FIAT CHRYSLER AUTOMOBILES

"A WCM methodology application: the digitalization of the Upstream Check and its organizational impact on the line quality control system"

Master thesis - Degree in "Ingegneria Gestionale"

Candidate: Cornacchia Lorenzo

Academic supervisors: Prof. Paolucci Emilio, Prof. Neirotti Paolo

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Thanksgivings

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Summary

Introduction

The composition proposed here aims to contribute to the innovative progress of automotive companies, working on the development of one of the new digital projects that will characterize and influence the new *modus operandi* of the industrial productive processes in the future. The content of the thesis consists in the automation of the so-called Upstream Check applied in an automotive plant with the **World Class Manufacturing** methodology, which happens when an operator is required to perform a bottom-up path in the opposite direction to the movement of the line to verify that a defect detected is not present in all the upstream vehicles. The study will analyze the technical problem and provide innovative solutions, taking advantage of the skills acquired by the student during the Master Degree in Management Engineering with Innovation emphasis in the Polytechnic of Turin; then it will also investigate the managerial acceptance of the project within the plants: for this purpose the author has decided to carry out a research in an Italian factory by administering interviews to employees belonging to two different organizational levels of the plant, the Team Leaders and the Supervisors. After the presentation of the hypotheses and the research method, the thesis will propose the results of the interviews and will discuss them, typifying the economic and organizational benefits. The composition will then illustrate the organizational changes induced by the WCM methodology within the line quality control system and, starting from the Upstream Check project, will try to outline the possible evolutionary scenarios of the internal plant organization due to the global digitalization. During the elaboration of the thesis, the project has grown through the use of digital tools evolved at the World Class Manufacturing Development Center (WCM DC) of **Fiat-Chrysler Automobiles** (FCA), exploiting in particular the WCM technical pillar called Quality Control. It is important to underline that the analysis is limited to the "Premium" factories, that are plants which produce luxury vehicles that are not placed in the mass market and that use the most advanced information systems: for this reason, the reference location that has been chosen to perform all the tests and to propound all the interviews, is the plant of Mirafiori[1], placed in the Turin outskirts. Furthermore, the project analyzes an activity which is carried out by the operators who work on the line, so it will have a greater influence on the labor intensive areas, in

[1] Fiat Mirafiori is an industrial plant in the south of Turin. The name Mirafiori derives from the homonymous district in which it is located, in turn derived from the name of an ancient castle of the Savoy family.

particular the Assembly Shop Unit. The last chapter of the thesis will in fact discuss the impacts of digitization in this type of area: the most innovative digital activity that is being worked on in the WCM DC office is currently the **New Plant Landscape** (NPL) development; it is a project that intends to provide all Fiat and Chrysler plants with the same latest generation technology, to manage factory processes in an integrated way; it is born as the interface that allows the operators to get in touch with the plant computer informative systems that collect the huge amount of data coming from the line. The main company functions that will result more influenced from this innovation are Manufacturing, Logistics, Finance and ICT: so, it is clearly required a transversal study that integrates communication phases with several different offices.

1. The World Class Manufacturing methodology in the FCA plants

1.1. The pillars partition and the Audit system

The World Class Manufacturing (or WCM) is a methodology that Fiat-Chrysler Automobiles has implemented in its plants from 2010. This program incorporates a lot of former approaches as the Toyota Production System (TPS), the Total Productive Maintenance (TPM), the Lean Production and the Total Quality Management (TQM)[2]. It comprehends ten technical and ten managerial pillars (the temple is shown in **Figure 1**) to better administer the development of the problems and the anomalies analysis within the automotive plants.

Technical Pillars

1. Safety (SA)
2. Cost Deployment (CD)
3. Focus Improvement
4. Autonomous Maintenance + Workplace Organization (AM+WO)
5. Professional Maintenance (PM)

[2] In order to explore these four methodologies, the reader can consult the vast literature available in books (in particular *Ono T., "Toyota Production System on Audio Tape: Beyond Large Scale Production", 1978* or *Kobayashi E., "The Truth about Toyota and Tps", 2009*) or online, given the popularity of such approaches.

6. Quality Control (QC)
7. Logistics and Customer Services (L&CS)
8. Early Equipment Management + Early Product Management (EEM+EPM)
9. Environment (ENV)
10. People Development (PD)

Managerial Pillars

1. Management commitment
2. Clarity of objectives
3. Route map to WCM
4. Allocation of high qualified people to model areas
5. Commitment of the organization
6. Competence of the organization towards improvement
7. Time and budget
8. Level of detail
9. Level of expansion
10. Motivation of operators

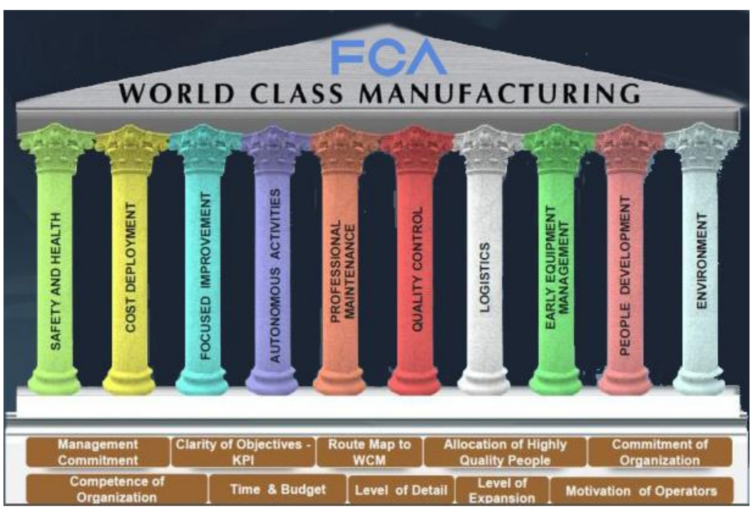


Figure 1: the World Class Manufacturing pillars temple.

The WCM ideology proposes the application of the pillar contents in several steps (usually seven) and implicates the creation and the continuous adoption of new standards within the plants. Some of the main pillars goals consist in the achievement of zero stocks, zero failures, maximum efficiency, zero waste, zero losses and zero quality defects in the company productive process; the last mentioned scope, that is to eliminate all the quality defects, is the one on which this elaborate aspires to work and commit. By in-depth analysis of the root cause of defects and anomalies, it is possible to solve every problem, but it is necessary the teams' involvement along the plant. The WCM embraces three types of approach: the **reactive** one is the first that needs to be completed and is expressed by the solution of the current anomalies. The **preventive** concept subsists, instead, in trying to avoid every problem has ever happened in an automotive "Premium" plant; this idea is strictly linked to the third approach, which consists in the **proactive** attitude to think of any possible inconsistency and avert it. In the WCM thinking current a perfect World Class plant rationalizes and operates in a proactive way in every single pillar.

To assess the progress of a production plant in terms of WCM activities, it has been developed a WCM Audit system. Each Audit has a required and an assigned score and each sector has its own plant and its Central Team that requires Audit planning. The maximum score for a plant is 85: each pillar is rated with a score from 1 to 5. If the score is at least 50 that means that the plant is at a Bronze level, if it is 60 or higher the plant is Silver, while from 70 to 85 there is the Gold range. Each pillar counts 5 points and must grow in step with each other; points are lost almost uniformly and to get the Gold mark each pillar must reach a certain minimum level. A comprehensive Audit calendar is compiled (it counts around 600 events per year), each of which may end up with a worse or the same or a better mark. There are different auditor levels:

- Junior.
- Regular.
- Regular licensed, who can assign Bronze but only if accompanied by at least one Junior Auditor.
- Senior, who can assign Bronze mark.
- Master Auditor, who is usually followed by a commission.

In order to get Silver or Gold, a plant needs to organize, two months before the Audit, a "Gate" in which a committee is assembled and in which it must be convinced that the factory has the requirements to reach the asked mark. Additionally, the Audit from Silver up is "Extended":

there is not just a guided route, but a specialized team is responsible for carrying out specific checks in the plant.

1.2. The general FCA automotive plant structure

It is now necessary to frame FCA in the context of the global automotive industry: the company owns 162 plants and 87 research and development centers. The EMEA Region (Europe, Middle East and Africa) is one of the five geographical areas in which Fiat-Chrysler Automobiles operates. The other four Regions are: NAFTA (North American Free Trade Agreement), LATAM (Latin America), China and APAC (Asia-Pacific). EMEA mission is to design, produce, sell and assist in Europe, Middle East and Africa, cars and commercial vehicles. The brands are Abarth, Alfa Romeo, Fiat, Jeep and Lancia, Chrysler for cars, Fiat Professional for commercial vehicles and MOPAR (Motor Parts) for spare parts and assistance services. In Italy FCA owns two different types of plants: part of them are dedicated to the mass market product while the others, as already mentioned, are called “Premium” plants and produce luxurious vehicles (for example Maserati brands) with cars such as Levante, Ghibli and Quattroporte currently produced in the factories of Agap and Mirafiori in the Turin province.
The traditional Italian “Premium” plant is structured in three main Units: the Body Shop, the Paint Shop and the Assembly Shop. Every part is supervised by a Unit Manager, who comes back to a single Plant Manager. While the Paint Shop is now full automated and only includes conductors, the Body Shop and especially the Assembly Shop are parts of the still labor intensive plant. In this sense, the anomalies generated by the production process of a car can then be divided into five types, called “4 M and 1 D”: man, method, material, machine, design. These five essentially represent the main possible causes of a defect generation. It is obvious that man problems are being analyzed and attached mostly in the Assembly Shop where they are most common because of the high percentage of manual human operations. The organizational structure (see **Figure 2**) is divided into “white collars” (or employees) and “blue collars” (or operators): these are generally grouped into Domains within which there are six operators and one Team Leader. The number of Team Leaders responding to a single Supervisor depends instead on the size of the line managed by the Supervisor himself and so on how many domains it counts: usually managers tend to keep the structure created in the Pomigliano plant in 2010

with the launch of the Nuova Panda[3], with six Team Leaders responding to a single Supervisor. Each Supervisor controls an Ute (*Unità Tecnica Elementare*), while each Team Leader manages a Domain. Within each Domain there are workstations which in turn contain specific workplaces.

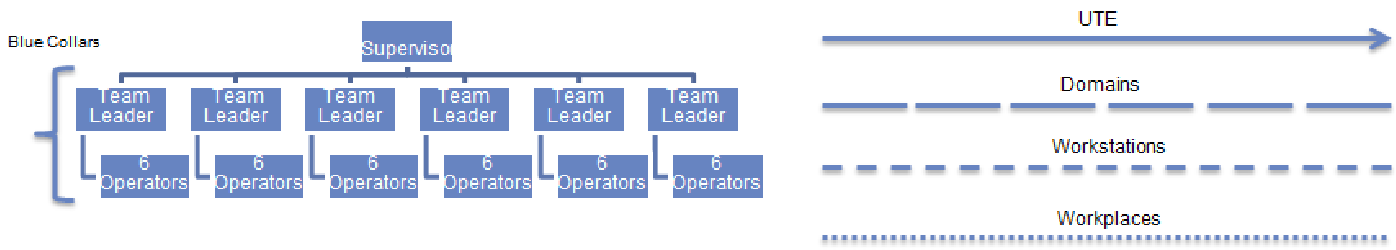


Figure 2: representation of the hierarchical structure of each line segment with focus on the subdivision of Domains, workstations and workplaces.

The Supervisor represents the latest hierarchical level of the "white collars" in the Manufacturing function. He responds to the Shift Manager which works in parallel with the Process Improvement Manager or PIM, who controls the Product Process Specialists or PPSs for the resolution of technical problems on the line, which the author will not dwell on until the Chapter 6 because of the low relevance in the context of the first five chapters treatment. This general "white collars" structure is shown in **Figure 3**, which details also the top manager professional figures who govern the plants and oversee the organizational complex.

[3] This topic will be in-depth analyzed in Chapter 4 where it will be explained the organizational revolution induced by Pomigliano in 2010.

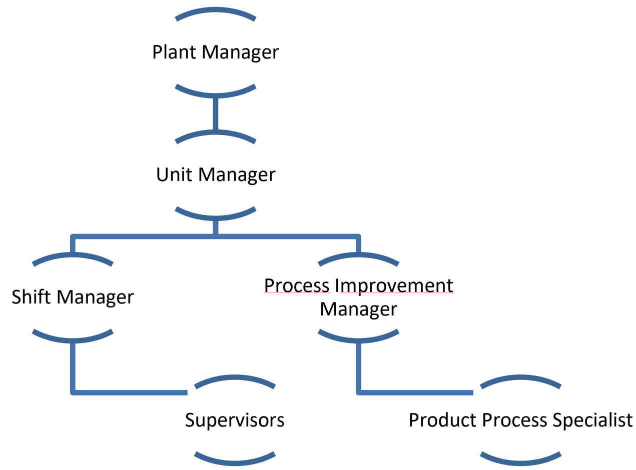


Figure 3: the "white collars" organization detail, including the Plant Manager and the Unit Manager position.

After a general organizational overview, is time for a Units plant introduction from when the body enter the factory, until the completed car exits the same. The **Body Shop** or Body in White is the first part of the plant and its principal activity consists in the match and subsequent assembly of three sub-groups coming from the Molding Area or from external suppliers as Fisher[4] (Austria) from which car mobile parts are obtained. The three subgroups are the chassis (central frame, front and rear), the sides with pavilion and the moving parts (coat, fender). The first two are also known as primary parts. In the quality control process there are three fundamental checks: chassis, body and final control.

Before the assembly phase, the product flows along the **Paint Shop** which is a completely capital intensive area. Firstly, the car is picked up from broaching, technical inspected, initial washed and degreased. Then the process involves the cataphoretic bath with overturned body. After the cataphoresis and the sealing applications, conductors monitor the sliding of the skid and the closing of the sheet metal. Later the car is cleaned again and goes through the first baking oven. After a background hand, there is a revision phase, the pre-cleaning with compressed air and a second cleaning with Emu feather brushes. After the coloration the car is treated with a final baking oven (matched with a final review). The last step consists in searching defects and in emitting deliberation.

[4] See "The Acquisition of Fisher Body by General Motors" by R. H. Coase (Journal of Law and Economics, Vol. 43, No. 1, pp. 15-32), April 2000.

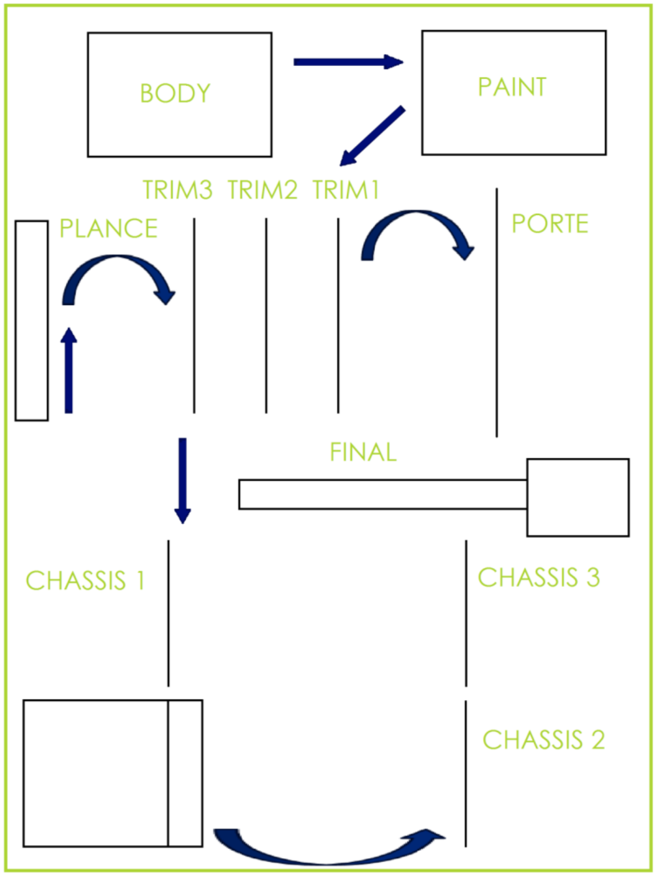


Figure 4: the traditional Assembly Shop layout of an automotive "Premium" plant; after the Body Shop and the Paint Shop, the product flows in three lines of Trim and in three lines of Chassis before arriving at the Final where all the controls are performed. The workings of the doors and the planks occur in parallel with the Trim.

The **Assembly Shop** (see **Figure 4**) is also called TCF (Trim-Chassis-Final): it works on two shifts eight hours a day (two teams). In this Unit the doors are separated from the rest of the car to be worked on a parallel line and then rejoined to the main body before the Final line. The image shows the layout of the three lines at the Mirafiori factory in Turin. On the Final, the last on-line quality check is performed: operators are provided with an optional list (OPT) that indicates how every vehicle must be assembled in its specific and different components. The additional tests that are performed after the final check are the TDF (dynamic functional test) and the CPA (Costumer Product Audit) for aesthetic control performed directly by the client.

