascribed to the lack of standards and norms. Moreover it can also be attributed to the fear of unauthorised access to the data. Even though some improvement has been made in the development of standards, for example by means of Open Platform Communications Unified Architecture, an international standard has not yet been applied.

A condition for achieving a high number of network partners is the realization and implementation of a secure standards and norms which as result will unfold the full economic potential of Industry 4.0. Currently, SMEs often adapt to the standard of the large company of which they are a supplier. It is hard joining the value creation network by SMEs in the case of lacking a general standards. The presence of different standard and norms narrowed the room for SMEs to manoeuvre. On top of this comes a worry that high investments will have to be written off if they fix on an interface technology that ultimately is not implemented. Thus most of the production SMEs only adopt Industry4.0 technologies if there is enough CPS interoperability and security by means of standardised interfaces and protocols.

An additional method to overcome interface problems would be the use of higher level cloud services. Also downstream services can be developed and provided via platforms. The most critical obstacle for utilizing cloud services are concerns of security. Obviously, there is a major concern that data which can be considered sensitive are not really secure in the cloud and might be accessed by third parties. More reasons for the abandonment of cloud services is the uncertainty about the geographical location where the company's data are stored and the applicable jurisdiction [20].

Chapter (5) Research and Findings

5.1 Process Data Collection after Implementation (Operator Portal):

The following will be detailed explanation of how the data will be entered by the operator after fully implementing the system. A step by step explanation of data entry will be discussed to be compared with the old means of data entry before implementing the MES when the factory was relying totally on massive paper works and procedures which at the time of introduction made sense but with the fast pace now, fierce competition in the market and the introduction of such technologies in IT systems, the old system doesn't make sense anymore nor can be justified to be used in the new era. During the writing of this dissertation, the implementation process is still going on and I am the one responsible of doing some tests on the system so I will document some of the problems faced us during the implementation and how it was tackled and solved by the management. Before starting a clarification should be done between the two portals used in the company after implementing the MES which are Sphera Term used by the operator which will be explained in this section and Sphera Gui used by the management which will be discussed later.

There is a terminal of a screen and a bar code reader for each machine or at least each group of machines in which the operator has to deal with for data entry along the whole process.

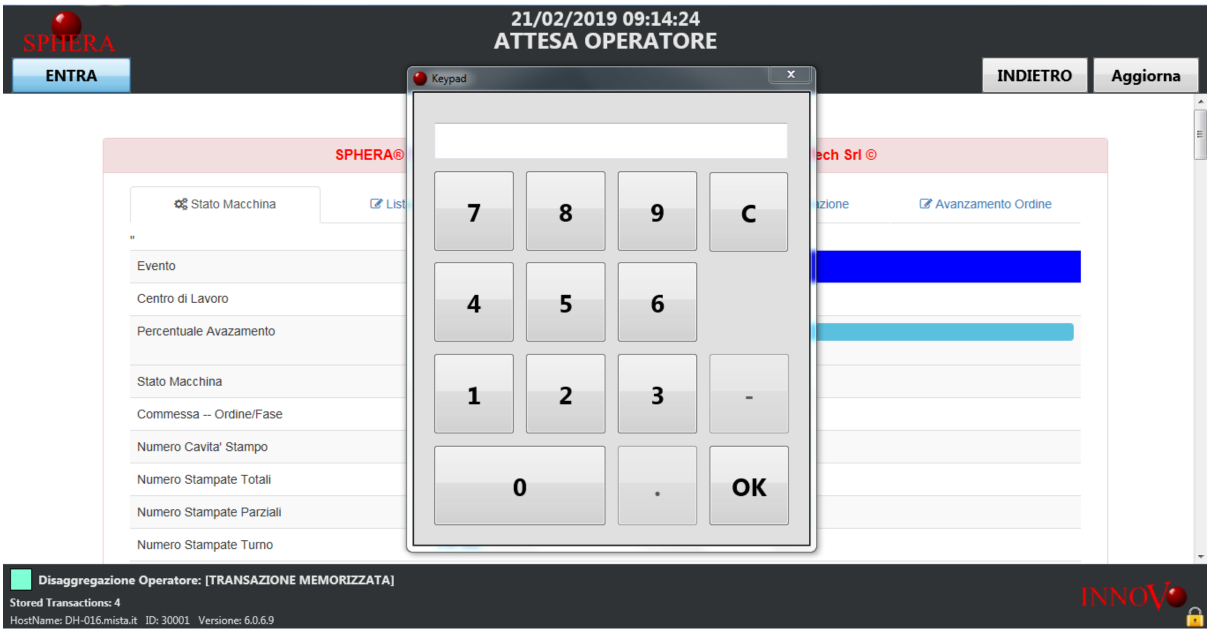


Figure 15: Operator's Portal (Log In)

Moreover, there is a suggestion that these screen should be a touch ones, in order to make the process much faster and easier for the operators.

As shown in Fig.15 the first thing an operator has to do is entering his badge number or use a bar code reader which will be implemented in a later step during the implementation process so that the system can recognise each operator dealing with the system uniquely for responsibilities assigning.

After logging in the operator has to aggregate himself or herself to the machine as under the option of “operatori” there are various commands that can be given. As shown in Fig.16 the operator can aggregate himself or disaggregate himself to the machine there is one button to disaggregate all the operators from a specific machine which can be done depending on the case maybe by the supervisor or the shift manager. Also there is one command that can disaggregate all the operators except the last one which can be useful in many cases according to the operators on the floor. Finally in this section of commands you can see the state of the operators “Stato Operatori”.

Figure 16: Operator’s Portal (Operators Section)

The system will interact with the operator with a message when any command is chosen to take place so it will answer the operator with a message in case the command is allowed or not allowed and the cause why the command is not executed. In case the command is executed the system will give a message as shown in Fig.18 with the message “Transazione Memorizzata” or “Movimento Valido”.

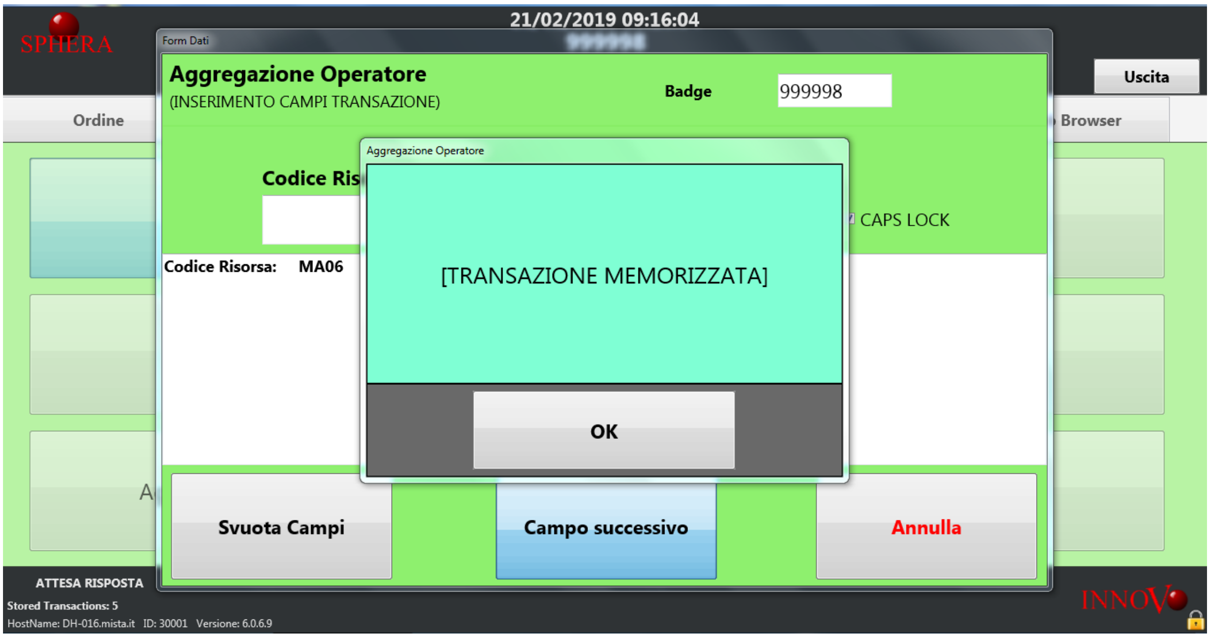


Figure 17: Operator's Portal (Communication Messages)

Moreover, after the login of the operator and his aggregation to the machine now it is the time to start a new order or continue an order which is stopped due to change in the shift or maybe finished and a new order should be initiated.

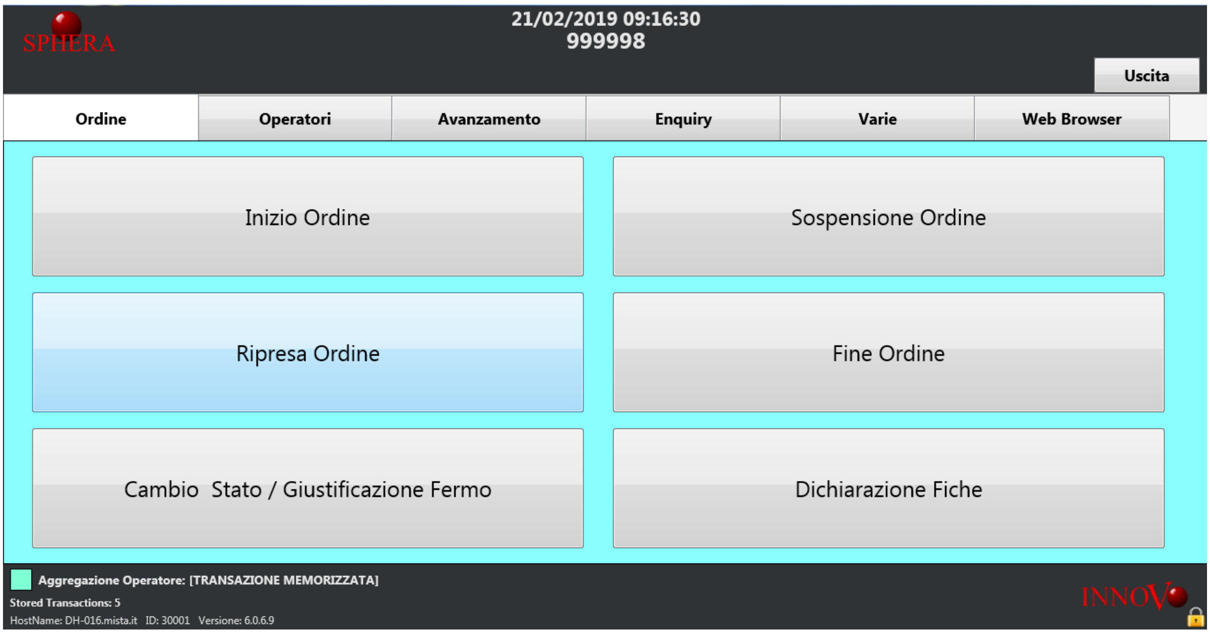


Figure 18: Operator's Portal (Orders Section)

As shown in Fig.17 there are various commands that can be done under the "ordine" page. Such as starting an order, suspending ,completing, finishing and changing the state of production which may be stopped due to various causes which was done manually in the past as we saw in the earlier section of process data collection. Now it may be needed to be entered in the system by the command “Cambio Stato” or with some machines and lines it is recorded automatically.

A shown in the below figure when pressing one of the following commands a page will appear with the order numbers in which a specific command is intended depending on the situation. The order numbers is generated automatically from the management system used by MISTA which is the SIGIP. During implementation there were some comments from the engineers and the operators working on some of the machines that the way of coding the order numbers doesn’t help in choosing the right one so a new way of coding is under processing by SORMA the SIGIP provider to make the system work more smoothly and accurately. Some information is associated with the order number such as the quantity to be produced.

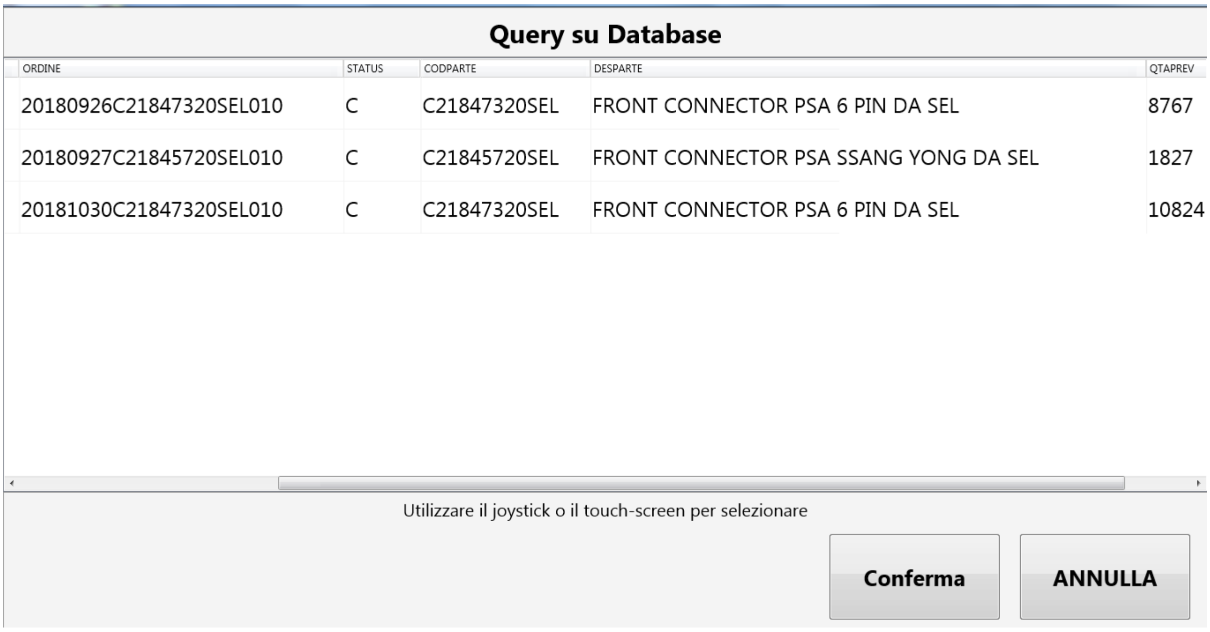


Figure 17: Operator's Portal (Work Orders Queued)

As shown in Fig.20, this the list of causes of changing the state of the machine and it appears according to the machine and the department automatically so that the operator finds the list which best suits and corresponds to the machine or line being worked on. As stated before in some cases if the line reaches an automation level, it directly changes the state in the MES without the need of any human intervention by means of data entry.

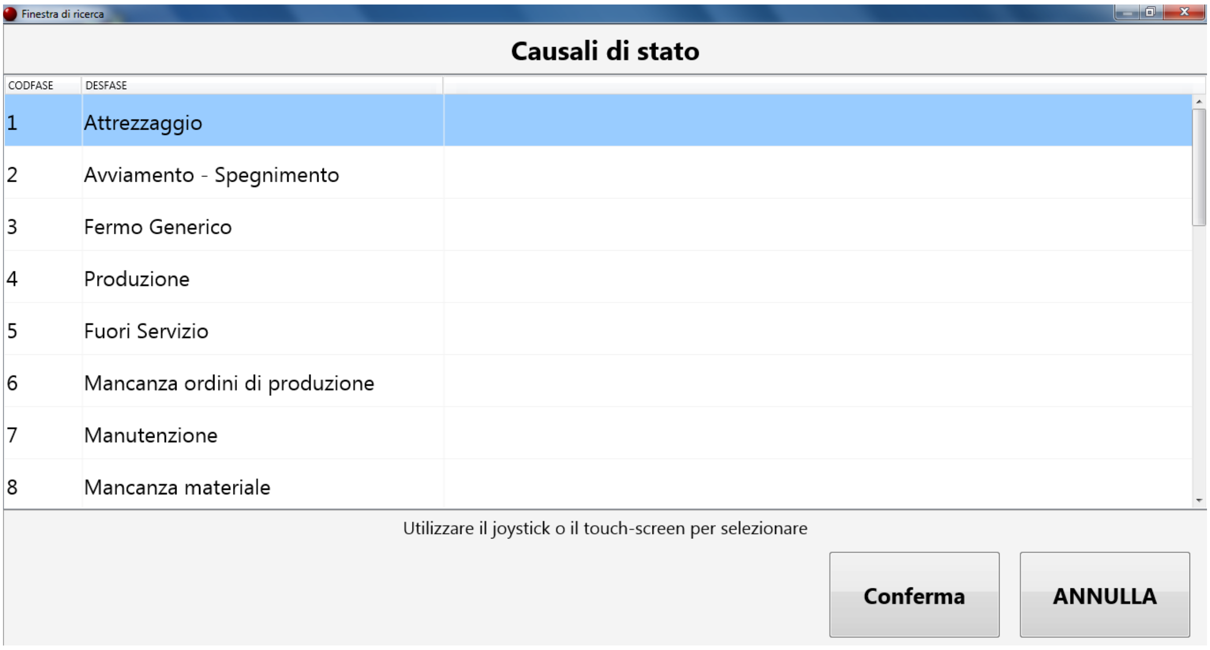


Figure 18: Operator's Portal (State of the Machine)

The next page of commands is "Avanzamento" where the operator can insert the quantity produced also the scrap amount and the cause of this scrap. The scrap amount is inserted manually after performing visual inspection or some inspection with means of tooling. However, with some machines another kind of scrap is calculated automatically and enters the system without any manual data entry which are the parts considered scrap by the machine itself if it is above certain level of automation and this scrap doesn't need any further inspection and shall be added automatically to the quantity inserted by the operator.

Figure 19: Operator's Portal (Progress Section)

As shown in Fig.21 there are some other commands such as the amount of parts produced which needs some kind of reworking.