Within this production flow briefly described, it is obviously possible to generate defects and therefore, in order to protect the customer, it is necessary to carry out checks to remedy where there is an anomaly that affects the quality of the product. From here onwards, it will therefore be necessary to refer to the Quality Control WCM pillar to explain quality assurance procedures and tools within automotive factories. Quality checks types in FCA's plants can be summarized from the list below:

- Quality Gate / Line QVS or Quality Verification System (→ Specific Workplaces → Fixed Terminals)
- Quality Gate / Final Quality Verification System (→ Specific Workplaces → Fixed Terminals)
- Conformity to order (→ Specific Workplaces → Mobile Terminals)
- Quality Gate / Transitional and critical Quality Verification System (→ Specific Workplaces → Fixed Terminals)
- Upstream Check (→ Specific Workplaces → Mobile Terminals)

The **Upstream Check** or Reaction Process will be the core quality type of control of the thesis. It has been chosen since it represents the most significant and potentially most damaging check that the current line quality control system of the "Premium" plants provides.

The so-called Deliberations or **Quality Gates** are present in each specific Unit and consist in checks performed on the car not yet totally coated, painted or assembled depending on the Unit. Below there is a general list of split Quality Gates per Unit:

- Body Shop:
    - Chassis
    - Full body shell
- Paint Shop:
    - Internal sealing
    - Underbody sealing
- Assembly Shop:
    - Saddling
    - High Mechanics
    - Low Mechanics
    - Doors

- Mechanics, at the discretion of the plant

The type of final Deliberations is a check performed on the car after the completion of the coating, painting and mounting operations. Here is the list of final Quality Gates divided by Unit:

- Body Shop:
    - Final
- Paint Shop:
    - Final Revision
- Assembly Shop:
    - Final
    - Testing Line, at the discretion of the plant
    - Certification Line (or “Bollino Verde”)
    - Rollers, at the discretion of the plant
    - Water Test
    - Shipping

After the Final, in the Assembly Shop there is the Testing phase, then the so-called “M phase” which is a stretch where the car passes from Assembly Shop responsibility to the customer audit stage. Later the vehicle passes to the TDF (*Test Dinamico Funzionale*) where 100% of “Premium” products and 10% of mass market products are checked with different cycles. The TDF tests all the static and dynamic controls by looking for the defects that the customer may find after the first 100 km of driving. Each encountered anomaly is assigned to an owner (for example Manufacturing or Supply Chain) and then a removal project is performed. After the TDF has repaired a car and has deliberated the goodness of the operation and once the test is completed, there is H2O water proof and lastly the vehicle arrives at the “Bollino Verde”: here all aesthetic checks are carried out on the 100% of the cars always, before delivery to the final customer; it is checked that everything the customer has ordered as optional is present and matches. In addition to the optional (OPT) control, there are also homologous labels’ checks; finally, there is an oversight on the profile games: to supervise them it is needed to refer to a regulatory control plan. It is also checked any damage to the paint and then, once repaired, the car is delivered to the logistics. A charge is taken (“PIC”, the car is no longer FCA’s ownership) and a check is carried out by an external company engaged by the Supply Chain office.

Lastly, the CPA is a Customer Product Audit that is divided into two parts: "CPA end of line" after the “M phase” where all the aesthetic and functional but non-dynamic controls are performed on five vehicles per turn. In this context it is monitored the goodness of the Deliberations of the Units: it is clear that the cars are to be taken at the end of the Assembly Shop where they have already been deliberated by the Body Shop and the Paint Shop. So, it is sufficient to take the Assembly Shop data and make the assessment; to the vehicle is attributed a demerit weight which can be 1, 10, 50 or 100:

- 100 = Priority 1, which means that there is a very serious defect that can jeopardize the main features and functionalities of the car or that can generate an obvious aesthetic defect that the customer cannot fail to notice or that may even prejudice the customers safety; this is basically a defect that can compromise the sale of the product.
- 50 = less important Priority 1 anomaly.
- 10 = low important defect with no abatement plan.
- 1 = not considered defect; the customer hardly gets it.

Later it takes place the insertion of the anomalies into a system called “Caps” that asks questions and, after the answers, releases as output a value: the system was developed by FCA and Chrysler jointly after the fusion. The second type is the “CPA Bollino Verde”, which takes only five cars per day, because the control is longer and includes the dynamic control part too. They are picked up after the “Bollino Verde” itself, so the car has already passed the TDF. It is therefore strange that a car in this latter control presents dynamic defects because it has been deliberated by the TDF. For the TDF, the main Key Performance Indicator is the R100:

$$R100 = \frac{Number\ of\ anomalies\ in\ 100\ vehicles}{100}$$

This indicator allows the Plant Quality to monitor the performance of each block of one hundred cars; the total value is divided by 100 to make the different values more readable and immediately comparable. For the "Bollino Verde" the main Key Performance Indicator is the number of defects entering the "Bollino Verde". In **Table 1** is shown an example of the CPA vehicle classification.

Table 1: example of CPA classification with the "demerited weight" assignment.

Score→	**1**	**10**	**50**	**100**	**Number of anomalies**	**Total score**
Vehicle X	4 anomalies				**4**	**4**
Vehicle Y	4 anomalies	1 anomaly			**5**	**14**
Vehicle Z	2 anomalies		1 anomaly		**3**	**52**

As the reader can observe, the Vehicle X presents a higher number of defects than the Vehicle Z, but its CPA score is significantly lower: that is caused by the high priority anomaly (50 points) detected on the Vehicle Z.

1.3. Theorization of how the line Quality System has evolved from traditional to digital with New Plant Landscape

FCA plants have undergone a significant change over the last decade, in particular thanks to the automation of many tools and the digitalization of several procedures. In this sense, this elaborate will present as a possible solution to a problem, the automation of the previously introduced Upstream Check, through the WCM methodology application. WCM approach is strictly related to the Industry 4.0 concept: the current trend of automation and data exchange in manufacturing technologies is reaching all the global automotive plants, thanks also to the advent of Internet of Things (IoT). In this way the term **Manufacturing 4.0** refers to the adoption of some innovative digital technologies (Smart Manufacturing Technologies) characterized by the ability to increase interconnection and cooperation of resources used in operating processes.

Recently, in Europe is born the AIOTI (Alliance for Internet of Things Innovation): the governments promote hi-tech industrial strategy from Industry 4.0 to foster industrial competitiveness, in order to take advantage of the latest communications and automation technologies to spread the smart factory featuring adaptation, efficiency and ergonomics. In this context the New Plant Landscape intends to provide all FCA plants with the same processes and the latest generation technology to handle the production in an integrated way: it is a new system which performs some studies on the operator interface that each line employees. The NPL is the interface that allows the employee to get in touch with the systems like MES, that perform the function of "container" of the huge amount of data coming from the line. Smart watches and smartphones are NPL extensions in the sense that they show the terminal, which in turn is in contact with the informative system like MES.

MES is the abbreviation of Manufacturing Execution System and consists in the actual computer informative system of the “Premium” plants, in which this analysis is circumscribed. Before the advent of MES the company plants used the *Ute digitale*, which included several paperwork operations; the most relevant interface in the Assembly Shop is the Operator Terminal, a computer installed on the workstation dedicated to line employees that allows to:

- view vehicle information that is passing through the line: sequence, market, chassis, car set-up;
- provide support for critical operations through visual SOPs (Standard Operating Procedures) and OPLs (One Point Lessons);
- provide guidance on the tools to be used and the components to be traced;
- make Upstream Check possible by addressing it for specific defects;
- display and report the arrival of a vehicle with a rare OPT.

The direct consequences of this application consist of:

- ❖ last generation technology on the production line;
- ❖ elimination of paper and physical stamps.

It is important to underline now that the sense of the term "digitalization" is accepted with two different meanings within the offices of the automobile companies. In the first vision, digitalization is the process of converting information into a computer-readable format, in which the information is organized into bits. The result is the representation of a document by generating a series of numbers that describe a discrete set of its points and is called digital representation. Digitalization is of crucial importance to data processing, storage and transmission, because it allows information to be carried with the same efficiency. While analog data are copied or transmitted, digital data can, in theory, be propagated indefinitely with no losses. The second current of thought believes that it is not possible to talk about digitalization in the presence of a simple computerization of data or documents: the system could not be defined as digital unless it is capable learning and therefore improving over time[5]. By increasing the number of data available, it must be able to process data and link it with simple or complex functions. The thesis does not intend to discuss which of the two definitions is more correct, but only to present the two different meanings and looking in the continuation of the discussion to satisfy both.

As explained in the introduction, the New Plant Landscape represents the most innovative project of FCA in terms of production processes. To lighten the reading and to make possible a broader understanding of this powerful tool, some examples of the innovations that NPL promotes are illustrated in **Table 2**.

Table 2: illustration of some innovative projects related to Manufacturing 4.0.

Innovation name	Reference Pillar	Type of Pillar	Description
Surveys app	Motivation of operators	Managerial	App on smartphone for the operator to launch surveys as an engagement tool
RFID	Logistics and Customer Service	Technical	Radio Frequency Identification to automatically store the information in order to ensure the proper placement of the components
Predictive maintenance	Professional Maintenance	Technical	Machine that controls parameters as the oil viscosity

[5] See “Paper vs digital reading is an exhausted debate” on www.theguardian.com.

sensorization			to predict failures (predictive maintenance operations)
Augmented reality	Workplace Organization	Technical	Augmented reality that illustrates all product features with support audiovisual

NPL could be intended as the perfect tool for enterprise resource planning, which integrates all the relevant business processes of the firm. In **Figure 5** are shown all the functions that NPL is supposed to influence: the inbound logistics is expected as an input combined with the Bill of Material (BOM) and all the documents essential for the demand forecasting. However, it is important to remember that NPL is a project that can affect the systems and functions of the "Premium" plants. MES is instead an information system, and as such it provides a flow of incoming and outgoing information.

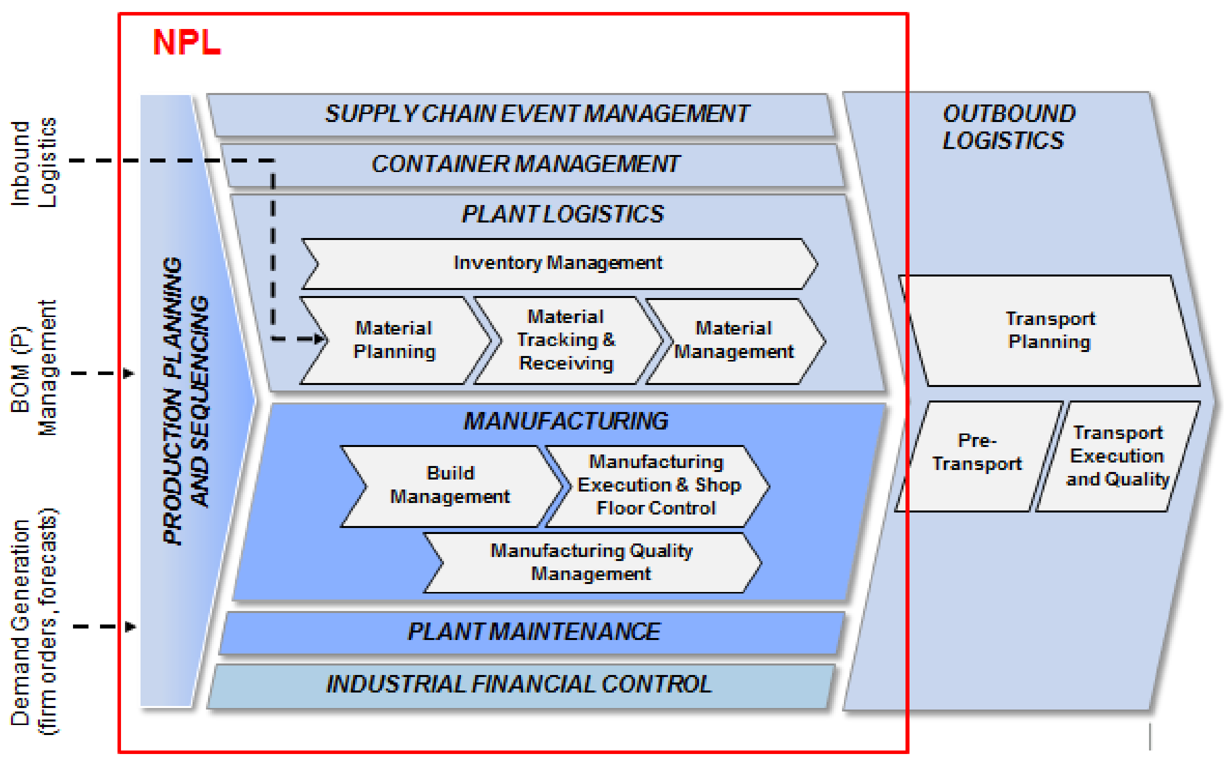


Figure 5: delineation of the field on which NPL could effect with its interfaces.

Nowadays every plant dispose of a digital structure powered by some upstream systems which influence it as inputs. In **Figure 6** is shown an example acquired from the Turin factory of Mirafiori, that is provided by the MES “Premium” system (Manufacturing Execution System). Although the aim of the thesis is not to enter into the details of the company ICT systems, the following briefly summarizes the meaning of inbound and outbound systems in relation to MES:

- RTM-ppi manages the base list in relation to the commercial order;
- Pdp schedules the production;
- SAP manages suppliers’ information;
- CODEP keeps track of the base list of the projects;
- VHS is an approval system;
- LOCEN is a commercial order system;
- Click is the inventories management system;
- ESM electronic control system or software management system;
- WebPoint and WebLaunch are plant configuration systems.

As the reader can observe, some of the output systems are the same of the input ones. NPL was exactly born in 2012 to provide all the FCA plants of the same system.

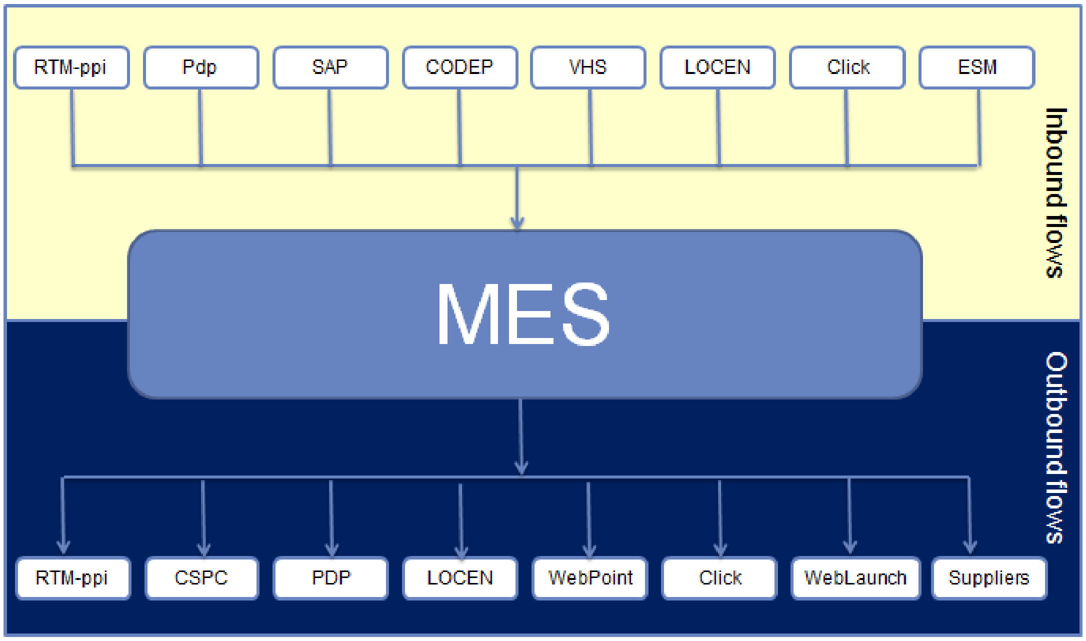


Figure 6: the scheme of the Mirafiori's digital system with underlined connections with the plant subsystems in input and output.

At this point it is necessary to introduce the concept of Vehicle Tracking Image, that resides in the continuous and complete line monitoring. There is an "encoder position tracking" that maps the position of the car by taking a shot every time unit (see **Figure 7**). When the car enters the station, the system knows which one it is. The body of each car is defined through a code called the CIS (*Codice Identificativo Scocca*), also encoded within a barcode. This code identifies the car both on the paperwork line system and on the MES system. With the assignment of a CIS, it is possible to declare the beginning of the working operations on the car, as well as to say that it is in line. At the beginning of the Assembly Shop, the car is "spread" and the system assigns it to a commercial order.

It results indisputable that the factory needs practical and effective tools to collect critical performance results or sensitive data. This topic will be deepened in Paragraph 3.4. Before the global automotive plants' digitalization the Italian factories were used to keep a document called SRDQ (*Scheda Raccolta Dati Qualità*) on which everything was written about each car. After the advent of Industry 4.0 it has been possible to map the product on the digital system, thanks to many codification tools, in particular the Tesis code[6].

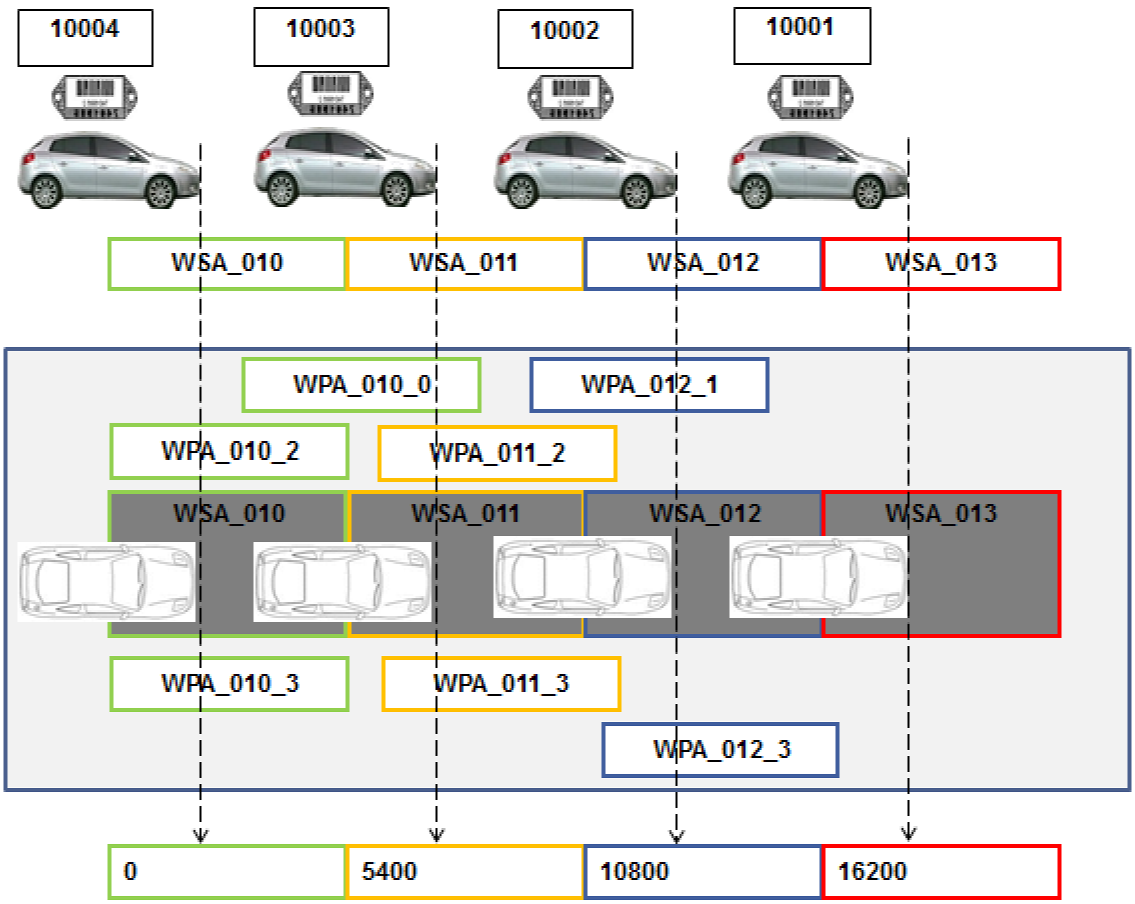


Figure 7: framework of the "Premium" plant line flow with an example of the different workstations (WSA) and workplaces (WPA) locations.

2. A digital project: Upstream Check automation

2.1. Problem description: the traceability problem along the line

The Upstream Check is a task of controlling and remedying mandatory defects for the Team Leader; he is required to check all the vehicles from the workplace where the defect was detected to the workstation where the defect was generated. The Team Leader who has to perform the

[6] This identification code requires a detailed explanation, since it will be largely mentioned during the treatment of this thesis. This analysis is foreseen in the Paragraph 2.4.

check is the one that oversees the domain where the workplace has created the defect. Nowadays all this reactive system is paperwork. The Reaction Process occurs in three cases:

- 3 repetitive anomalies of the same type in two hours
- 5 repetitive anomalies of the same type in eight hours (one shift)
- 1 “Priority 1” anomaly

As the reader can observe in the case illustrated in **Figure 8**, the Domain 2 of Trim 3 detects three defects (hypothesize identical and repetitive) in four consecutive vehicles: the working cycle time of each workplace in the "Premium" plants is about six minutes, so it is realistic to think that these anomalies have been discovered in just twenty-four minutes (six minutes for four cars). After the third anomaly found in less than two hours, the Team Leader of the Domain in question reports to the Team Leader of the Domain responsible for the defect that a so-called Reaction Sheet (see the current form on **Attachment 1**) has been opened and that it is necessary to perform the Upstream Check. Nowadays, this signaling is done by telephone and control is carried out manually and with a paper system. It is clear that this obsolete procedure involves some obvious inefficiencies: first, the Team Leader, after controlling the vehicles until his Domain, must manually transcribe on the computer system what he has found during the Reaction Process; secondly, for reporting the signal to the correct Domain, it is a necessary condition for all Team Leaders to know perfectly the process and all the defects that each other Domain could generate. It is evident that this high level of training is not always possible for operators, but the thesis will return later to this issue in discussing the managerial and organizational impacts of digitalizing this control system.

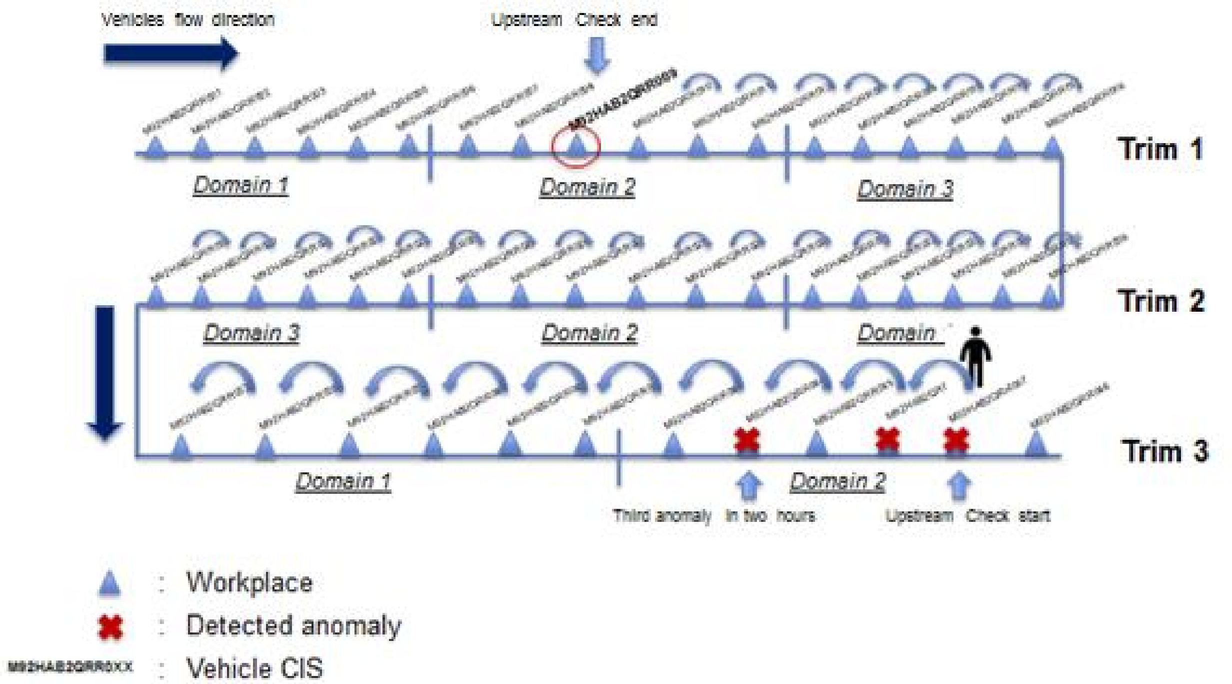


Figure 8: graphic display of Upstream Check; the second workplace of Domain 2 (Trim 3) detects three anomalies in few minutes; note that the Team Leader who must perform the control does not start from the workstation that detected the defect, but from the first of the three cars presenting the anomaly; during the check, the Team Leader must not only verify that all cars are in conformity but also repair them in the event of anomaly found.

As it is possible to see, the figure is a static illustration of the process. In this example, the Domain that generated the anomaly is the second of Trim 1. The Team Leader (represented by the black man) has been called by his Domain (Trim 1, Domain 2) and has just reached the starting point of the Upstream Check. From there, it will check each car up to his Domain: before performing the control it is necessary for the Team Leader to understand the cause of the defect and, if it is a Man or Method defect, he will make it notice to the responsible operator, making sure that he will not cause again the problem. In the case of Material or Machine anomalies, the standard procedures to be followed to determine root cause are defined: the first case implicates the involvement of the so-called "supply table", where the supplier will be notified of non-compliance, whereas in the latter case, it is applied the so-called “Autonomous Maintenance cycle" with the involvement of the plant maintainers and eventually the WCM Autonomous Maintenance pillar leader[7].

The Upstream Check automation is based on the possibility of triggering a process that allows the system to trace the plant and to monitor the Team Leaders who looks for cars that may find the same defect, performing a bottom-up path against the line movement. First of all, it is necessary to remember that henceforth, for convenience of notation, the two terms Upstream Check and Reaction Process will be used to indicate the same reaction activity: the reasons for this choice are justified by the fact that the defect detection currently requires the Deliberator (or operator of a Quality Gate Domain) to call the Team Leader to make the check by operating an upstream control process. Secondly, note that this process is solely of a reactive nature as it is an attempt to solve a problem without having prevented it. In the new model that this thesis intends to define and implement, the process will then be automated and executed with a mobile terminal by the Team Leader of a reference Ute (indicated at the time of opening). The operator will traverse the line from the detected car, entering the terminal by barcode reading or manually identifying the CIS of the vehicles encountered. The terminal will then be able to indicate the presence or absence of the fault on the car using an OK-KO buttons. If the fault is present, the procedure will assign a Tesis association to the car; the graphic illustration of the interface on the mobile terminal and a detailed Tesis codes explanation will be provided to the reader in the next paragraphs. In case the car is OK, nothing will be added on the interface. On the terminal there will also be the possibility to repair the default as it is in the Deliberation stations.

It is required to take an image of the anomaly in deliberation, so that it can be used as a reference during the Upstream Check. On the mobile terminal, there is the possibility to view the list of Reaction Processes open at any time (they can be more than one, and coded according to a naming convention) through a list that shows (see **Table 3**):

- The upstream Code with the sheet opening date and hour.
- Tesis code of the detected anomaly
- Optional description of the Upstream Check
- Number of cars examined

7 These two standard procedures will be indicated in the Flowchart of Paragraph 3.1, but they will not be analyzed further.

- Date and time when the Upstream Check has been accepted (when the Team Leader open the sheet from the device)
- Reference Ute for the defect (Ute of the source workplace of the problem)
- Team Leader identifier (more than one if the Reaction Process needs two or more rounds)
- The link to any reference image (optional).

Table 3: example of list of features that characterize every Reaction Process in the ideal digital system and that will appear on the interface.

Upstream check code with date and hour	Description of the Upstream Check (Tesis code + optional free space)	Number of cars examined	Date and hour referring to when the Team Leader has accepted the job	Reference Ute	Image
Upstream Check 1	Fender rifling	48	2017-05-03	Ute 1	
Upstream Check 2	Missing radio	15	2017-05-03	Ute 2	
....	....	....	....	....	....
....	....	....	....	....	....

Pressing on each line the system opens details of the Upstream Check including any associated picture of the associated fault, the screen for entering the CIS in check and the OK / KO buttons. Specifically, in the CIS input screen there is a blank space to enter or display the description of the solution taken during the Upstream Check. It should be foreseen the possibility of modifying the reference Ute, if a defect source different from the supposed one is detected during the Reaction Process: then you can choose a drop-down button from the drop-down menu (workshop - Line - Ute) to indicate a new reference Ute. It can be expected a counter to indicate how many cars have detected an anomaly during the current reaction.

As already mentioned, in order to better control the upstream triggering, a series of thresholds for repetition of model anomalies could be assumed, which automatically cause the Upstream Check as indicated in the Manufacturing Quality System[8]:

A. 3 anomalies of the same type in two hours
B. 5 anomalies of the same type in eight hours
C. 1 "Priority 1" anomaly from CPA-TDF-VLO systems

To determine what anomalies are to be considered Priority 1, it must be implemented the option of entering a specific Priority 1 flag directly from the Quality Gate terminal, with a button to be pressed before opening the single defect. In case of certain problems for which the process step is to be considered compulsory, the Priority 1 parameter will be entered directly into the register. The problem that the project wants to solve is that the Upstream Check is handled manually, by printing a document called Reaction Sheet, which is drawn up on paper by the reactive operator. In order to automate the process, it is expected that, when any of the three events indicated occurs, a Reaction Sheet is automatically created, coded with a unique name according to a shared naming convention. The event will be accompanied by a sound or visual alert:

- on the reference instrument resolution station (indicated by the decelerator at the upstream opening)
- on the domain relative to the reference tool
- on the reference Team Leader smartphone (where available)
- on the Quality Gate terminal where the control is triggered (in the case of automatic events of type A and B)

[8] The MQS is a is the set of rules governing the quality control of the group. This is clearly a confidential document, so the reader will have to be content with knowing the significant principles and procedures for the elaborate.

Note that it is often not possible to check all the cars in sequence by tracing the line because often the plants have over-line tracts. It is therefore almost always necessary to return a few minutes later on the cars that during the control were not trackable. An example of a quick control and repair after several minutes is shown in **Figure 9**.

Figure 9: example of on line repair on a car that could not be checked during the Reaction Process as it was in an elevated position.

At the end of the Upstream Check, that is when he returns to his own Domain, the Team Leader updates the online Reaction Sheet that was previously open to him. He is required to complete the first level diagnosis but, if he feels that the defect was generated in the previous shift, he cannot close the Sheet, but must leave it as Work In Progress (WIP). In that case, the Team Leader of the previous shift will close the board the day after by completing the second level analysis. Once the Sheet is opened and saved in a dedicated share-point, it can be replayed on the mobile terminal from which it is resumed by a dedicated interface that allows you to fill in the most important fields. For these reasons, it could be hoped that in the future there will be an interface with automatic reaction management system. To avoid the opening of multiple Reaction Sheets for the same anomaly, six different states must be provided:

- ✓ “Open”, when the ascending event occurs.
- ✓ “Assigned”, when a user assigns an anomaly to an Elementary Technical Unit (Ute).
- ✓ “Taking charge”, when a user starts to check, opening it from a mobile terminal.
- ✓ “Temporary solution”, when a quick fix to a failure has already been taken.

- ✓ "Definitive solution" (processing after diagnosis).
- ✓ "Closed", when the anomaly is resolved; from this now on it is possible to resume the Upstream Check in the event of a new presence of the fault on the model.

After thinking about the solution to improve the Upstream Check, the first critical issues to be solved are to ensure that the Team Leader can easily access the open Reaction Sheet from the system: the solution identified is to add an extra entry to a drop-down menu directly visible on the Team Leader page; for him, therefore, it is sufficient to log in the personal page, taking advantage of this additional functionality.

A second problem emerges from the inflexible and unambiguous definition of what anomalies are to be considered in the aperture of Reaction Sheet: it is desirable to consider all anomalies except the impurities caused by Paint Shop and the scrapings or splashes coming from the Body Shop. When the system detects the third anomaly in two hours, except for a list of special cases identified by Tesis code, the Upstream Check is automatically opened, which is always active and forces the Deliberator[9] or the Team Leader to control the line. It is not permitted to the workshop the ability to deactivate, for example only for few days, this function. The list of exceptions must be established by the Quality of Plant with modifications via portal interface (reading of editable Excel Files): so, there is only one certification per each check, which must be inherent to one defect. The Deliberator who has detected the defect is required to take a picture and load it to the system in order to display it to the Team Leader responsible for the defect.

It is therefore advisable to follow the now illustrated procedure: when someone starts the Upstream Check, fills in the box "Car type to check" through a pull-down menu focusing not on features but on motoring only. The "Number of checked cars" item is evaluated automatically by the counter that is activated when the Team Leader ticks the check box for the reaction. At this point the Deliberator hypothesizes the reference Ute, which in turn may reject the assignment of responsibility; in this case the system does not suggest the possible replacement Ute. Consequently, a provisional solution is taken: the responsible Team Leader returns to his Domain, writes a note to expose the temporary countermeasure implemented, and at that time the

[9] From now on the "Deliberator" term will refer to the Team Leader of one of the Deliberations or Quality Gates indicated in the Paragraph 1.2.

system tracks that there is a transitional resolution; he then proceeds to study a definitive countermeasure. If the solution is effective with the first level diagnosis, then the Ute declares the countermeasure definitive; otherwise, if the problem is more complicated, a second level diagnosis is essential because it that may involve other actors such as the Technologist, the Information Communication Technologies office, and the Technical Department. The button that allows the person to close the Sheet appears only to who has opened the same: if this is a Priority 1 click on that option automatically generates mails that require the approval of a manager, specifically the Head of Plant Quality.