The following figure shows the list of causes of scrap (about 160 cause) that the system asks for after inserting the amount. Actually, it was one of the problems discussed after testing the system on one of the machines. The list included too many causes so after discussing the issue with the management it has been decided to put the most frequent and important ones for each department to the corresponding machine to make the process easier, in need for less time and to eliminate any source of confusion to the operators. After showing the problem to the operators and asking them about their opinion in the issue to include them in the implementation process, because if they feel distant from the process they will start fighting the change and not coping with it. The operators comment was to put also the most common ones which were used by the old system with their established corresponding code as all of them are familiar with the codes of the causes from the old system as it was being used for many years.

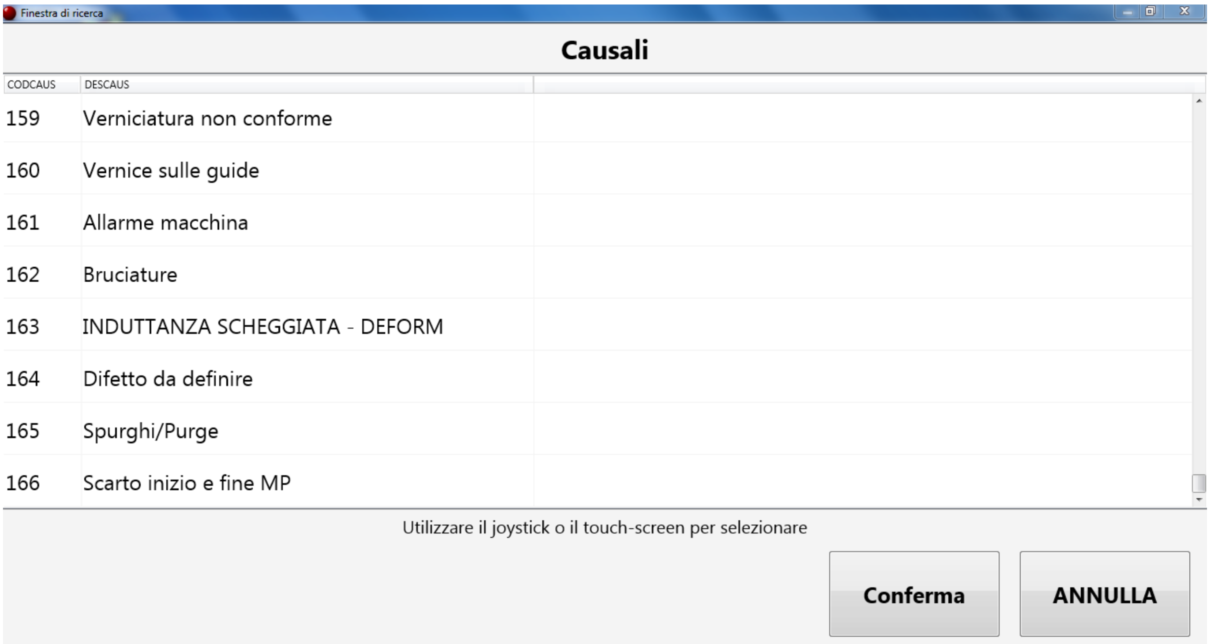


Figure 20: Operator's Portal (Causes of Scrap)

Fig.23 shows the first page that the operator deal with before even being aggregated to the machine or starting a work order. This page also shows a lot of valuable information for the operator along the production process. It shows the state of the machine whether it is stopped, in setup or in production. The percentage of the work done is showed with a loading form of progress. Moreover, it shows the quantity produced, scrap and the total quantity to be produced to finish the order. One of the most important things shown are the theoretical and real cycle time which actually enters in a lot of equation for data analysis in the other portal which is used by the management team which will be discussed in details later in the next section. It gives an estimate of the time needed to finish working on the order. Also from this page as shown in the upper part of the figure the operator can choose between different pages with different data to be presented on the terminal. For example there is the state of the operator which shows information about the operators aggregated on the machine and the work order they are working on. Also some documents can be accessed which is related to the part being produced such as drawing of the part, steps for the quality control and any other document which may be helpful for the operator during the process.

Figure 21: Operator's Portal (Information Screen)

5.2 Management Portal:

In this section, the Sphera Gui which is the portal for the management side will be explained in details with the KPIs which can be calculated and monitored to make improvements to the process.

As shown in Fig.24 in dealing with this portal you will find the main classification of commands are Registries (Anagrafiche), Planning (Pianificazione), Monitoring (Monitoraggio), Progress (Avanzamento) and KPI/Reports which will be explained in a separate section later on. The Registries where you can register by adding, removing or modifying data in the system. The lists of data that can be modified are connected also with the other portal for data entry and this portal for commands being explained in this section. Examples of such lists are operators, Causes for stopping the production, and the machines connected with their unique code.

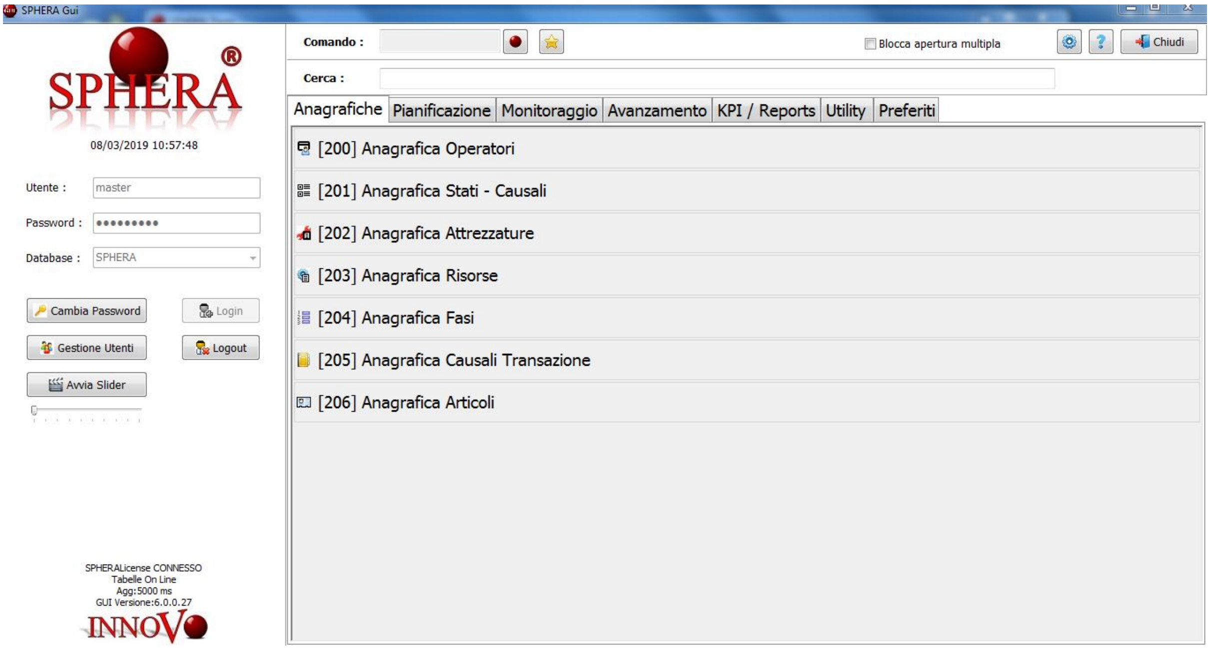


Figure 22: Management Portal Main Features

One of the features allowed by the portal is to give different permission to access different features with username and password so each one in the management can use the portal with just the features needed to service the needs of the task assigned. As the system can collect massive amount of data with analysis, so the confidentiality of this data should be protected.

Roaming thorough the portal, a group of features which need some attention are under the monitoring category as it is one of the critical requirement justifying the implementation of the MES. The ability to monitor the production process with all its attributes in real time is one of the most basic steps to for industry 4.0. The Monitoring is divided into two main categories which are the machine and the operator. For monitoring the machine the system shows the layout of the floor in each department with each machine showing some information such as the state and the progress, to give an outlined view for the management about what is happening in the floor. The following figure shows the machines in the injection moulding department which are going to be connected in the first phase and as the implementation is still in progress while writing this, only two machines are shown to be in production demonstrated with the green colour. The important one here is the machine labelled as FC which is the linea Ficosa and it gets its importance due to two reasons, first because it is automated and secondly it was the first machine to be tested with MES so all the data and graphs shown later will be extracted from FC.