2.2. Business Process Improvement

Analyzing the project and the impact it has on factory routines, it is clear that it can be placed in the context of the process improvement solutions: it is an innovation not to redesign the process, but to improve it in the perspective of continuous improvement. What is partially altered in this case is the dynamic between people, technologies and information involved in the upstream Reaction Process: impacts on dynamics between hierarchical levels will be discussed later in Chapter 5.

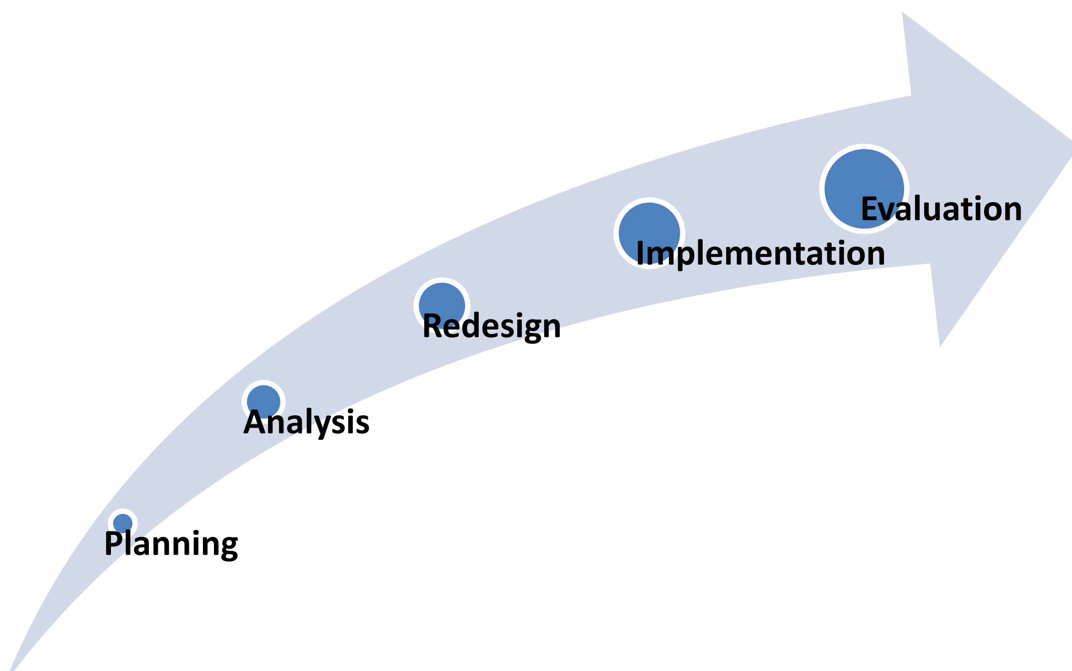


Figure 10: graphical representation of the main steps of BPI.

One of the expected management benefits will be the change in the so-called "process mindset" of the Team Leader figure, expected to become more aware of the need to effectively carry out the Upstream Checks to remedy the defects and avoid with the countermeasures that the problems appear again. The objective of the Supervisor is instead to keep in control of his team and the part of the process (or the group of Domains) that competes with him; this project, with the introduction of digitalization, let the employees to increase performance and save time, which could be dedicated to other activities: without the need for demonstrations, it is immediately clear that the automation of the control procedure allows the Team Leader to carry out all the activity through a device (for example a tablet or a smartphone) connected to the mobile terminal; with a simple click he can therefore confirm to the system that he has carried out the control on a car, without the need to use paper documents and without having to write anything on the computer. As in all cases where a new Business Process Improvement (BPI) is needed, there is a cause: in this case the reason is the inefficiency of an activity (paper Upstream Check) related to performance issues; a more obvious cause is the change of scenario within the plant, with the advent of new technologies, with the increasingly widespread digitization and the implementation of NPL. The macro-phases of this business improvement process are essentially five and are shown in the Roadmap representation (**Figure 10**). The standard procedure of the company in which the analysis of the thesis is carried out includes some fundamental steps to consider whenever someone intends to implement a process improvement with economically quantifiable benefits. After the preliminary plan it is sometimes necessary to redesign the process[10] before the implementation in the line; after the standardization of the process it is preferable to perform a constant evaluation of the actual improvement and of the achievement of the target.

[10] See Cantamessa M. Rafele C. Cobos E., "*Il project management. Un approccio sistemico alla gestione dei progetti*", 2007.

Figure 11: the FCA typical product development flow; the main milestones are Target definition, Approved concept, Preliminary standard approval, Final standard approval, Verification process, Pre-series, Job 1 after which starts the production rump-up.

However, the scope of this paragraph is just to underline, generally speaking, the "symptoms" that have highlighted the need to apply this BPI: following the production flow, an ineffective Upstream Check generates more anomalies at the end of the Assembly line, so more corrective actions are needed and the customer is less protected. In general, from a purely reactive point of view, the Quality Gate is statistically unable to detect all the defects on the cars, so it is necessary to prevent the work of correction by strengthening the process and making it reliable even before what is called in FCA Job 1, that is the fundamental milestone that precedes the production rump-up.

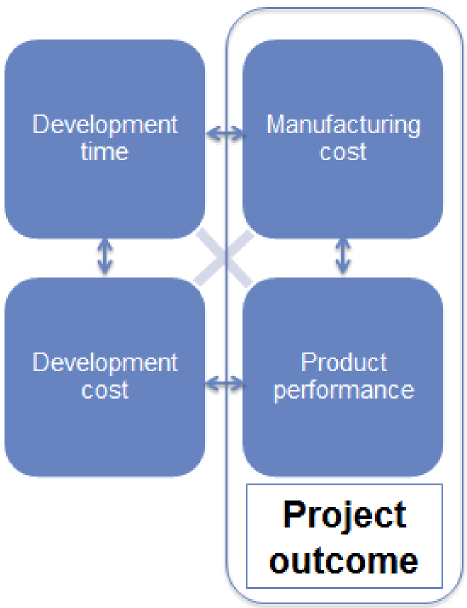


Figure 12: the process development model designed by Preston Smith and Donald Reinertsen.

So, indirectly the Team Leaders delays result in customer defects and customer dissatisfaction, that is possible to assess and evaluate after the Job 1 (all the product development phases of FCA are shown in **Figure 11**). About the most important decision variables and tradeoffs[11] that will be considered during the technical analysis of Chapter 3, a possible suggestion should come from the Smith and Reinertsen model, which is clearly represented in **Figure 12**. However, before proceeding with the technical analysis of the project, it is still necessary to introduce the main Quality Control tools introduced by the WCM in the plants. It will also be necessary to briefly deepen the Tesis codes, which represent the "key" to make digital the Upstream Check performed by the Team Leader.

2.3. The Quality Control pillar and the most useful tools

As already explained, the Quality Control pillar aims to implement a process which generates ideally zero defects and which increases the skills of workers to solve and prevent quality problems and reduce non-quality losses. The conceptual vision consists in achieving the full customer satisfaction through excellence; a non-conformity occurs when a characteristic of a finished component or product deviates or departs from the specifications intended to satisfy the customer; this happens according to a specific mode called "defect mode". The seven main steps of this pillar are:

- ❖ Reactive phase
    - Step 1: choose the issue to be solved, make sure the problem is critical.
    - Step 2: understand the situation and set targets.
    - Step 3: plan.
- ❖ Preventive phase
    - Step 4: causes analysis.
    - Step 5: consider and implement the solution.
- ❖ Proactive phase
    - Step 6: check the results.

[11] See Smith P., Reinertsen D., "Developing Products in Half the Time: New Rules, New Tools", 1997.

- Step 7: standardize and establish a control, document the change by avoiding the problem forever.

Theoretically speaking, a detected defect in the process provokes a Reaction Process from the station where the anomaly has been caught to the one where it has been generated. The digitalization of this activity will be the core of the elaborate; but before proceeding with the writing of the thesis and with the explanation of the technical solution that the author has studied and proposed, it is necessary to introduce in an extremely general way some of the principal tools of the pillar. Note that these methodologies will be exposed in a very synthetic way: the explanation of the practical use of each method will be clarified during the treatment. The reader is now required to have a general introduction to the main Quality Control documents and tools, to become familiar with them and to begin to understand the logic of their operation.

Before the tools introduction, it is helpful to write about the main documents on the Quality Control side of the Totem in every Domain of the line. A Totem (see **Figure 13**), in the context of the automotive production plant, is a three-sided billboard, each of which presents useful documents for the work in the line of three WCM pillars:

- Safety
- Workplace Organization
- Quality Control

As already stated above, the analysis will focus on the third of these pillars. The most important document is the **QA Matrix**, which is usually printed on an A3 sheet and is placed at the top left of the Totem. After explaining the structure and function of the QA Matrix and the main tools, it will be presented below a recent update of the Quality Control Totem structure, carried out by the writer and other colleagues at one of the FCA "Premium" plants.

Figure 13: the WCM Totem in front of the line; it contains three different sides for Safety, Workplace Organization and Quality Control pillars.

To keep track of all the defects found the Plant Quality offices use the so-called QA (Quality Assurance) Matrix (see **Attachment 2**), which is a list of defects that synthesizes them into a single Priority Index using a single Pareto Diagram. The main indicators shown in the QA Matrix for every single anomaly are: definition, frequency, severity. QA Matrix is a tool used to define the appropriate priorities for:

- Attack and delete product non-conformity
- Improve processes

The QC pillar, in fact, does not receive the priorities directly from the Cost Deployment because quality costs:

- are often hardly visible and quantifiable
- are related to aspects that do not always get in touch with the non-conformities produced
- manifest themselves as a consequence only after a long time

The Quality Assurance Matrix is a list of all the chronic defects which have been verified during the reference period. It includes:

1. defects caused by input materials (received from suppliers)
2. defects caused and identified during the activities carried out at the factory
3. defects that are not internally recognized but are identified by the external customer

With regard to this latter case, the WCM methodology requires that the Totem keeps track of defects complained by customers. These anomalies found and highlighted by the final client are listed in a document called **Customer Voice**, often printed in A4 format and composed of several sheets, each featuring a detail of a single anomaly. This document is usually located at the bottom right of the Totem side of the Quality Control pillar.
Another very important Domain totem document is the **QA Network**. By observing the example in **Attachment 3**, this document is used to indicate in which workplace any defect can be generated (red box). In addition to describing the anomaly, this tool also indicates the first level diagnosis and in which workplaces the presence of the defect cannot be detected, as it is covered by an assembly operation[12] (grey box). It is also indicated the workplace in the production flow in which a control has been placed for each anomaly, and it is also specified the type of check (see the legend at the top right). If the control is placed in a workplace downstream of the Domain or in a Quality Gate, this check is indicated on the right of the Domain workplaces columns. QA Matrix and QA Network are the two leading Quality Controls document at Domain level and help Team Leaders keep track of their part of line process.
In all these documents the problems are classified with the **4 M and 1 D** methodology, graphically shown in **Figure 14**: it is a tool used for analyzing a phenomenon by detailing possible causes, aggravating factors or sub-causes that are the root cause of the undesired phenomenon. The list is categorized; WCM proposes to group factors into the following classes:

- Manpower or (simply) Man
- Method

[12] To the importance of this functionality of the document, the thesis will also refer in Chapter 5 when some improvement proposals emerged from interviews with Team Leader will be discussed.

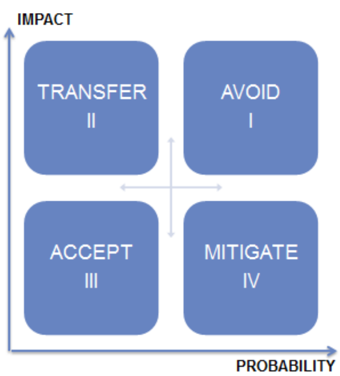
- Material
- Machine
- Design

This problem solving tool goal is to represent the concept of relation and causality, in particular during the planning phase (Step 3) to forecast potential problems, during the diagnostic phase (Step 4) to generate possible theories about the causes of a deviation, during the decision phase (Step 5) to generate solutions and assess the risks involved in them[13].

4M1D Color Standards			
4M1D		**FUNCTION**	
MAN			MANUFACTURING
METHOD			
MACHINE			
MATERIAL			SUPPLIER
DESIGN			DESIGN

Figure 14: the 4M and 1D tool image with the color standards and the offices involved.

[13] In the Project Management course of Polytechnic of Turin it has been studied a possible solution which consists in planning risks to give strategic answers as transfer part of the financial effects to third parts. It is possible to create a risks taxonomy table:



the four main possible responses to the risks based on the likelihood of occurrence and potential impact are: to avoid risky failures (quadrant I), to ensure risk by moving it to third parties (quadrant II), accepting the risks by setting them to "contingency budget" (quadrant III), mitigating them by risking activities out of the critical process and standardizing (quadrant IV).

Another form to solve problems in the line is the **5 W + 1 H**, that is a tool for logical analysis used in quality improvement techniques to ensure that the investigation of a problem takes proper account of all the most important factors:

- What
- When
- Where
- Who
- Which
- How

These six questions allow the quality expert to get a full grasp of a situation inside a plant and to focus on the key issue. The questions can be divided up into different levels, depending on how much in-depth the analyzer needs to go into a problem.

5 G is instead a methodology designed to describe and analyze a loss phenomenon as defects, breakdowns, operating anomalies. In essence, the instrument consists of five factors, well summed up in the **Figure 15**.

"Gemba" (Shop floor)	Go down to the shop floor
"Gembutsu" (Real things)	Examine the object
"Genjitsu" (Context)	Check facts and numbers
"Genri" (Theory)	Refer to theory
"Gensoku" (Rules and principles)	Follow operating standards

Figure 15: detail of the five 5G factors with the original Japanese names.

The tool results useful to thoroughly describe situations circumstances, to make a connection between theory and practice, to approach phenomena in a rational way.

Again, one of the most important WCM tool is the **5 Whys** for finding the causes of an abnormal phenomenon using a series of questions to train operators and Team Leaders to ask themselves why the defect was generated and to find an answer using their intelligence.

Very important is the **Poka Yoke** concept: it is a countermeasure, emerged from a project proposed by on line operators or Team Leaders, to avoid any incident; literally means "mistakenly" and is very similar to the American concept of “fool proof”. “Fool proof” concept means that the operator does not make a mistake right away; for example, inserts a block to the left to prevent it from being mounted there because it must be mounted to the right. “Error proof” has a different undertone: an example could be the conveyor belt that goes forward the Assembly Shop line with two straight pieces and one crooked, but the third blocks it. So, it makes the defect go on for a while, but at the end of the transport the block tells the Team Leader that an operator of his Domain has put it badly. The number of Poka Yoke for every Domain is usually monitored in a document called “Poka Yoke trend”

The last important tool for the analysis of this thesis, which is also a possible Totem document, is the **Occurrence and Release** or simply O&R. The Occurrence is the probability to generate the defect in the station, while the Release is defined as the probability to release the defect from the station that generated the issue. It is the analysis to improve processes to avoid defects (occurrence) and passing the defect to the following steps (release). It is applied in all the areas of the plant (Body, Paint, Assembly). Priority is to so-called AA defect potential operations, expanding then to A, B and C. It should be used by:

- Main pillar leader: QC, WO, LCS, AM, PM, EEM, EPM
- Ute team (Team Leader, Supervisor, PPS)
- Quality and Logistics specialists
- Quality Support
- Process Specialist
- Maintenance team

O&R is ideally applied proactively starting from the priority operations, separating each person job into potential defect types, analyzing each defect type using appropriate table. In **Figure 16** there are all the priority symbols.

Safety, Regulatory, Homologation, Walk Home	**AA**
Function, includes Feel & Hear	**A**
Asthetic	**B**
Workability/Other	**C**

Figure 16: AA, A, B and C mark meaning detail.

After an area is complete, re-application of the tool is useful because the knowledge of the team improves, hidden changes to the workstation occur where the tool has not been applied, the tool improves with new failure modes. In order to select the defect types that are needed by the plant there are 5 steps:

1. Prioritize what operations have the highest priority, and begin there.
2. Identify every step in an operation (for example pick, position, fasten).
3. Apply the appropriate O&R questions (note, it is common to have more than one O&R table applied to a single step).
4. Assign an occurrence/release level for each step.
5. If not in the green zone work to improve occurrence/release levels starting from AA.

The procedure involves also the possibility to track the improvement of the operation, and the area with a before/current state; other possible examples are:

- Wrong picking of parts / Missed pick of part
- Incorrect fastening / Missed fastening

So, the Plant Quality office and the Team Leaders have to associate each possible quality defect (failure mode) with severity classification (AA, A, B, C). They use O& R Matrix (**Figure 17**) to determine risk of each possible defect: obviously the green region is target.

AA	1	2	3	4
1	AA	AA	AA	
2	AA			
3	AA			
4				

A	1	2	3	4
1				A
2		A		
3				
4	A			

B&C	1	2	3	4
1				
2			B&C	
3		B&C		
4				

Figure 17: O&R Matrix for every severity classification.

The analysis of the next chapters (in particular the 3rd and 7th) will focus on the anomalies generated along the production line: in order to proceed, it is necessary to introduce the concept of riskiness of a defect. A level of Severity, Occurrence and Release can be associated with each anomaly. Then it is possible to calculate the Risk Index, that is the probability that a transformation will generate an anomaly. The result of:

$$Risk\ Index = Severity\ \times Occurrence \times Release$$

establishes that risk is associated with every defect and represents an important working tool for those who analyze data in the offices concerning the quality of the product.

During the internship experience prior to the writing of this thesis, the author participated in a revision of the logic of the part of the domain totem inherent the WCM technical pillar of Quality Control. The As Is is illustrated in **Figure 18** and was built before the release of the Global Standards of FCA in May 2017. Initially, the dominant document was an invented sheet from the plant called “Human Errors trend”. This list was based on anomalies from three different documents, in particular Customer Voice, Reaction Sheet trends and QA Matrix. There were also two sheets for QA Network, a Reactive one and a Preventive one. After a careful analysis, it emerged that in the evolution of “Human Errors trend”, Man or Method defects were indistinguishable, and such anomalies were then plotted along the line in the QA Network Reactive. QA Network Preventive was, on the other hand, fully provided by the Occurence and Release, composed of the new luxury models’ defects produced by the Group at other plants. This setting of the QC side of the totem clearly made work much easier and faster for the Team Leader but had many disadvantages over the quality objectives of the "Premium" factories. Specifically:

- It only allowed to monitor Man and Method anomalies and did not allow Team Leader to handle Material and Machine defects.
- It created confusion at QA Network level, limiting Team Leader's work to tracing and tracking the only anomalies that occurred during the process (just a reactive work); therefore, it limited the Team Leader to only responsive work, leaving the preventive phase just improved by external information.
- It did not help the Team Leader and therefore the operators to differentiate Man anomalies from those of Method.

Basically, with that totem structure, the Team Leaders did not bother to prevent anomalies and there was not even the basis for them to be able to work proactively in the future.

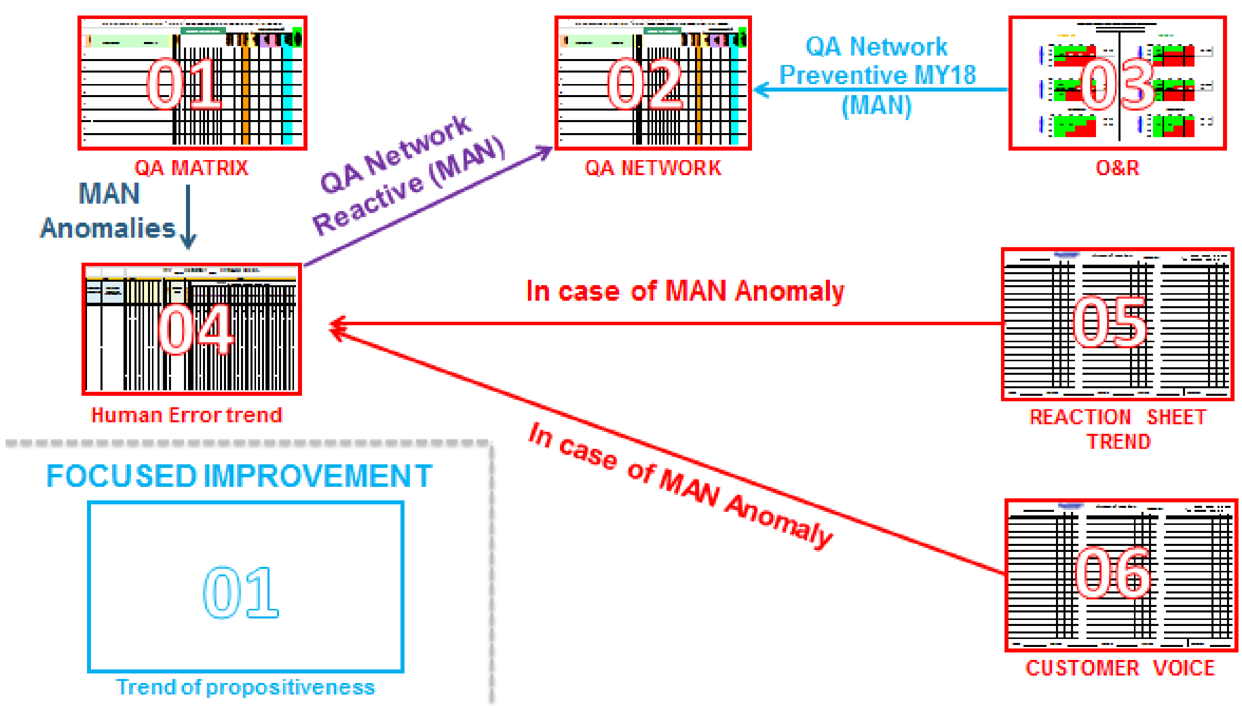


Figure 18: Domain QC side totem "As Is" in Assembly Shop.

With the help of the new Global Standards, the quality side of the totem was restructured: first of all, it was given greater weight to the "great" quality document, namely the QA Matrix. The centralization of the role of this tool has made Team Leaders aware of all the defects of 4M and

1D: they have started to participate more frequently in the supply tables and the AM cycles for the machines. Now Team Leaders handle many more anomalies, but the logic of the totem is simpler and more effective. This new structure is shown in **Figure 19**: by creating a single QA Network and expanding, as mentioned, the size of QA Matrix it has been given to the Team Leaders two very large but powerful tools to manage their Domains and their own process. The QA Network is now powered by the QA Matrix with the anomalies of all 4M and 1D: the "Human Errors trend" has thus become a sub-cluster of the QA Network where malfunctions are handled by the operators themselves; in addition, it was decided to move the O&R sheet to a sheet collector near the line (always managed by the Team Leader) and to replace it with the "Poka Yoke trend". With these two operations, the importance of the workers was also increased on the totem, making this facade more useful for on line work. In this new structure, the work of the operator is "visible" and emphasized as he can see his possible human errors and how to handle them in "Human Errors trend", and may possibly see his own improvement proposals actually transformed into actual realities in the "Poka Yoke trend" document.

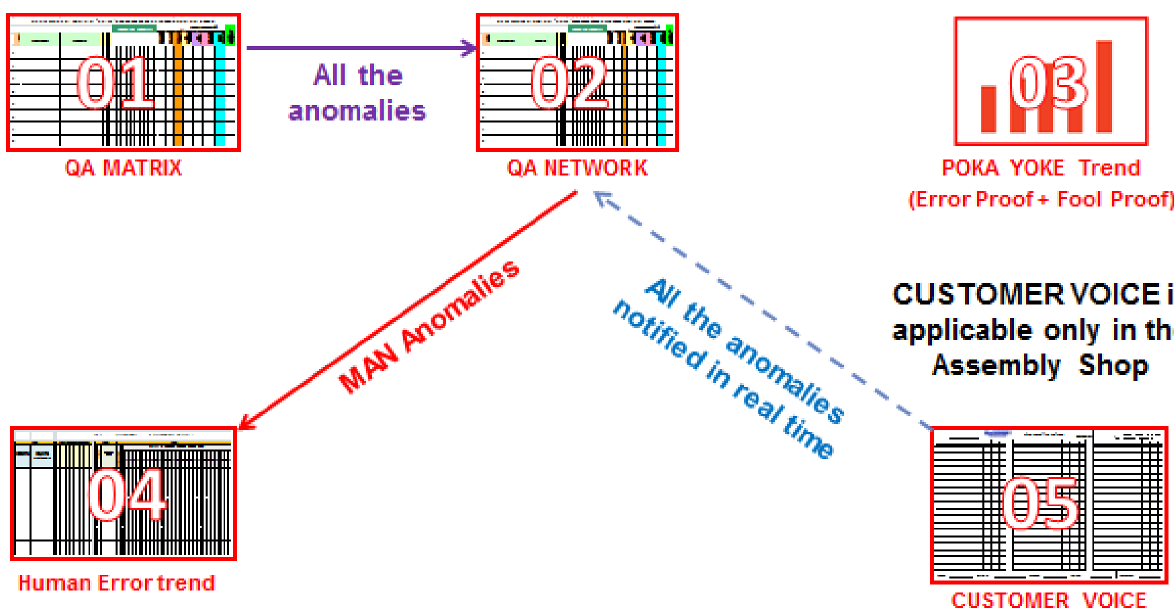


Figure 19: Domain QC side totem "To Be" in Assembly Shop.

Lastly, in this paragraph, it is necessary to underline the role of NPL to create a link between the first chapters introduced until here. Nowadays, NPL works are focusing on human errors, how to avoid them and how to catch them. After the identification of human error, NPL system could result very useful for example helping in the collection of data or allowing to separate the repetitive and sporadic errors. The system now gives also effective feedback to the operator when he makes a mistake with forms of communication such as lights or alarm bells that recall, for example, that in a particular vehicle it has not been assembled the radio. NPL goal coincides, or even overlaps, with the aim of the managerial discussion that will be presented in Chapter 4: make people become responsible for their own work area.

2.4. Tesis code

In the description of the problem in Paragraph 2.1, a reference was made to the Tesis code, useful to identify each defect on every type of vehicle. The Tesis code has born as a coding in design environment to monitor product reliability; it was used in particular when launching a new product, as it allowed to see how a certain component behaved in the previous models. It is therefore born as a tool for comparing the role of the same component on different car models. It has been later used in After-sales department. There are two methods in production today to identify components: one physical and one logical. The first consists in coding the technical drawing, the hierarchical collocation of which is illustrated in **Figure 20**.

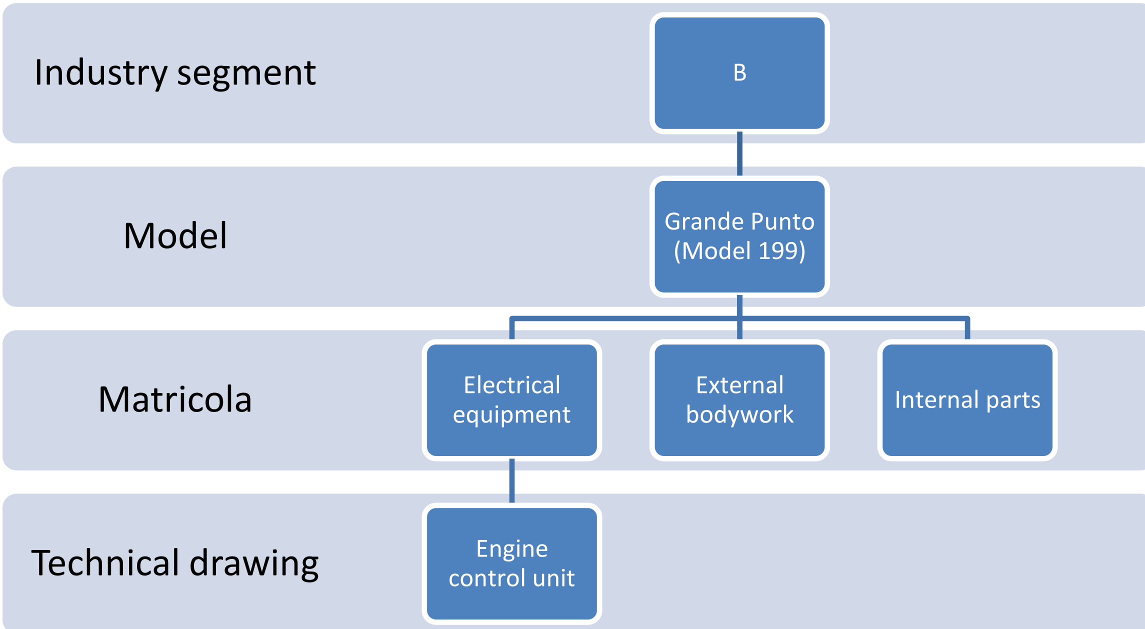


Figure 20: the physical method to identify the components in the manufacturing system.

Each model can therefore, depending on the engine, have more than one associated engine control unit (for example 1300 diesel or 1400 petrol). There is a unique code for each control unit; the Tesis has instead a single logical code with which the component is identifiable (see **Figure 21**). In this latter concept lies the logical identification, that is, the second method of identification. Nowadays every car before launching (before Job 1) is physically carried in After-sales or Technical-service department and counts the time of demolition of each component to which the Tesis code is associated. If the component is completely new, this is first logged on to the system with a new assigned Tesis code. Consequently, those who are baptized for the first time are currently the Technical-services responsible; however, there are cases where the people in charge do not notice the existence of new components, in which case the entity that detects the presence of a new component is the Manufacturing as a plant, when the quality office detects the piece and does not have the code. After the need communication, the owner decides whether to release the encoding and in what way: from a managerial point of view, if the component is actually replaced on the network, the Quality Manager[14] tends to favor the registration, but if it is irrelevant he is contrary in order to avoid the replacing of all the anomalies.

Tesis Category Name	Digits
Section	1
Group	3
Subgroup	4
Assembly	5
Unit	6
Part	8

Figure 21: number of digits for every Tesis category name.

The primary application of After-sales is called SIGI and uses Tesis encoding: this software is used in all major dealers. Other organizations such as Manufacturing Quality and Engineering Design use software that, thanks to the data recorded on SIGI, documents anomalies on each component and from there, they start their own reasoning. Tesis encoding is currently used in all EMEA region. Some recent adjustments have however slightly modified the concept of the Tesis; it is now no longer intended as a "component", but to this code are now associated three elements for a total of 13 characters: the part (8 characters), the anomaly (2 characters), the position (3 characters), all shown in **Figure 22**. In the After-sales and Engineering design functions only the first two are used, but for Manufacturing it is also important to detect the position of the defective component: the purpose is to differentiate car zones and better manage repetitive components (for example pegs).

Note, for example, that a component (such as a battery) may exhibit some issues that are more relevant to Engineering design, such as the absence of electrical current, and others that are more concerned with Manufacturing, such as failure to assembly the battery to the support. For the purpose of the Reaction Process, the enterprise is also clearly interested in identifying and tracking where the defect was generated: when the component is factory-coded, the location where it will be mounted is also registered; the responsible can then proceed to further encoding to find the most critical workstations to work on. When a new model is created, it is indicated on MES and on *Ute digitale* and it is recorded for each station which components are mounted.

[14] With the terms "Quality Manager" or "Quality Responsible" the thesis refers to the head of the Plant Quality office which is located in the plant and works on the quality problems of the line with employees called QC Specialists.

Thus, the correctness of the Tesis encoding is extremely important for Upstream Check automation, since it indicates the component, the defect mode and the anomaly position. In order to make the upstream control of the Team Leader faster, the third part of the coding is very important: indeed, if the position of a damaged screw is not correct, those who go back to the line should check all the screws of all upstream cars of the Deliberation where the defect was detected (up to the workplace where it was generated), with obvious consequent time losses.

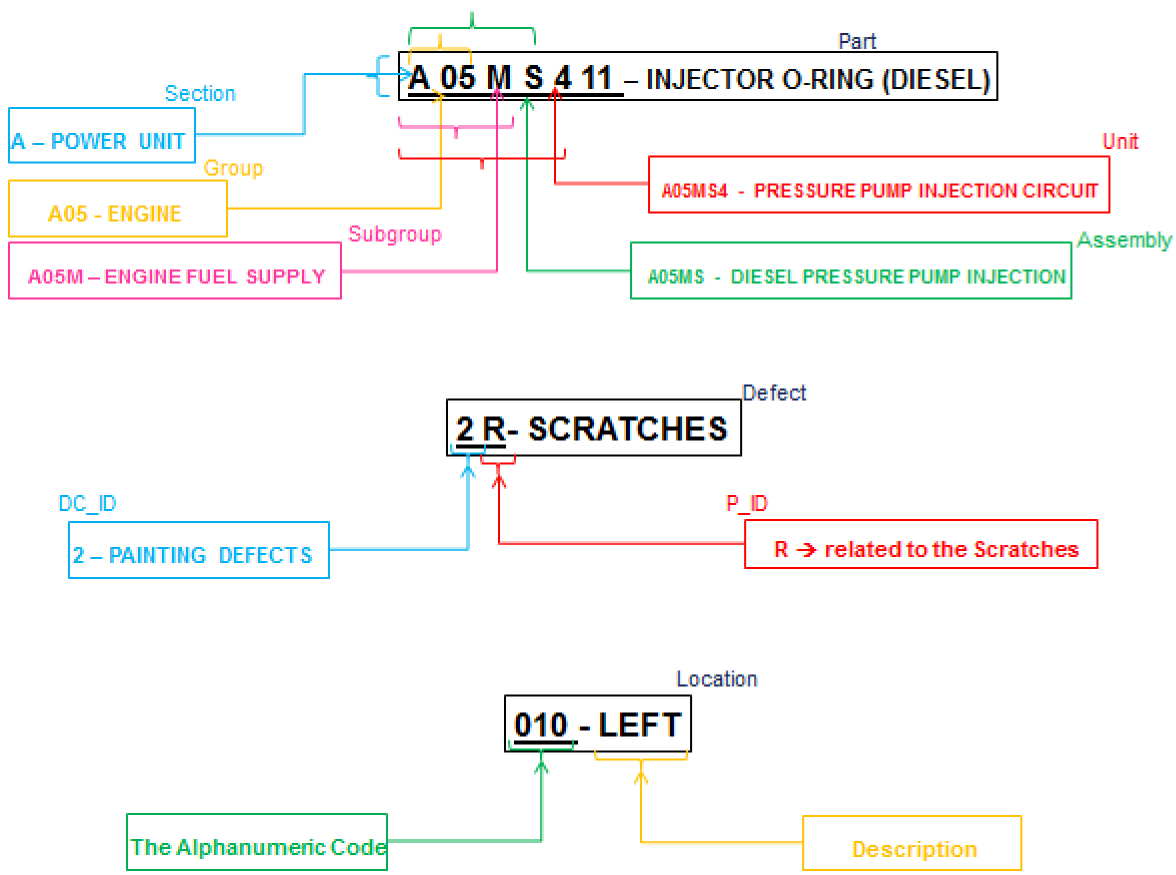


Figure 22: component, defect mode, location digits code details (from the top to the bottom).