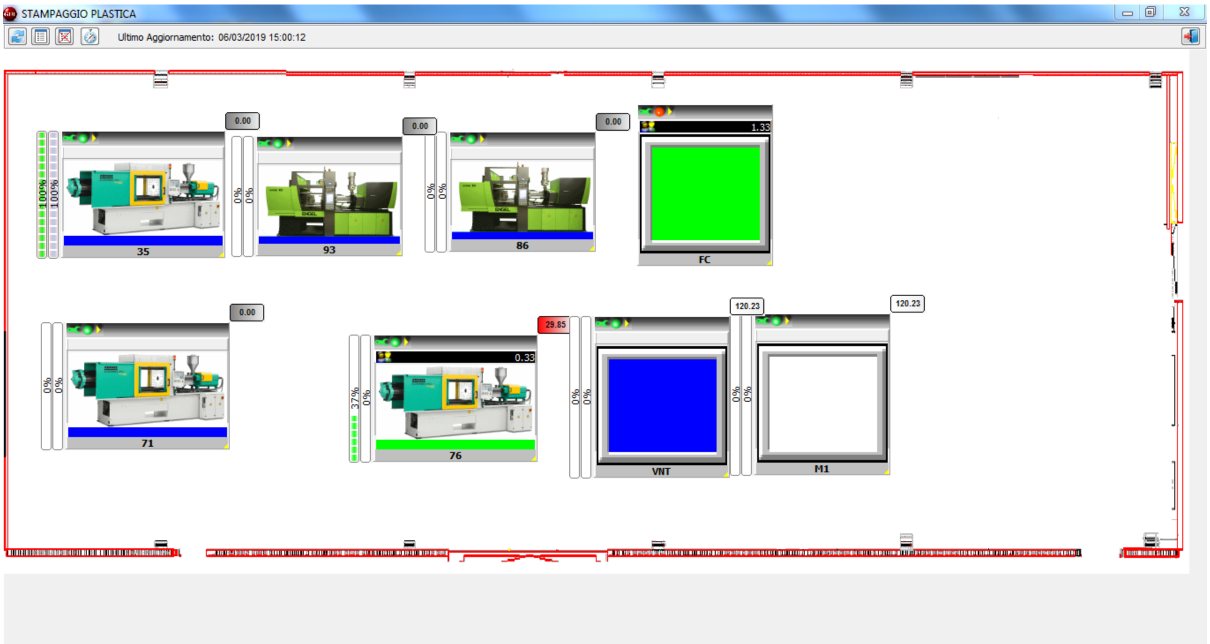


Figure 23: Management Portal (Layout of Machines)

Some other features under the monitoring category for the machine are the situation of the machines, Details of the machines and machines in alarm. Most probably all the parts produced for machine under alarm will be considered scrap. However, for the 'Situazione Risorse' or the machines situation as shown in Fig.26 a more detailed information can be monitored. The management will be able to know in real time the situation of each machine on the floor with which work orders under progress. Also some information as quantities produced, to be produced, scrap and the theoretical and real progress in work. For example in the figure it shows that the percentage of real progress is 85% while theoretically it exceeded the 100% which means that this work order should have been finished. Also from the timeline which appears you can identify any problems encountered the production during the life of processing the order which most probably the reason of delay here and by clicking on it, a window will appear with some information about the problem such as the exact time it started and ended for further inspection and analysis to be done to understand it. Mainly trying to avoid it in the future or take some measures if the problem was found to be frequent on this machine.

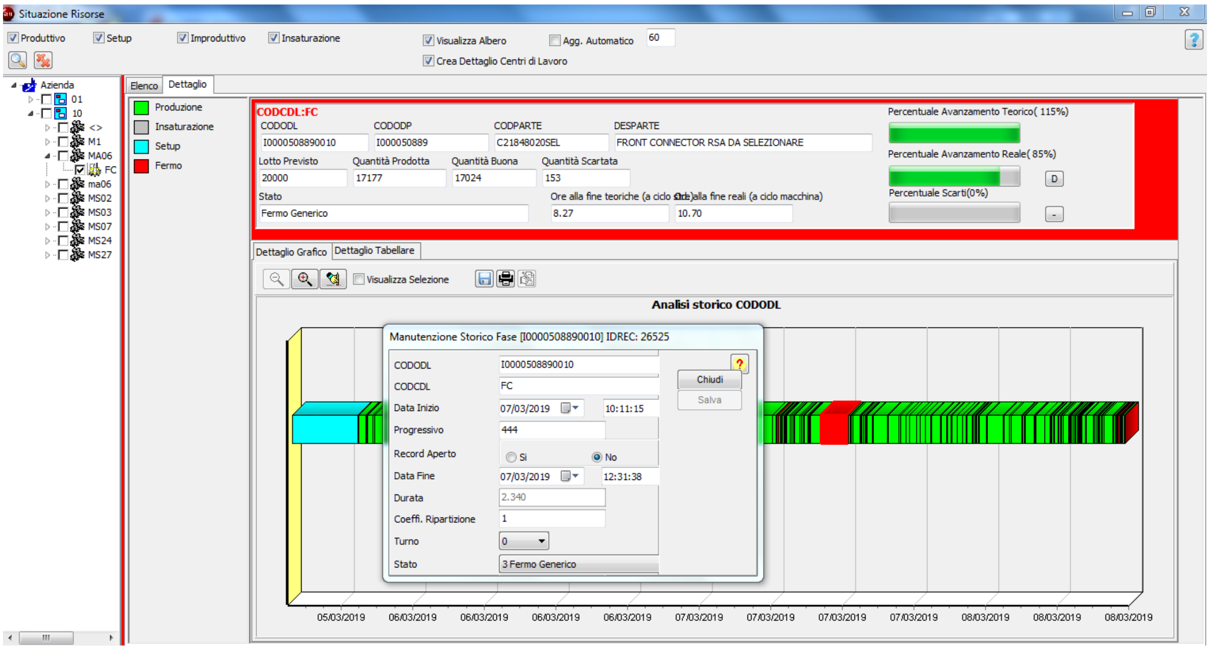


Figure 24: Management Portal (Machine situation)

For the machines in alarm feature as shown in Fig.27, it shows the event which may be for quality control or its just an alarm, the machine and the exact time of the incident. Also by studying this if there is pattern or frequent incidents of the same machine maybe in the same shift, a lot of conclusions can be withdrawn after further study. For example if it is frequent with one machine at a certain shift this means that most probably the problem is associated with the operators working on the machine at that shift. So some measures should be taken to tackle the problem in a way that would needed a lot resource to tackle under the old system before the implementation of MES.

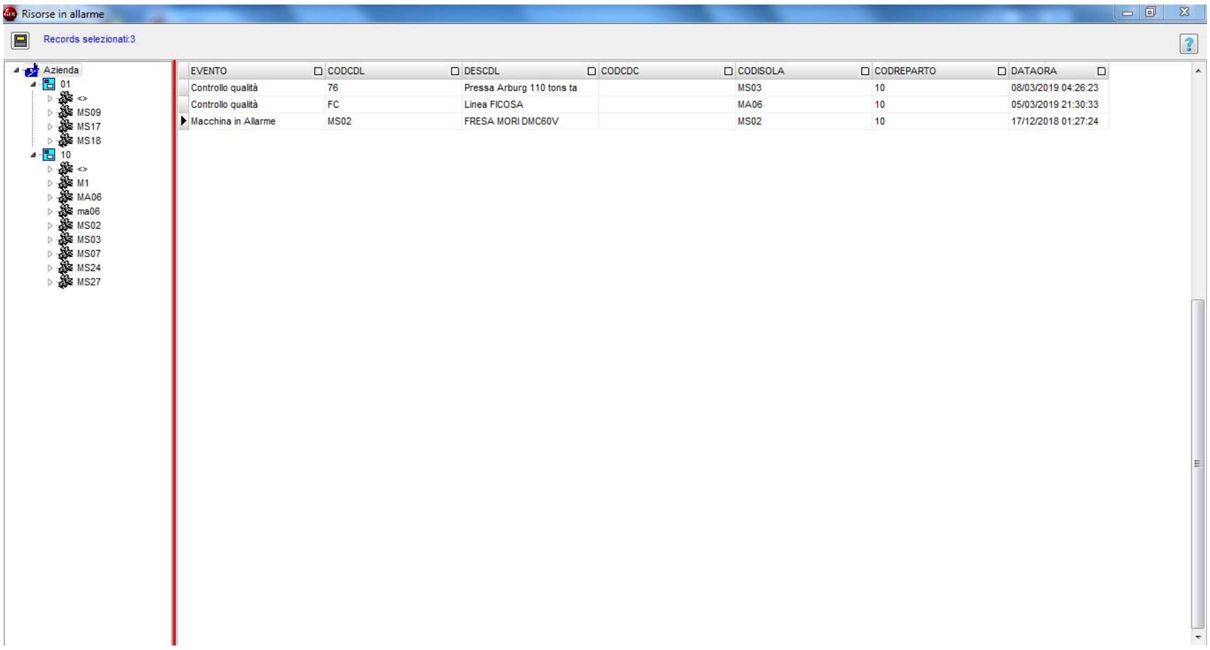


Figure 25:Management Portal(Machines in Alarm)

Regarding the monitoring category for operators, it includes features such as the presence or absence of the operator, situation of the operator and details of the active operators. These features can help the company a lot in monitoring the operator in an efficient way, it can beused to know which operators need some training or support and which are considered delinquent.

Moreover, There is category named 'Avanzamento' which means progress and it includes some helpful features such as checking the orders progress. As seen in Fig.28 you can check all the orders queued for a specific machine or a group of machines or even for the entire floor. It shows some information related to the progress of the order such as the state of the order if it closed, in production, suspended or queued for production as shown in the coloured column in the figure. Moreover other information such as the MRP material profile which is the production planning, scheduling, and inventory control system used to manage manufacturing process, also the active operators and historical record of past orders and their data.