3. Technical solution

3.1. Process Flowchart

As explained in the previous chapter, during the Upstream Check, the operator walks along the line with a configured mobile terminal containing the correct CIS sequence of cars to be tracked with code, whereas each anomaly is characterized by an image. Note that it is not possible to open a Reaction Sheet by indicating the only Tesis code without attaching the name of the Domain Team Leader who has generated the anomaly. A simple example could consist in the check of a hypothetical anomaly consisting in the non-fixing of the seat along the Ute (that can be translated in English as "Elemental Technical Unit"): in this case the Team Leader of the Domain concerned observes on its mobile terminal the signaling of the fault with attached an image of the unmounted seat; next, the Team Leader observes the sequence to be checked, which includes the cars between the defect detection point (in case of Priority 1) or between the point of detection of the first anomaly (in case of repetitive defects) and the last vehicle worked by the responsible operator before the same is warned of the error (Man or Method) and corrects it with his Team Leader. After identifying a provisional countermeasure, the Team Leader controls all the vehicles indicated and signals through its mobile terminal (the interface is detailed in **Figure 23**) the check on each potentially defective car: therefore, he verifies that the seat is fixed and in cases where it is not, he remedies to his operator's error. After the control along the line, the Supervisor and the Team Leader perform the first level diagnosis with tools such as 5G or 5W + 1H, assess whether the countermeasures are effective and therefore can become definitive, or if a project is needed to improve the provisional solution: root cause detection is the main objective of this procedure.

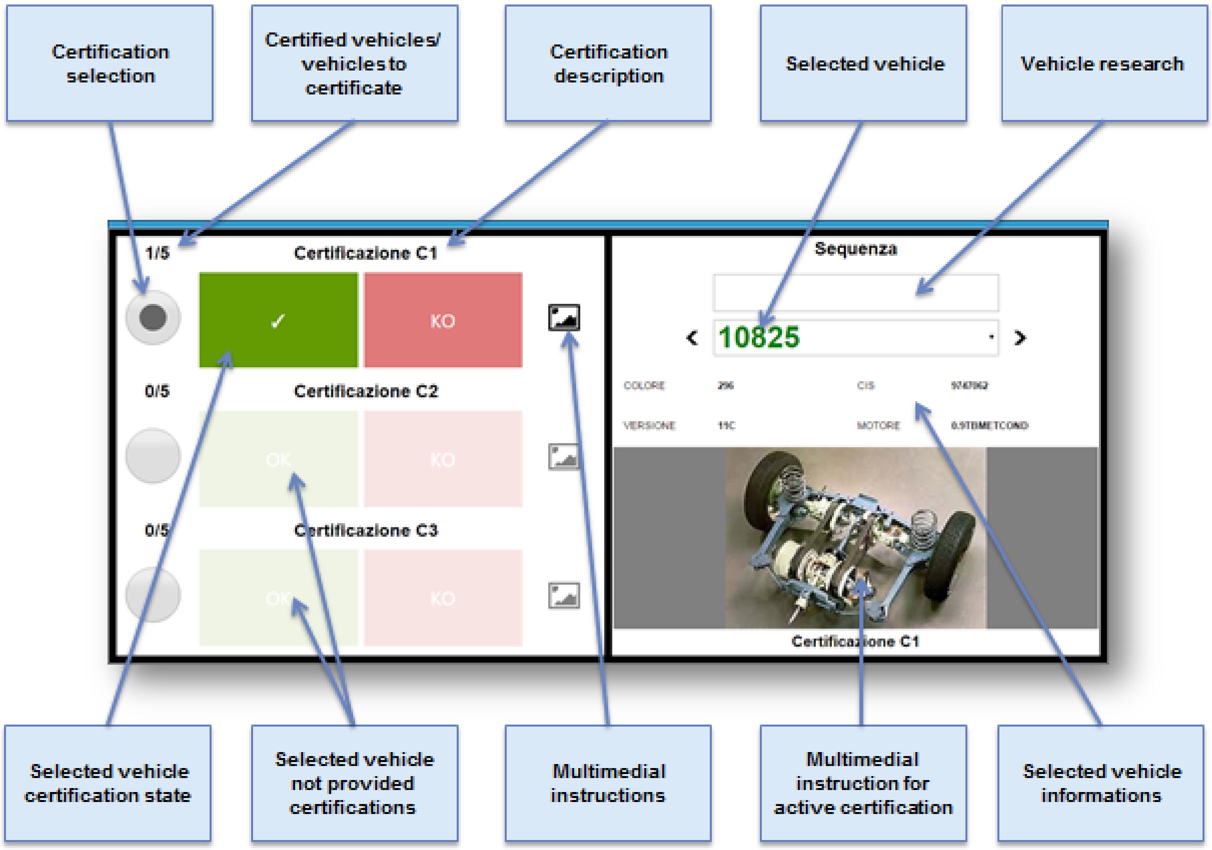


Figure 23: detailed explanation of the Team Leader mobile terminal interface

After the first level diagnosis and the application of a provisional countermeasure, the Team Leader can start the check: the flow diagram is shown in **Attachment 4**. The conclusion of the check is a necessary but not sufficient condition for the closure of the Reaction Sheet: it is also essential that a definitive countermeasure is confirmed; it may consist of simply confirming the provisional solution, if effective, or in the result of a second level analysis. At system level, the Team Leaders interface with the Supervisor, which gives the first confirmation to the system that the solution is definitive. In order to close the Reaction Sheet, it is only more necessary to await the confirmation of the Quality Manager of the plant. As shown in the flowchart, the defect analysis procedure depends on which of the 4M and 1D is involved and especially on the offices that it is necessary to involve in identifying the root cause and studying a definitive solution. The Supervisor interacts with his own boss, the Shift Manager, who, assisted by the PIM[15], directs

[15] As already briefly said in the Paragraph 1.2 the PIM is the Process Improvement Manager: a more detailed explanation of the organizational structure within the automotive plant will be given to the reader in Chapter 6.

the Team Leader and the Supervisor to the optimal interlocutor for defect analysis: there are many involved offices, including Manufacturing Quality, Manufacturing Engineering, Logistics, Technical Service.
As indicated in the flowchart, to the Team Leader is given the option of refusing the Upstream Check if he feels that the anomaly does not belong to his Domain. In this case, the Team Leader himself is required to fill a free space where it justifies the reason for the refusal. This notification reaches the Supervisor who, after careful analysis, reassigns the defect responsibility to a Domain: it is specified that the Domain chosen by the Supervisor may coincide with the starting one. Once the M to which the defect belongs is established, there are two cases: if this is a Man or Method problem, the procedure is the one mentioned in Paragraph 2.1. If, on the other hand, these are defects caused by Material or Machine, then standard procedures are followed (the squared symbol with the double strokes on the sides in the flowchart indicates the "standard procedure"): in the first case, the Team Leader works with the "supplier table", where who provided the material is required to analyze the problem; in the second case, it is applied the Autonomous Maintenance cycle. In the Assembly Shop, Machine defects are very rare, an example is the assembly machine of the windscreen front crystals. In capital intensive areas such as Paint Shop the AM cycle is performed by the conductor. In the few cases in the Assembly Shop that affect this discussion, however, the loop is run by Team Leader himself with the help of a maintainer[16]. It should be noted that in both cases the Team Leader is then required to interface with the system, indicating that the defect has been solved and that the countermeasure has been identified. As already mentioned, it is then necessary the Quality Manager confirmation to let the MES system to close the Reaction Sheet.

3.2. Use Case and cost evaluation

To define the project Use Case is first of all indispensable to compose and shape the loss type that this solution can attack (**Figure 24**). Clearly the project is digital and could be effective in

[16] The different organizational levels of the maintenance personnel will be explained in detail during the discussion of Chapter 6. For the time being, the reader is required to settle for the definition of a generic maintenance role that belongs to a different functional branch compared to the production one of the Shift Manager, the Supervisors and the Team Leaders.

the most labor intensive Unit, the Assembly Shop. It should be useful to faster rework the quality defects and to save time for the Team Leader. As already mentioned, the tool become automatic from paper.

CD	IMPACT ON COST DEPLOYMENT*: ☑ CD DIGITAL ☐ CD PLUS	LOSS CATEGORY*:	Labor	
		LOSS TYPE*:	Quality Defect / Reworks	Tool change
	ACTIVITY*:	Reaction Process	CLUSTER*:	Plant Quality
	AREA OF APPLICATION*:	Assembly Shop	USER*:	Team Leader

Figure 24: first project impact evaluation on the Cost Deployment WCM pillar.

The As Is situation and the To Be expected conditions and goals are depicted and exemplified in **Figure 25** and in **Figure 26**. As every project the scope is to bring a "before" condition to an improvement "after" the digital application.

AS IS	BEFORE*:	
	The Upstream Check (or Upstream Process or "Risalita di processo") is based on the possibility of triggering a process that, starting from detecting a defect on a vehicle at a Deliberation Station, allows the Team Leader to subsequently trace along the line to look for the cars that may find the same defect, performing a bottom-up path contrary to the line movement. Specifically, in the event of repeated defects occurring according to the periodicity indicated in the MQS TR01 or following a manual trigger, it is possible to indicate the anomaly that causes the Upstream Process from the vehicle concerned. Nowadays, this operation is paperwork and is manually carried out: therefore, the system does not keep track of the succeeded control on each car during the Upstream Check.	
	LIMIT*:	KEY WORDS
	No traceability on system, no accountability, only Reaction Sheet, manual trigger	Reaction Sheet, Upstream Process, Team Leader, Process Recall, Upstream Check

Figure 25: As Is detail enriched by key words and limits of the procedure.

To complete the writing of the Use Case, a meeting was held with the company Engineering, supplier of FCA of software codes and programming languages. Estimated cost to implement the solution is 56 000 €, which is solely the cost of the software vendor's workforce. Development times have been estimated in four months: this time is called conventionally "elapsed time" and represents the start up of the project after which the start will be possible[17].

<table>
<tr><td rowspan="4">TO BE</td><td colspan="2">AFTER*:</td></tr>
<tr><td colspan="2">In the above indicated cases, the system triggers automatically the Process Recall without human intervention. The process is now executed with a mobile terminal (for example a tablet) by the Team Leader of a reference Domain (indicated at the time of opening). The operator traverses the line from the detected car, inserting on the terminal by barcode reading the CIS identifiers of the vehicles encountered. Then, the terminal is able to indicate the presence or absence of the anomaly on the car using the OK-KO buttons. If the defect is present, the procedure assigns a Tesis association to the vehicle. It is possible to repair the defect as it is in today's deliberations. The automated Upstream Process is enabled on the whole plant, except for specific abnormalities, indicated and maintained by Manufacturing Quality through the system portal interface (for example MES in Mirafiori).</td></tr>
<tr><td>GOAL*:</td><td>KEY WORDS:</td></tr>
<tr><td>Reduce reaction time and trace the line, following a bottom-up check for an anomaly that is detected at a Deliberation Station</td><td>Mobile terminal, Digitalization, Automation, New Plant Landscape, Upstream Process, Team Leader, Process Recall, Upstream Check</td></tr>
</table>

Figure 26: To Be detail enriched by key words and goals of the innovation.

To quantify the economic benefits, a simulation of the control process was carried out using Excel and a “Python” machine learning software. This simulation is illustrated in the next paragraph. The managerial and organizational benefits will be discussed later from Chapter 4 till the end of the elaborate and will not only address the analysis of this project, but more generally the impacts of the digital proposals that are emerging in the automotive productive realities.

3.3 Upstream Check simulation and Python code

Before starting the simulation, the reader should be referred to Figure 7 of Paragraph 2.1. By observing that image and remembering the procedure described in the same paragraph, you can perform a static simulation and carry out some additional analysis. It should be noted that the work was completed on real data from one of the "Premium" plants containing the anomalies generated from Monday to Thursday of a week of October 2017. The raw data are presented in

[17] Following the Project Management definitions, the start up involves the definition of key milestones, criticalities, risks, strategies and engagements; the start it is simply the first activity of the project in a timely optics, for this reason it is conventionally said that start up delays the start.

Attachment 5. The first step was that to filter the data for Tesis code: 13-digit code 0000013800000 was selected because represents the most frequent defect (see **Table 4** with the Tesis code description in Italian language), regarding the failure to secure the left flank of the dashboard.

Table 4: example of detailed list of the most common anomalies with Tesis code, description, Ute and responsible team.

TESIS CODE	TESIS CODE DESCRIPTION	MODEL	UTE	TEAM	TESIS OCCOURRENCE
0000013800000	KO-FISS.MAS.PLAN.FIANC.SX	492	A1	07	30
0000196500000	KO-FISS. PLANCIA LATO DX	492	A1	6	26
0000062300000	KO-TRACC.FIBIA.CS.CENTRALE.SX	492	A3	02	22
0000196600000	KO-FISS. PLANCIA LATO SX	492	A1	6	13
D60AA130RS090	KO-TRACC. ARROTOL. ANT DX	492	A1	06	13
D75VM350RS000	KO-TRACC. RAMO 3 POST CENTR	492	A1	06	13
D75VM310RS010	KO-TRACC. RAMO CINT.POST.SX	492	A1	06	12
D60AE120GF000	KO-FISS.PRET.ANT.SX	492	A3	02	9

Thirty cases were recorded: for each of these, the differences between the closing day and time and the opening day and time of the anomalies were calculated; the details of each anomaly are always shown in Attachment 4. Calculating the average of these times (see **Table 5**), an average time of 13 minutes and 27 seconds of anomalies was recorded. Among the hypothesis are the 2 shifts per employee working day, the fact that the data come from 4 consecutive days, so the total number of shifts involved is 8, each of which lasts 8 hours. By summing all the time devoted to solving the anomaly studied and dividing by the number of shifts involved, it emerges that the Team Leader of the Domain responsible for generating this defect dedicates every turn an averaged amount of time equal to 50 minutes and 27 seconds in solving the anomaly downstream. This is an exorbitant time of approximately 10.51% of the turn, which makes it even clearer how important it is to implement innovations that save time. In fact, Team Leader must carry out many activities in his Domain that will be described in the next chapters, as well as substituting on line operators when needed. In order to continue the analysis, it is necessary to specify that the Takt Time[18] of the "Premium" plants is about 6 minutes, which is significantly

[18] The so-called Takt Time is given by the total available time per vehicle requested by the customer:

$$Takt\ Time = \frac{Total\ available\ time\ per\ day}{Number\ of\ pieces\ requested\ by\ the\ customer\ per\ day}$$

higher than that of mass market cars. In luxury cars, operators work 6 minutes on each car but there are obviously many more tasks to complete than those of the operators who work for example on Fiat Panda (Takt Time for about two minutes). By dividing the hours of the turn for Takt Time, therefore, the number of cars worked on average by an operator in each turn is equal to 80 products. It a single turn, out that 10.51% of these cars, so more than 8 vehicles in turn, are worked by operators without the supervision of the Team Leader on the Domain, because he is committed to solving the anomaly.

Table 5: variables and numerical values of the main data needed to simulate a Upstream Check along the Assembly Shop line of a "Premium" plant.

Variables	**Calculated data**
Total time to solve anomalies	06:43:32
Total number of anomalies	30
Average time to solve anomalies	00:13:27
Shifts per day	2
Days	4
Total number of shifts	8
Average time to solve anomalies per shift	00:50:27
Takt time	00:06:00
Time available per shift	08:00:00
Percentage time to solve anomalies per shift	10,5087%
Total number of vehicles per shift	80
Number of vehicles worked without Team Leader per shift	8,406944

Takt Time must not to be confused with Time Cycle, which is the manual working time needed to complete the assembly operation.

A second analysis was then carried out on the duration of defect resolutions in chronological order. Looking at the graph in **Figure 27**, it can be observed the time employed by Team Leader in solving the anomalies; remember that this is always the same anomaly, so it's normal that after spending a lot of time repairing the car for the first time, Team Leader takes less time to repair the next cars. Interpolating the data with the line with the Excel program shows that the trend is typical of the logarithmic function, although the variability in the final anomalies is fairly high; this should not surprise the reader, because after understanding how to fix a defect, the Team Leader can solve it immediately or meet some difficulties due to other factors, but, as the reader can see, he no longer takes the exorbitant time that was wasted at the beginning in the first six cases to understand how to repair the vehicle. It then emerges that, after a rapid improvement in repair speed, after some anomalies (about six in four days), Team Leader is no longer able to fall over a certain average recovery time.

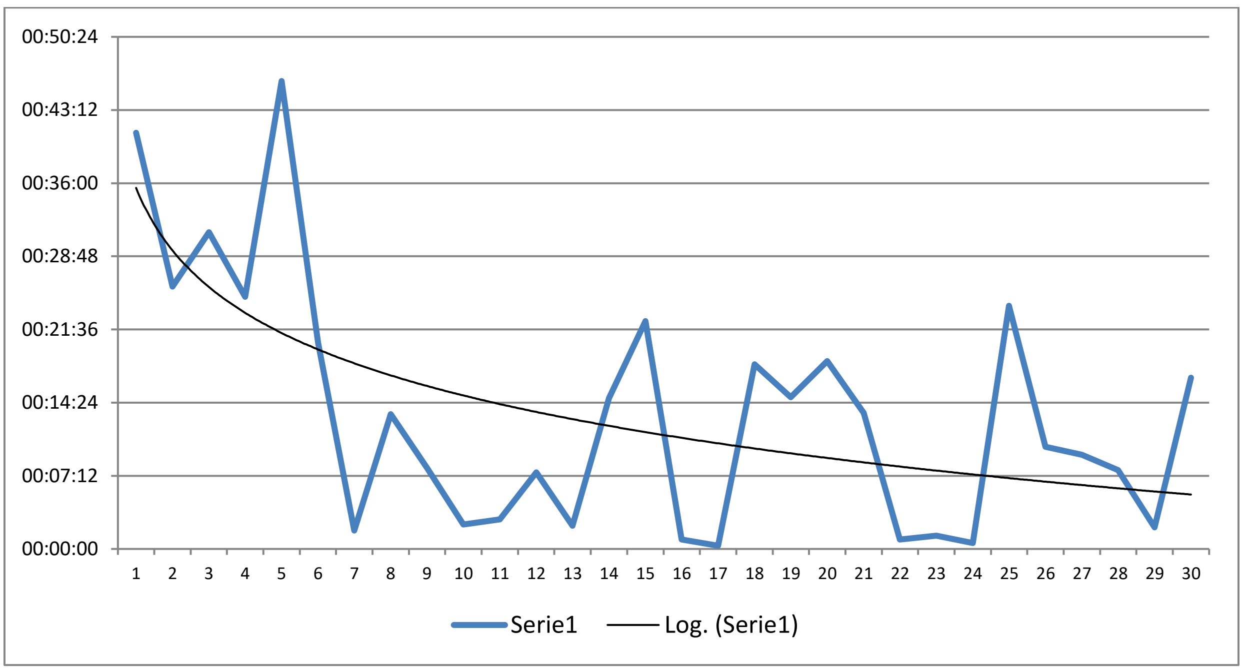


Figure 27: anomaly resolution time trend from Monday to Thursday of a generic week in a "Premium" plant.

After this first analysis, it is important to make sure that the system is able to understand when it is necessary to open a Reaction Sheet, so it can signal the need to perform Upstream Check of the Team Leader of the responsible Domain. As discussed in Paragraph 2.1 there are three cases where all cars must be checked along the line: in the case of Priority 1, the system automatically recognizes that a Reaction Sheet must be opened because, as said, it has a database, continuously updated by the Plant Quality office, containing all possible priorities. The problem arises when it is needed to open a repetitive defect Reaction Sheet: the cases are two, that is, three anomalies in two hours or five in eight hours. The following is the computer code implemented on the machine learning software called "Python" that can generate the opening of the Reaction Sheets in case of repetitive anomalies. More specifically, by way of example, the author has created a code that can count how many Upstream Checks should be generated in the event of the defect previously chosen.

“

```
import pandas as pd
import datetime

df = pd.ExcelFile("Attachment 4 - Defects row data from
Trim.xls",sheet_name="TESIS_Details")
df1 = df.parse(2)
listTesis=df1["TESIS"]
ListTesisCodesDifferent=listTesis.unique()
CriticalTesis=ListTesisCodesDifferent[1]
datasetcritical=df1[df1.TESIS==CriticalTesis]
date_time_opening = datasetcritical.DT_OPEN
date_time_closing = datasetcritical.DT_SOLVED
ii=0
EightHours=60*60*8
NumberReactionSheets=0
TwoHours=60*60*2
while ii<len(datasetcritical)-4:

    datetime1=datetime.datetime.strptime(date_time_opening.values[ii], "%d/%m/%Y
%H:%M:%S")
```

```
    datatime2=datetime.datetime.strptime(date_time_opening.values[ii+1], "%d/%m/%Y %H:%M:%S")
    datetime3=datetime.datetime.strptime(date_time_opening.values[ii+2], "%d/%m/%Y %H:%M:%S")
    datetime4=datetime.datetime.strptime(date_time_opening.values[ii+3], "%d/%m/%Y %H:%M:%S")
    datetime5=datetime.datetime.strptime(date_time_opening.values[ii+4], "%d/%m/%Y %H:%M:%S")
    difference=datetime3-datetime1
    difference2=datetime5-datetime1

    if ((difference).seconds < TwoHours ):
      NumberReactionSheets=NumberReactionSheets+1
      ii=ii+3
      print ("Reaction Sheet opened after defect", ii)
    elif ((difference2).seconds < EightHours):
        NumberReactionSheets=NumberReactionSheets+1
        ii=ii+5
        print ("Reaction Sheet opened after defect", ii)

    else:
      ii=ii+1
"
```

First of all, the file and the sheet concerned were taken into consideration, specifying with the necessary commands the type of file (Excel) and the name of the sheet inside it. Then the column indicating date and time of opening of the defects was selected. Since the selected anomaly is repetitive, the software was then asked to calculate all the pairs of differences between the consecutive anomalies and to calculate if there were three of them in two hours or five of them in eight hours. Obviously, the dates and times of the shift have also been considered since two anomalies, for example one detected at the last minute of work on the day *y* and the other at the first minute of the day $y+1$ must be considered consecutive and critical. The "elif" command is nothing more than an "if" command with the possibility of inserting more than one "else" condition: it is necessary to specify all the "if" for each of the following "else" to clarify in which specific cases must be considered the commands contained in the various "else".

The output is shown in **Figure 28**, which indicates that 7 Upstream Checks were opened with the term "Reaction Sheet after defect x", and **Figure 29**. Assigning an integer to each defect in chronological order, “x” indicates the number of anomaly that caused the Upstream Check.

```
runfile('D:/users/Desktop/Master_Thesis/Attachment
4 - Defects row data from Trim.py',

Reaction Sheet opened after defect 3
Reaction Sheet opened after defect 6
Reaction Sheet opened after defect 9
Reaction Sheet opened after defect 12
Reaction Sheet opened after defect 17
Reaction Sheet opened after defect 20
Reaction Sheet opened after defect 27
```

Figure 28: Anaconda Python machine learning output.

If the reader observes Attachment 4, the result is correct because the system generates a Reaction Process every 3 anomalies for the first 12 defects, because these are very close and then included in two hours. The system does not generate Reaction Sheets until the seventeenth anomaly because, between defect 13 and defect 18, there are not three cases in two hours or five cases in eight hours.

Name	Type	Size	Value
CriticalTesis	str	1	0000013800000
EightHours	int	1	28800
ListTesisCodesDifferent	object	(30,)	ndarray object of numpy module
NumberReactionSheets	int	1	7
TwoHours	int	1	7200
datasetcritical	DataFrame	(30, 33)	Column names: CIS, MODEL, TESIS, UTE, TEAM, TESISPK, DT_UTE_TRANSIT, Q ...
datatime2	datetime	1	datetime.datetime(2017, 10, 26, 7, 12, 12)
date_time_closing	Series	(30,)	Series object of pandas.core.series module
date_time_opening	Series	(30,)	Series object of pandas.core.series module
datetime1	datetime	1	datetime.datetime(2017, 10, 26, 7, 6, 45)
datetime3	datetime	1	datetime.datetime(2017, 10, 26, 7, 22, 55)
datetime4	datetime	1	datetime.datetime(2017, 10, 26, 7, 56, 7)
datetime5	datetime	1	datetime.datetime(2017, 10, 26, 8, 59, 44)
df1	DataFrame	(315, 33)	Column names: CIS, MODEL, TESIS, UTE, TEAM, TESISPK, DT_UTE_TRANSIT, Q ...
ii	int	1	27
listTesis	Series	(315,)	Series object of pandas.core.series module

Figure 29: Anaconda Python machine learning detailed output with variables results.

Before proceeding with cost analysis, it is necessary to specify that the benefits of this innovation fall into the category of "soft savings"; it is also important to point out that the main stakeholder with which the analysis was conducted is the ICT (Information and Communication Technology) office. As detailed in **Figure 30**, the simulation thus revealed that the proposed digitization will lead to a reduction of about a third of Team Leader's reaction time in this activity, which can thus be used in other ways. As we will see in the next chapter, the survey focused on Supervisors interviews revealed the need to allow the Team Leader to dedicate more time to analyze the defects root cause and to identify an effective provisional countermeasure that could become more likely definitive.

IoT Sensors Notes

	Impact		
Benefit	€ 34.5 [€/1000]	Notes on Benefits	Economic and financial impact - To be evaluated
Platform Cost	€ 1.725 [€/1000] 5% benefit	Notes on Costs	56000 € + 6000 €/plant for roll-out, installation and support
App development cost	€ 25 [€/000] 20 x App		
Other Costs	€ 0 [€/000] (sensors...)		
Perimeter of Costs	Mirafiori	Notes on Perimeter	Technical and managerial impact - To be evaluted
B/C Ratio	1.29092609915809		

Figure 30: detailed and accurate results of the costs and economic benefits; as can be noted, the cost benefit ratio (or B / C ratio) is defined, as the low app cost development.

First of all, it is important to state that this thesis was written before the project was implemented in the factories, therefore it was not possible to calculate the benefits in terms of time after the implementation of this innovative improvement to the Upstream Check. Furthermore, it must be cleared in mind that quantifying in economic terms an undefined and not calculated time saving is extremely complicated. The only way to carry out a first draft cost analysis is to quantify the benefit as being able to save 10.5% (data calculated in Table 5) of the Team Leader's time to resolve the anomaly per shift. This calculation must be performed on a total of about 80 defective cars per shift in a "Premium" plant and this guarantees a net saving of € 345,000 / year assuming 250 working days per year. Finally, the development costs of the App indicated in Figure 29 were defined with a consultation provided by two ICT Specialists and with a subsequent integration through secondary research on the Internet regarding the development of the App to support informative and digital projects in the automotive industry.

Finally, it is possible to carry out an analysis of the costs that would be recorded in the future if the project was successful and expanded to other plants. As who reads can see in **Figure 31**, three cases of expansion were outlined: the worst one, the expected one and the best one. In the worst case the author expects the project to be at least extended over the years to 12.3% of FCA plants, so to the main European factories which contains at least one of five main Units (Stamping, Mechanics, Body, Paint, Assembly Shops) therefore 20 out of 162. In the expected case, it was assumed that the project will be implemented in 37% of FCA plants (60 in total), so in the ones suitable for the production of vehicles belonging to the luxury sector of the market. In the best case, the automation functionality of the Upstream Check could even be extended to all FCA plants (number approximate to 160).

	Best	Expected	Worst
Year 1	10	5	1
Year 2	25	15	5
Year 3	80	40	10
Year 4	160	60	20

Figure 31: number of involved plants detail per every year from 2018 to 2021.

Starting from € 56,000 of fixed cost, it is then necessary to add the € 6,000 variable cost for each plant involved (see **Figure 32**). The best scenario is clearly characterized by higher costs as this implies a greater number of plants involved. The considerable uncertainty due to the youthfulness of the project explains the significant span (red symbol) in the fourth year between the best case and the worst case.

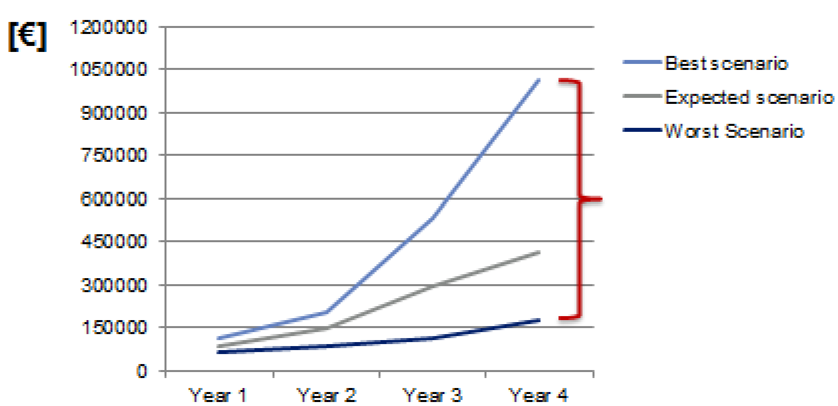


Figure 32: total implementation project cost in the first 4 years.

4. Managerial impact investigation: research questions

4.1. The WCM managerial revolution in the line Quality Control system

Before the managerial discussion that implies this project, as well as many other digital innovations, some historical references should be made to contextualize the FCA Group from an organizational point of view. However, this introduction will be extremely general and will only embrace the essential aspects of the discussion of this paragraph: Chapter 6 will further deepen the history of the organization of "Premium" automotive plants, their current status and the possible future scenarios. In order to make the text comprehension clear and immediate, it is suggested to the reader to briefly review and examine Figure 2 and the left branch of Figure 3, while the more complete structure will be explained later. The great organizational revolution of FCA took place at the launch of the Fiat Panda in 2011 at the Italian plant of Pomigliano[19]: it was planned to rearrange the structure of the plant. The old organization implicated that the so-called "Capo Ute" (then Supervisor) managed between 60 and 80 workers, so he was not able to follow the team by managing in an effective way communication and improving activities such as Kaizen[20]. There was also insufficient support from general staff[21] and the opportunity to talk to people inside the factory was limited. At the time, in the labor intensive areas, there was already a kind of unofficial Team Leader figure, approximately 1 per 15 operators. However, this role included a very high percentage of time devoted to working on the line. The other important issue was that Domain teams could not control quality issues. Given this starting situation, a new organization was conceived: creating a new figure (the Team Leader) with a ratio of 1:6 with the operators, born from benchmarking activities[22]; the official task of Team Leader was rewritten to minimize the work of substitution caused by the absenteeism of the operators and the pursuit of problems or defects, which would then be realized in a first raw form of Upstream Check. It was also organizationally changed the Supervisor's figure; below there are some examples of

[19] The Alfa Romeo plant in Pomigliano d'Arco, commonly known as the Alfasud of Pomigliano and renamed in 2008 in the "Giambattista Vico" plant in memory of the Neapolitan philosopher, is a factory located in the north-eastern area of the metropolitan city of Naples.

[20] Kaizen (改善) is the composition of two Japanese terms, KAI (Change, Improvement) and ZEN (Good, Better), and literally means better change, continuous improvement. A Kaizen should be Advanced, Major, Standard or Quick depending on the time needed, the firm functions engaged and the economical amount of benefits.

[21] The plant staff consists in the total number of employment offices supporting on activities on line (Human Resources, Quality, Engineering, Supply Chain).

[22] Especially with Toyota and Honda companies.

operational activities that he first performed poorly and are now carried out on the line by Team Leader:

- Pick up operators' proposals for improvement.
- Open Quick Kaizen for improvements in his area.
- Interrogate Plant Quality in case of anomalies related to that pillar.

These activities, if done on the field, are extremely effective. Another central theme behind the WCM revolution resides in talking to people who work on the line, in listening to them, in accomplishing what they would like or suggest. Particularly, in a labor intensive area like the Assembly Shop, the human relationship is preeminent. The Supervisor now manages larger areas, but some "field activities" are now carried out by the Team Leader in its place. The revolution lies in the creation of a team of 1 Team Leader and 6 operators: that group is a central entity with which the staff entities has to interact. Thus, it started from this concept (illustrated in **Figure 33**) the fundamental nucleus with which all Manufacturing employees should communicate.

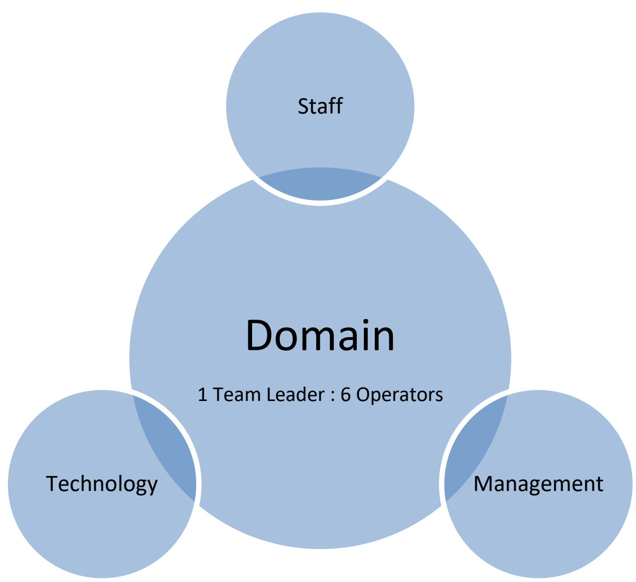


Figure 33: an illustration that highlights the centrality of the team consisting of 1 Team Leader and 6 operators in the WCM ideology, detailing the main offices and roles required to interfere with it.