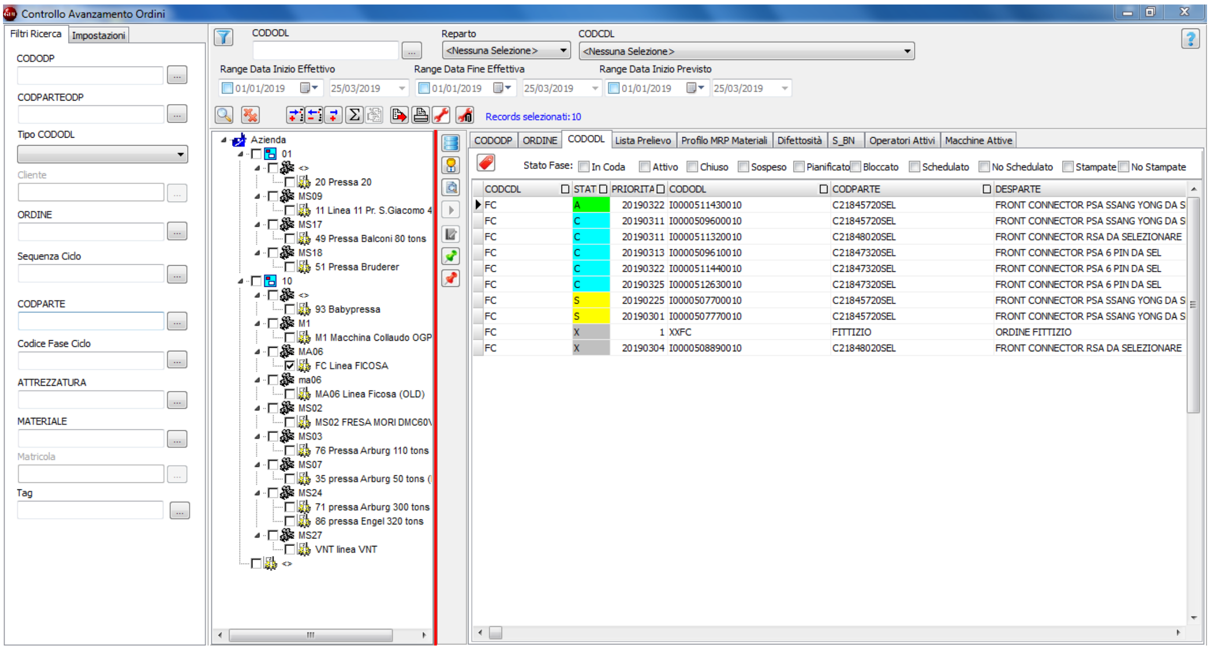


Figure 26: Management Portal (work orders)

5.2.1 Key Performance Indicators:

The most important category of features in the management portal is the KPI. Because studying and understanding the KPI by the management will help them evaluate the process efficiency and then take decisions and measures to improve it. The improvement of the process itself is the purpose of implementing the system as it will help in cutting some cost and increase the ability of the company to compete, manoeuvre and take greater share of the market.

First it is better to fully understand one of the most beneficial KPI which is the OEE and the TEEP which the portal regularly calculate on real time throughout the entire factory (Machines connected).

Identifying any potential losses and getting to understand where exactly is the process falling short is what OEE helps in achieving. OEE stands for overall equipment effectiveness, the availability **(A),** performance **(P)** and quality **(Q)** of the machine are combined in an equation to calculate the OEE. At the end what is important is the three factors affecting the OEE because it is just a number but what really explain the process in a more detailed way are the three factors used in the equation. OEE can be calculated in two ways, a simple one which doesn't help in analysing the situation and a more complicated way by calculating the three machine's attributes. The following is the two ways of calculating:

$$OEE = \frac{Good\ Count * Ideal\ Cycle\ Time}{Planned\ Production\ Time}$$

OR

$$\boldsymbol{OEE = A * P * Q}$$

- **Availability:**
  Any event that stopped the planned production time long enough, which is relative from manufacturing process to another but typically several minutes in which tracking a reason for being down makes sense. All such stops should be taken into consideration whether they are planned (Changeovers) or unplanned (Breakdowns).
  $$A = \frac{Run\ Time}{Planned\ Production\ Time}$$

- **Performance:**

  The maximum possible speed should give us 100% which is the ideal case, so any event that causes the manufacturing process to run less than that should be taken into consideration. Example of such events are slow cycles and any small stops.

  $$P = \frac{Ideal\ Cycle\ Time * Total\ Count}{Run\ Time}$$

- **Quality:**

  Measures the quality of the manufacturing process by considering any part which doesn't conform with the standard from the first time. So it takes into consideration the parts that need rework along with the scrap of course.

  $$Q = \frac{Good\ Count}{Total\ Count}$$

On the long run the OEE score will help the company to track the improvement as any increase in it means the manufacturing process is running in a more effective way. However, it doesn't give any insight about the underlying causes for lost productivity. This gives the most important role for the factors discussed before. Sometimes an increase in the OEE score is not desired by the company for example most of companies wouldn't accept an increase on the Availability by 8% at the expense of decreasing in the quality by 7%.

Moreover, there are two other metrics that helps a manufacturing company for setting a continuously improving strategy: Overall Operations Effectiveness (OOE) and Total Effective Equipment Performance (TEEP). All these metrics actually study how much good products was made versus how much could have been made. But the critical difference between them is how the availability is defined. The variable that changes from one metric to another is defining the maximum time available for the machine to run.

- **TEEP:**

  It considers all the time to be available time, as it takes the 24 hrs/day and 365 days/year.

$$TEEP = A * P * Q \quad \text{where,} \quad A = \frac{Actual\ Production\ Time}{All\ Time}$$

- **OOE:**

  It takes into account the unscheduled time, looking at Total Operations Time as the maximum.

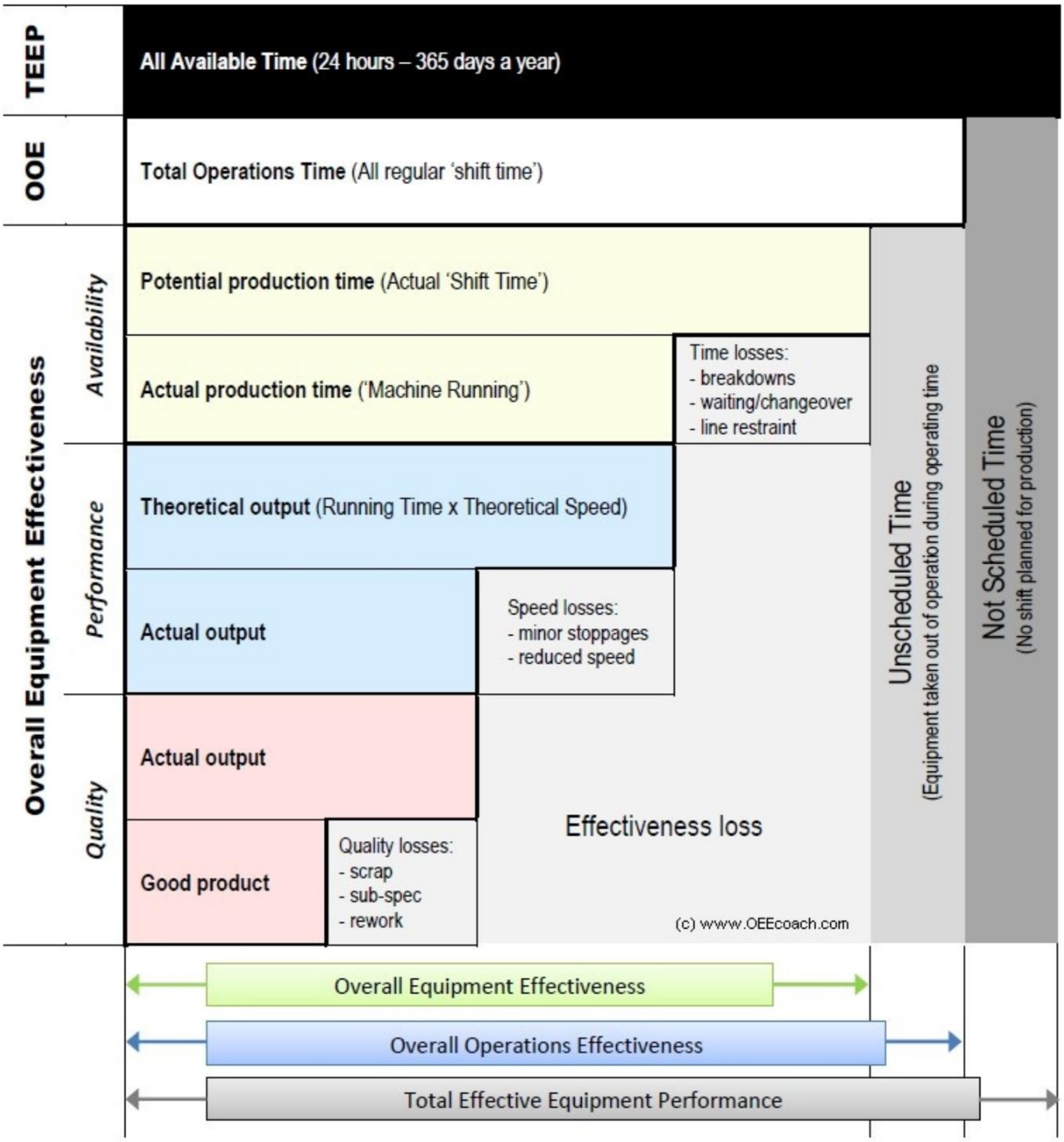


Figure 27:OEE, OOE & TEEP

As shown in Fig.29, the difference between the three metrics is in defining the time frame and each one has a useful indication of the performance and can be used to understand the situation better for decision making. For example, deciding whether or not to purchase a new equipment to meet an increase in the production demand needs. In trying to reach a decision in such a matter the department in authority needs to answer some questions first to reach the most economic solution for the company. The first question is does the process actually in need for additional capacity. Two options are available whether to purchase the new equipment or simply get more from the existing machine or equipment. Depending on time frame definition, the right metric can be used to show how much room there is to increase the existing capacity. TEEP shows how much potential you have increase the output of production with the current equipment.

From the three factors discussed before and as seen in Fig.29, the company can decide the causes of loss in the effectiveness and decide the priority for any improvement steps. For example, if the priority is to improve the performance, an investigation should be made to see if the major cause is due to minor stoppages or reduced speed of cycle time. Minor stoppages can be due to problems regarding the machine or the operator himself, which raises the need for better training and monitoring the operators. The reduced speed which means there is a critical difference between the real and theoretical cycle time may be because the theoretical cycle time itself is underestimated and a more realistic value should be set.

The Sphera Gui will supply Mista with calculation of different KPI metrics, graphs and reports on real time to have a better usage of the information flow being stored after implementing the system.

The figures in this section is just to illustrate the idea but some numbers dont make sense such as the setup scrap as it was an initial test of the system and some exaggerated numbers was inserted manually to test their effect on different features. The same applies for the values of the unproductive hours in respect to the total hours.

First as shown in the Fig.30 you can monitor an order during processing or even after for studying matter, as this feature can show all information about quantity and time in both tabular and graphical mode to serve in helping the management team understand more about the process in an organized way.

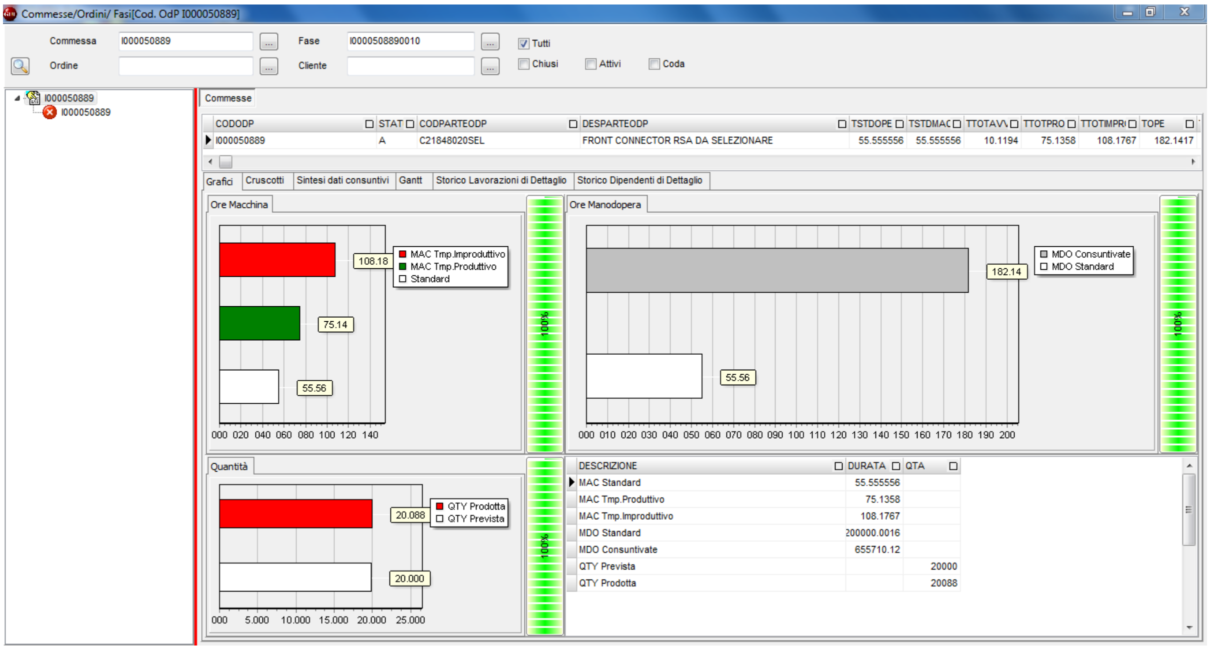


Figure 28: Management Portal (Time and Quantity)

For example Fig.30 shows different times for machine and manpower. To be more specific the productive, unproductive and the standard time. The standard time is the time calculated based on the ideal cycle time.

Moreover, another way of using the data by the system is presenting some of them in graphs such as in Fig.31 showing the change from shift to another and from day to day regarding some production characters such as time and quantity. For example, good parts, scrap, setup scrap and reworked parts.

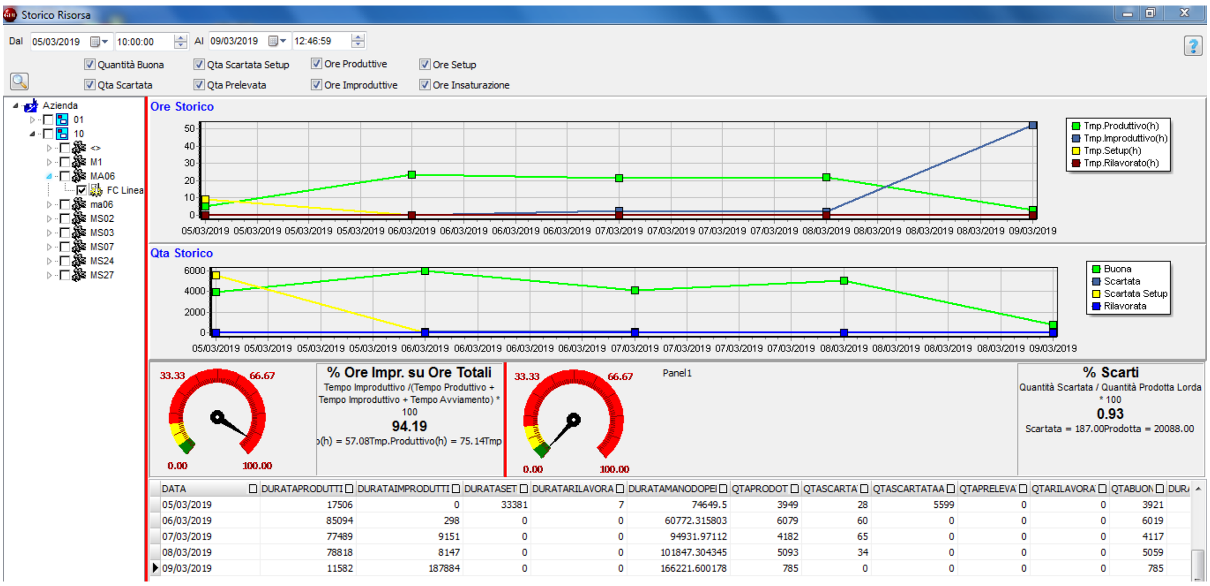


Figure 29: Management Portal Machine History)

Also an important feature is the analysis shown in the following figure which present the scrap quantity in more details dividing them according to their cause, which can be used by the company to improve the quality of the process by tackling the scrap causes as it is one of the sources of the effectiveness loss discussed earlier in this section.

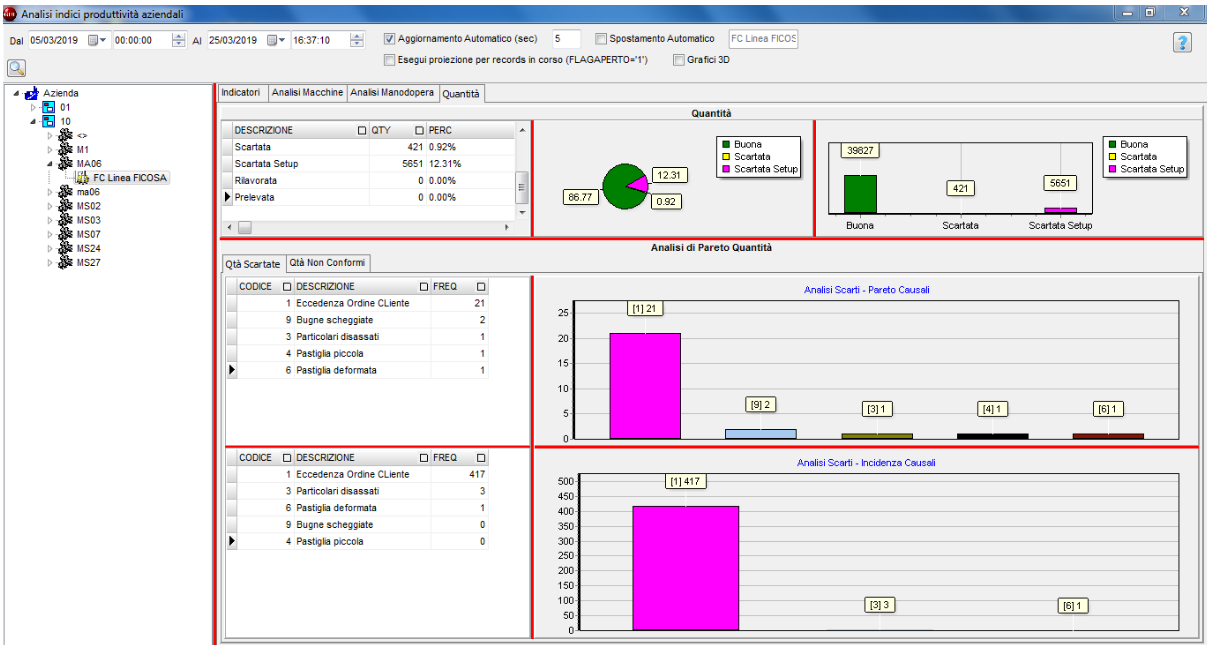


Figure 30: Management Portal (Causes of Scrap)

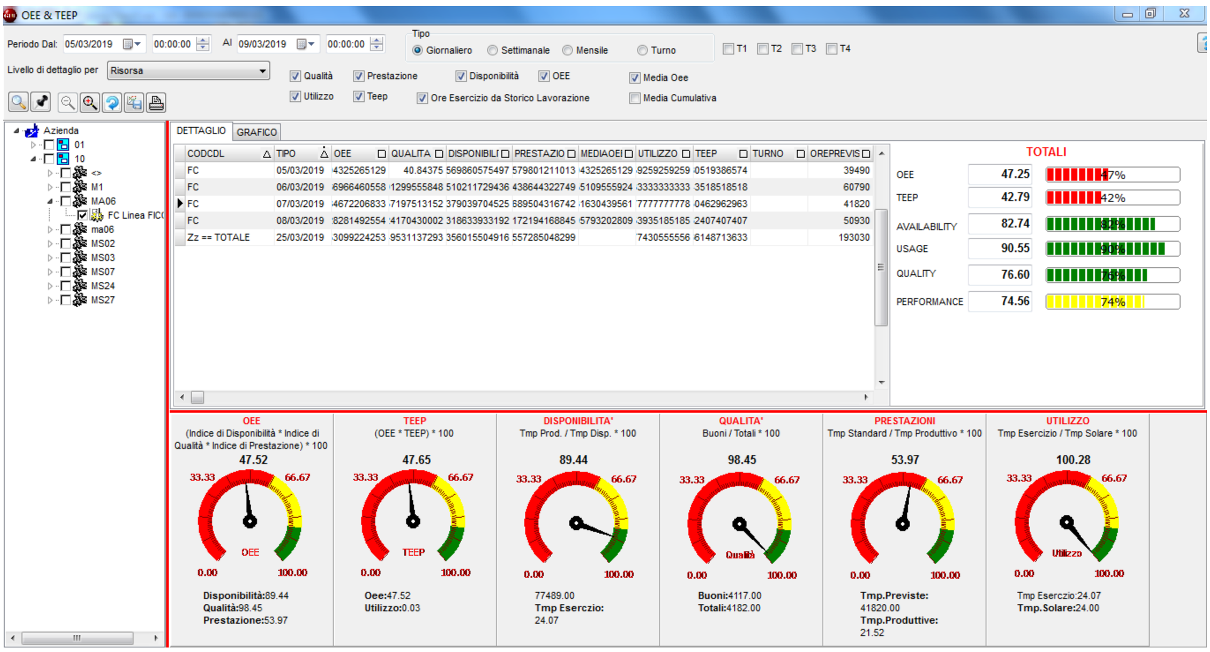


Figure 31:Management Portal(OEE & Factors)

Finally, the portal shows on real time some of the most important KPIs such as the OEE, TEEP and OLE (Overall labour effectiveness). Fig.33 shows the calculation of the metrics and their factors. Sphera Gui allows the management team the ability to show it on real time, based on a specific order number or time frame.

5.3 Financial Analysis of the project:

The following will be mainly a cost benefit analysis, compiling a comprehensive list that includes all the cost and benefit associated with the project. The goal of the analysis is to verify the financial and economic sustainability of the investment. The derived benefits from the implementation should overcome the costs incurred for its realization, in order for the investment to be supported. Moreover, the analysis should cover up the entire lifecycle of the product. Exclusively considering the costs and the benefits for the time of acquisition would result in misleading results and therefore false decisions.

Cost is a representation of the value of the resources consumed for the realization of the project. Therefore it is important to divide the costs into:

- **Tangible:** These are the costs to be incurred, or actual expenses in terms of money. In our case this includes the hardware purchase costs, software licenses, personnel for design, installation and training. These costs consist of both fixed and variable costs. An example of the former is the design cost, which does not change as the presses to be connected to the MES change. The variable ones refer to unit costs such as software licenses, which go multiplied by the number of machines to be equipped with ICT technology.
- **Intangible:** These costs cannot be quantified and therefore cannot be associated with an outlay of cash, but an estimation can be made only through qualitative assessments An example for this is the awareness campaigns for company's personnel on the right way for the use of the new ICT technology, definition or possible review of company operating procedures giving the new tools and supports used. Also distinguishing them in terms of fixed and variable costs is important. An example of intangible variable cost is the time taken to adapt to the new technology by the line operator.

Revenue is just a monetary entry but the concept of benefits goes beyond that, as it also includes any resource saved as a consequence of the installation of the MES. The benefits deriving from the investment should be identified, specified and then quantified to be measured in economic terms. Moreover, non-quantifiable benefits should be also taken into consideration.

Benefits mainly can be estimated and measured by calculating the difference between various situations prior and post the implementation of MES and as cost they are divided into the two categories:

Tangible: a further distinction can be made between those that can be easily quantified in cash, such as:

- **Waste Reduction:** The MES is a computerized system involving a digital master log and a device history record which helps in the reduction of filling, storing and tracking paperwork resulting in saving time and resources a resources and time. Also for the manufacturing part it reduces waste in the sense of having more conforming products thus reducing scrap and saving material.
- **Increase in Productivity:** For an example if there is material which is needed for production and it is not in stock this can lead to time waste and needs for extra resources to try to reach out for various individual trying to solve the problem. Also this can lead to maybe queuing in the machine and delays in various orders. But with MES everything will be registered in a universal system accessible by all team members decreasing the possibility of such incidents.
- **Minimizing material and product inventory:** MES allows the company to be more confident about the amount of inventory whether raw material or finished product for the future. Minimizing excess inventory saves money and management time.
- **Reduction in cost of labour.**

Moreover there are others that are more difficult to measure in economic terms such as an improved capacity of decision-making in relation to a certain activity or better service performance indexes.

Intangible: These not associable with an outlay of money and only estimable through qualitative assessments such as:

- The improvement of company's position with respect to its competitors.
- Sharing of the know-how within the company.
- Possible new sales strategies.

The following two tables shows the software, equipment and their services for Italy and Tunisia.

DESCRIPTION	TOTAL PRICE (€)
SPHERA SOFTWARE LICENCE, SERVICES, CONTRACTS	60,428.30
QUALITY CONTROL	4,920
MAINTENANCE MANAGEMENT	3,820
TIME&PROD	3,680
GANTT	4,840
TOTAL ITALY- SOFTWARE&SERVICES	77,688.30
INTERFACING WITH BRANKAMP (18 trance)	4,600
EQUIPMENT, SERVICES rep TRANCE (31 trance)	7,680
EQUIPMENT, SERVICES rep PRESSE (9 Arburg I / O)	2,820
EQUIPMENT, SERVICES rep PRESSE (18 Arburg serial)	11,190
EQUIPMENT, SERVICES Rep Equipment	2,040
TOTAL ITALY - APPLIANCES AND SERVICES (*)	28,330`
TOTAL ITALY (*)	106,018.30

Table 5: Initial Cost for Italy's Plant

DESCRIPTION	TOTAL PRICE (€)
SPHERA SOFTWARE LICENCE, SERVICES, CONTRACTS	21,234
OPTIONS	5,580
TOTAL TUNISIA - SOFTWARE AND SERVICES (*)	26,814
EQUIPMENT, SERVICES rep. PRESSES (11 I / O presses)	4,080
EQUIPMENT, SERVICES rep. PRESSES (16 serial presses)	8,880
TOTAL TUNISIA - EQUIPMENT AND SERVICES (*)	12,960
TOTAL TUNISIA (*)	39,774

Table 6: initial Cost for Tunisia's Plant

During the first phase of implementation other costs arise such as some machine protocol licences and also the need for downgrading the protocol of some machines to be connected to the MES. The management estimated all other costs to be around 60-70 K€. So the total cost of the projected is estimated to be around 215K€.

On the other hand, the process of quantifying and giving some values for the benefits of the project was very complex. As discussed before there are a lot of intangible benefits from this kind of projects and even the tangible ones are interconnected and affecting in each other. However, the Management estimated with percentage the decrease in the waste on both levels the management one in paper waste and production one in terms of saving raw material. Also the increase in the performance which will lead to an increase in sales and reduction in late deliveries that cost the company some penalties . The result was clear that the project is justified by high return on investment even without quantifying other intangible benefits. Taking into account that the purchase of the system was before the end of 2018, the Italian government offered an incentive by applying reduction on the taxes which can account for a high percentage of the project's cost.

5.4 Conclusion and Recommendation:

Mista S.p.A as most of the SMEs is characterized by a relatively high proportion of manual and hybrid activities. Usually SMEs face more challenges in the process of implementing such projects because they have less resources and know how than large companies and Mista was not a special case. Actually the managers themselves had to go through tasks of assessing MES in respect to its technological maturity and business potential because they don't have their own IT department.

The same issue for the implementation process which result in delays as there are no established human resources dedicated to the matter. Moreover, lack of standards and norms are one of the major issues threatening the implementation of Industry 4.0 generally for small to medium sized enterprises. During my research and documenting all the challenges and problems encountered by the company, it became more clear that the problem areas in the implementation process are due to one or combination of the following:

- Organisation struggle: doing an initial project definition and scoping in a proper way was challengeable.
- Organisation was lacking high level commitment from senior managers in order to drive the change.
- A proper information analysis for the requirements is not done up-front leading to uncertainty in the compatibility between certain systems before the starting the implementation resulting in some major integration issues between the systems containing various bits of information.(Different protocols issue)
- Incomplete designed solution: From the highest level to the lowest level before the implementation's onset.
- Not specifying the hardware in a complete and a correct way and this causes installation and configuration problems.
- Training is not properly done during the implementation of the pilot to ensure that operators are fully comfortable with the system.

The first step of implementing the MES in Mista was accompanied by a lot of challenges but in just two months some machines were connected and a flow of data is acquired as shown in the Management Portal section which was discussed in Chapter 5. Giving the opportunity for Mista to evaluate the production process for the first time in terms of KPIs (Key Performance Indicators). Acquiring the data with the old system was working fine for the company for day to day management of the production but it resulted in a massive paperwork which is useless in evaluating or improving the process or at least it would need huge dedicated resources to reach any kind of evaluation.

The understanding of KPIs such as OEE, OOE and TEEP is essential so that the firm can accurately forecast, plan and schedule production. Regardless of the values of such KPIs, if they have been consistent, the company can schedule what it can manufacture for its customers with a high degree of accuracy. Once the metrics are understood, the management team can then begin to look at each of the loss categories such as quality, availability and performance for both machines and labour and use the appropriate reliability tool to reduce the losses. Trying to bolster the productivity will increase the uptime, which is the paramount of success of any manufacturing facility.

After being present and working in the company during the first phase of implementation, some recommendations can be helpful for other SMEs. First organisations have to research MES thoroughly and once there is a good level of expertise in the organisation, it can then start planning the process from top to bottom and bottom to the top. Also, organisations should better use small pilot implementations to test the feasibility of MES in certain units of the business. The final and most important one is that the organisations have to ensure high level commitment by management to drive the project from the top.

Finally, I think it is appropriate to write a few words on the technological progress that is in a constant and rapid evolvement. Growth is now exponential and it shouldn't be confronted but rather trying to use the resources to keep up with it. The incredible creation of wealth is enough for everyone and will not detract from humanity. The fourth industrial revolution is not the beginning neither the end. There is still a hard and long but promising digital road ahead of us.

Bibliography:

[1] Industrial Internet Consortium, Industrial Internet Reference Architecture, Version 1.7, 2015.

[2] Presentation at the French Embassy in the Germany, “Industry of the future“, 2015. Available at.http://www.ambafrance-de.org/Vorstellung-des-neuen-franzosischen-PlansIndustrie-du-Futur-in-der-Botschaft.

[3] The State Council of the People's Republic of China, “Made in China 2025“, Available at: http://english.gov.cn/2016special/madeinchina2025/.

[4] P. Huang and M. Sakurai, “Factory automation: the Japanese experience,” IEEE Transactions on Engineering Management, vol. 37, no. 2, May 1990, pp. 102–108.

[5] D. Adler, J. Herkamp, D. Henricks and R. Moss, “Does a manufacturing execution system reduce the cost of production for bulk pharmaceuticals?,” ISA Transactions, vol. 34, issue 4, Dec. 1995, pp. 343–347.

[6] E. Barkmeyer, P. Denno, S. Feng, A. Jones and E. Wallace, NIST Response to MES Request for Information, NISTIR 6397, National Institute of Standards and Technology, Gaithersburg, MD, 1999.

[7] “Meeting the manufacturing challenge: Performance advantage of MES,” Strategic Direction, vol.20, no.11, Nov. 2004, pp. 28–30.

[8] MESA International, “MES explained: A high level vision,” MESA International - White Paper Number 6, 1997.

[9] G. Kulcsár, O. Hornyák and F. Erdélyi, “Shop floor control decision supporting and MES functions in customized mass production,” Manufacturing Systems Development–Industry Expectation, 2005.

[10] R. Füricht, H. Prähofer, T. Hofinger and J. Altmann, “A component-based application framework for manufacturing execution systems in C# and .NET,” 40th International Conference on Technology of Object- Oriented Languages and Systems (TOOLS Pacific 2002), Sidney, Australia, 2002, pp.169–178.

[11] J. Fraser, “At the heart of manufacturing: New views of MES,” Managing Automation Magazine, vol. 12 issue 9, Aug. 1997, pp. 1 – 5.

[12] R. Kaplan, “Must CIM be justified by faith alone?,” Harvard Business Review, March-April 1986, pp. 87 – 95.

[13] J. Meredith and N. Suresh, "Justification techniques for advanced manufacturing technologies," International Journal of Production Research, vol. 24, no. 5, Sep. – Oct. 1986, pp. 1043–1057

[14] Experton Group 2014: Industrie 4.0, Status Quo und Entwicklungen in Deutschland [Industry 4.0, status quo and developments in Germany], Ismaning.

[15] Forstner, Lisa; Dümmler, Mathias 2014: Integrierte Wertschöpfungsnetzwerke – Chancen und Potenziale durch Industrie 4.0 [Integrated value creation networks – opportunities and potentials of Industry 4.0], in: Elektrotechnik & Informationstechnik 131 (7), 199–201.

[16] Mussbach-Witer, Ute; Schatz, Anja: Vertikale IT-Integration im Auftragsmanagementprozess: Aspekte der Aufgabenverteilung und des Informationsaustauschs zwischen ERP- und MES-Software [Vertical IT integration in task management: Aspects of task allocation and exchange of information between ERP MES software], in: Software Markt, 1–6 (5), http://www. it-matchmaker.com/public/downloads/1062.pdf

[17] Wischmann, Steffen; Wangler, Leo; Botthof, Alfons 2015: Autononomik Industrie 4.0: Volks- und betriebswirtschaftliche Faktoren für den Standort Deutschland [Autonomics and Industry 4.0: Economic and business factors for Germany as an industrial location]. Eine Studie im Rahmen der Begleitforschung zum Technologieprogramm AUTONOMIK für Industrie 4.0, Berlin,http://www.bmwi.de/BMWi/Redaktion/PDF/F/industrie-4-0-volksund_20betriebswirtschaftliche-faktoren-deutschland,property=pdf, bereich=bmwi2012,sprache=de,rwb=true.pdf

[18] Pierre Audoin Consultants 2015: IT Innovation Readiness Index 2015, Part 1, http://www.freudenberg-it.com/de/it-innovation-readiness-index-2015/teil-1-2015.html

[19] Institut der deutschen Wirtschaft Consult (IW Consult); FIR 2015: Industrie 4.0-Readiness, commissioned by the IMPULS-Stiftung of the VDMA, Frankfurt, http://www.impuls-stiftung.de/studien;jsessionid=D371AF8942274C06B 67E99721D269ED4

[20] Schröder, Christian 2015: Auf dem Weg zur vernetzten Wertschöpfung: Existiert eine Digitalisierungslücke im deutschen Mittelstand? [On the way to networked value creation: Is there a digitalisation gap in the German Mittelstand?], IfM Bonn: Denkpapier 02/15, Bonn, http://www.ifm-bonn.org// uploads/tx_ifmstudies/ denkpapier_digitalisierung_2015.pdf