The first major mission was to raise awareness among staff members in helping Team Leader: in this sense, providing Team Leader with a cell phone to call staff for each issue was an epochal change. Another important aspect lies in the location of the offices in the plant close to the lines: this operation was aimed at establishing a sort of forced contact between supporting offices and the line employees. In general, the small, seemingly insignificant, but incisive steps in mentality change were to:

- give the uniform to every employee within the factory;
- place canteens and relaxation areas common to workers, employed in offices and managers;
- build the offices themselves inside the plant and no longer in far-off buildings.

These operations go exactly in the direction of making the small team on the line more and more central and subsidizing the system to interact with the line as much as possible. Consequently, the WCM managerial pillars were unknowingly applied (for the list see Chapter 1.1) and they were going to be defined precisely in those years. The **Motivation of Operator** (whose five criteria are listed in the **Figure 34**), very focused on the management of teamwork, moves the line control system in that direction. The empowerment of the operator naturally led to the search for more schooled and trained people for that role.

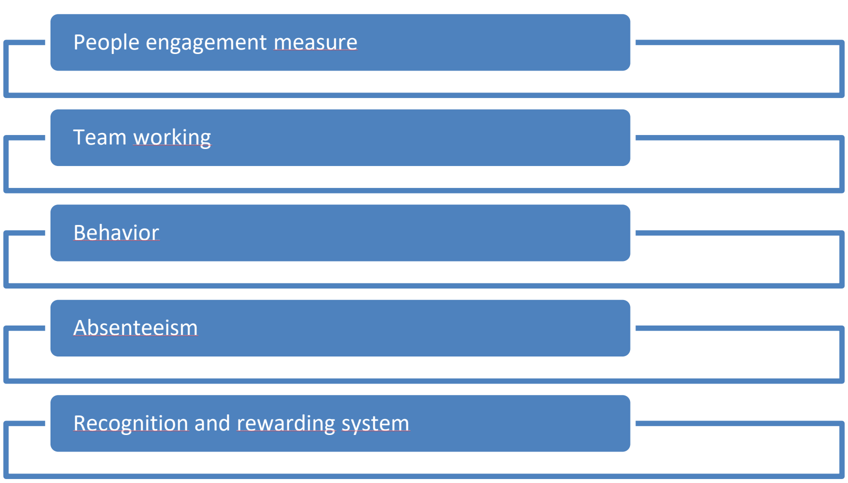


Figure 34: Motivation of Operator managerial pillar five criteria.

After this change the Team Leader has even begun to play and outline the ideal work day and the way in which he performs the activities, so he has become protagonists of his work: all roles have changed, starting with Pomigliano's reference system, which has basically played the role of a pilot model from which, gathered the first results, the new organizational structure was first distributed to EMEA and immediately afterwards in the other regions, clearly with different implementation speeds.

The **Management commitment** pillar focuses on the system of meetings and on WCM training and skills of plant people; it includes a plan to make Plant Managers, Shift Managers and Supervisors (review Figure 3) become auditors. The five main criteria are:

1. Alignment of the organization
2. Understanding of problems
3. Leadership at all levels
4. Meetings and auditing
5. Coordination between pillars

The most important in our analysis is the first one, which is evaluated (as all the other criteria) assigning a level between the five shown and explained in **Figure 35**.

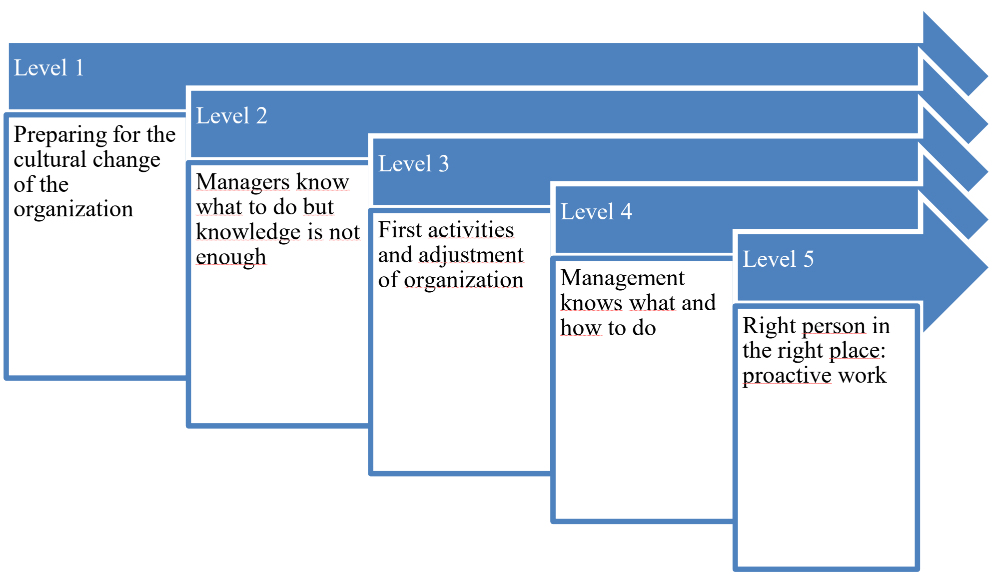


Figure 35: the five levels application of the "Alignment of organization" criteria of the "Management of commitment" managerial pillar.

As already said, this application did not happen consciously; this has been possible because managerial pillars are more flexible, do not require a systematic approach as many of the technical ones.

Finally, **Clarity of Objectives** (whose criteria are shown in the **Figure 36**) requires to set, measure and finally deploy goals to the last level: at the Team Leader grade the targets are visible on the Domain totem, managed and perpetually monitored. There is therefore a link between top management objectives and top-level scopes. Equally important is the involvement of some "Blue collars" in the form of Team Leader in designing their own workstation.

Figure 36: the five theoretical criteria of Clarity of Objectives (managerial pillar).

Project Portfolio Management (PPM) approach has therefore shifted from top-down, where projects were far from the needs of individual business operations and closer to the "big decisions", to bottom-up, where projects are close to the needs of the individual line operations[23]. Finally, the plants started to work with the concept of Workplace Integration (WPI) for launches and later extended to the concept of WPI on continuous improvement, hence improvements during the production: these are possible improvements that the operator notes while he is working and that could not be noticed before starting to produce.

[23] From the course of the Polytechnic of Turin *Management of Innovation and Product Development* it is well known that a bottom-up PPM approach involves the greatest difficulty in implementing plant-level strategies, giving priority to small-scale strategies at Ute level.

Organizational change has generated improvements in terms of plant efficiency, vehicles quality, employees' involvement, operators suggestions, number of Kaizen performed. In this respect, two new indicators could be introduced:

$$Averaged\ number\ of\ suggestions = \frac{Total\ number\ of\ suggestions\ in\ a\ month}{Number\ of\ active\ operators}$$

$$Number\ of\ Quick\ Kaizen\ opened = \frac{Number\ of\ Quick\ Kaizen\ closed\ in\ a\ month}{Number\ of\ active\ operators}$$

The first indicates how many suggestions are proposed on average by an individual operator each month, and is obviously only calculated for Assembly Shop Unit. The second is an indicator that monitors the number of Kaizen opened and closed with improvement projects within a month from each domain.

From this organizational change, arises the need to include documents close to the line that would help Team Leader to manage the quality of his Domain: in particular, QA Matrix and QA Network were created (see Chapter 2 for the explanation). Similar initiatives with different declinations (especially in capital intensive areas) have been extended to other sectors of FCA. However, the concept has passed at group level: the Team Leader's perception of centrality has been extended; a further demonstration is the attention to data such as FTQ In and FTQ Out, First Time Quality Inbound and Outbound in each Domain, that is, the number of cars under the minimum defects tolerance at the first input entered and exited Domain[24]. These indicators have been monitored since those years to assess the performance of the "core team": they are currently being recorded at all "Premium" plants in the Quality Gates.

[24] So, the Deliberation efficiency formula is:

$$FTQ = \frac{FTQ\ Out - FTQ\ In}{FTQ\ In}$$

4.2. Gaps in literature

As explained in the first paragraph of Chapter 2, the Upstream Check is a tool centralized on the figure of the Team Leader: he is the central “actor” who holds authority and dominance on the quality control system of the Assembly Shop and is the most influential player in the “managerial revolution”, if so can be defined, that the trend introduced by the World Class Manufacturing has resulted. When FCA started to apply its first automation projects in 1989, it was obviously expected that these innovations would increase the productivity and quality of the plants. In terms of quality there were recorded actual benefits, but at the beginning productivity was growing steadily. To cite an example, Cassino[25] plant productivity between 1990 and 1991 was about 1200 vehicles per day against the estimated 1600. At that time, demand was also very high, so huge losses were recorded. The reasons for such production difficulties are detectable in too complex or very high technology, which was difficult to integrate into a discrete flow process characterized by both capital intensive and human intensive Units. In general, there are two major categories of production processes: in the pure capital intensive one there are no operators; the Team Leader does not need to exist, since it is a figure that necessitates to handle a group of people by definition. Thus, is necessary a "process manager" that is known in the "Premium" factories as "conductor". The Assembly Shop is predominantly labor intensive, therefore it is indispensable to handle the people within it, and for that purpose it has been conceived the role of Team Leader. The other significant variable is that a firm can be characterized by a continuous flow production process (such as that of oil refinery) and discrete or "piece by piece" production. Some intermediate solutions between the two extremes are made up of small lots and large lots. Continuous flow production is much more automated, it is a process that requires less men; is automated by definition, because it is necessary to work on process variables but not on the product, contrary to discrete production. Conversely, manual activities are the main variables of the Assembly Shop. The advantages of ensuring automatic controls in a manual area consist mainly of maintaining, using and sharing information. Compared to the continuous process, in fact, there is no possibilities to know what happened before to the car. Contrariwise, in a refinery, the automatic operations of every drop of oil are perfectly known.

[25] The Alfa Romeo plant in Cassino is a factory of the FCA Group located in the municipality of Piedimonte San Germano, three kilometers from Cassino, in the province of Frosinone. The plant was built in 1972, enlarging over the years to reach the current two million square meters, of which 400 thousand covered.

Starting from this brief historical introduction, the WCM methodology intends to introduce within the plants a new culture according to which the quality is made in the station and is responsibility of the Team Leader. The managerial switch consists in the concept that the factory led by Team Leaders could go ahead even without a managerial organizational chart overlying. In this context, the digital is a tool to support the Team Leader in order to increase its effectiveness and to provide and always ensure the speed of solving problems. From this assumption emerges the need for a digital Upstream Check inside the Assembly Shop Unit. In this regard, the discussion could go into speeches concerning the diversity of culture between Italy, or more generally the European West, and Japan where most of the methodologies subsequently confluent to WCM were born. The rewarding system, in particular the incentive procedure, is often heavily influenced by local culture: for example, who criticizes the method used in a non-belonging Domain is welcomed in the East, much less in the European West[26]. The influence of the local environment on the organizational development of capabilities has often been discussed in the literature of subjects as strategy and organizational design[27]: many academicians have empirically supported and proven over the years that the local environment greatly influences on capabilities development. Often, within an organization, resources and skills are indeed the result of culture, social complexity and legal ambiance; other factors influencing are the local demand conditions, the structure and the rivalry grade in the reference market, the support industries stability and the geographic location of the structures and plants. However, aside from these essays on cultural diversity and on environment influence and how they both affect the way in which companies are managed, there are very few treatises in literature[28] concerning the evolution of the Integrated Factory in recent years; if it narrows the scope to the effects that digitization and Manufacturing 4.0 are having on organizational and managerial dynamics in the automotive industry, references to literature are even fewer. Before the WCM, existing studies had already underlined the Team Leaders central role in the automotive production systems (Benders and Van Hootegem, 1999; Delbridge et al., 2000). However, these studies have also noted that there are not enough studies on Team Leaders behaviors. For example, Delbridge et al. (2000) states "*the role of the Team Leader within teams is typically neglected or treated as*

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[26] See learning library, "Dealing cultural diversity project management", from Project Management Institute official site (www.pmi.org).
[27] From Grant, R. "Contemporary Strategic analysis", John Wiley.
[28] One is "*Le persone e la fabbrica, Una ricerca sugli operai fca-cnhi*", Luigi Campagna, Alberto Cipriani, Luisella Erlicher, Paolo Neirotti, Luciano Pero.

unproblematic in debates over team effectiveness or organizational performance". To go into such a delicate and ambitious discourse, first of all, some field researches are needed. The next paragraph will describe what the thesis intends to investigate and expects to discover with the research, in addition to explain the hypothesis and method by which the author has proceeded with his analysis.

4.3. Hypothesis and attitude evaluation method

In addition to the analysis of the technical and financial impact of the project, this thesis attempts also to investigate the organizational benefits and the eventual spillovers[29] that this innovation should originate; first of all, digital projects, such as the one proposed, also have an obvious impact on factory routines and can therefore change the behaviors and how to do management within the organization. Recalling the structure presented earlier in Figure 2 and Figure 3, the author has decided to interview the Team Leaders and the Supervisors of a reference "Premium" plant. The reasons that have supported this choice are the following:

1. These two are the roles on which a managerial discussion can be based, since they both manage teams of people (while the operators do not)
2. They are the two key roles between "blue collars" (operators and Team Leaders) and "white collars" (Supervisors and top management), hence between the traditional figure of the worker and the manager
3. They are the two management roles closest to the production line and therefore closest to the reality of production and manufacturing life.

The two interviews with the Team Leaders and the Supervisors of Assembly Shop were designed on 6 and 7 open questions respectively. The interviews were conducted on the Supervisor's work tables or desks located at the end of their reference Ute. About the sample, it is known by the "Statistics" and "Quality Engineering" courses of the Polytechnic of Turin that the more the population is narrow, the greater the percentage of population included in the sample on which to base the research. At the Mirafiori factory (chosen as a reference) worked in 2017 on two shifts

[29] To deepen the meaning of this term, have a look to Cantamessa M. Rafele C. Cobos E., "*Il project management. Un approccio sistemico alla gestione dei progetti*", 2007.

60 Team Leader (two for each of the 30 Domains) and 12 Supervisors. Regarding the Supervisors, there was a record of the availability of 10 of them to participate in the survey, so the high percentage of population in the sample (83.33%) guarantees the significance of the interview. For Team Leaders, as they are much more committed on the line and so being unable to interview the entire population, it has been chosen to interview 30 of them (on 60) but all from different Domains: assuming that the two Team Leaders of a same Domain do not reason differently, the research carried out on this population also becomes highly significant. All data from the 30 Team Leaders and the 10 Supervisors interviews have been collected and processed. After the end of the research, a language-matching work was also carried out to make two identical open answers similar to each other, if expressing the same concept. The research lasted two weeks and involved the Mirafiori and Agap plants. The two interviews are shown in **Attachment 6** and have been designed for exploratory purposes; indeed, the questions are not statistically treatable and the answers open (see **Figure 37**). It is assumed that the subpopulation of these two plants of Mirafiori and Agap is representative of the entire population of FCA "Premium" factories. The reliability of the results obtainable with a distorted sampling is justified by the assumption that individuals within these two plants do not reason differently from colleagues of the same level from other "Premium" automotive realities.

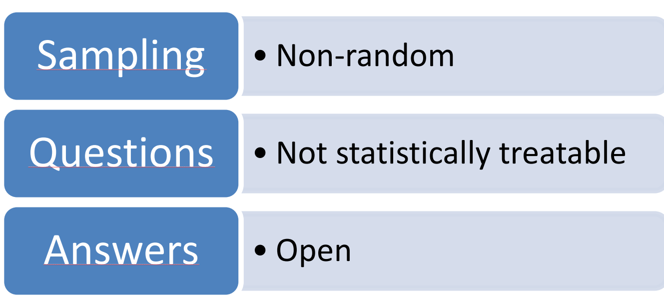

Figure 37: interviews characteristics detail.

As can be seen, both interviews are divided into two parts: in the first, some questions are asked about the current Upstream Check paper system; the second part of the questions is instead postulated after the explanation of the digital innovation that the Reaction Process might undergo. Some questions are identical for both the interviews: the first question is the same and it is intended to understand if the problem exists and what are the main needs of those who work in the plant about the reaction system; in the following questions, interviewees are asked differently about what benefits the organization could get through this digital project: in particular the author expects to record the increase in communication efficiency and in time saving. As already explained this survey was designed to initially investigate the project acceptance within the plant, so it was decided to give open questions. However, the author structured two questions, one in the Team Leaders interview and one in the Supervisors one, so that they both could provide some statistically treatable data: the two mentioned questions are the number 6 for the Team Leaders and the number 2 for Supervisors. The first case concerns the last question in which it was asked to indicate which tool Team Leaders prefer to use to carry out the control. The second case concerns the second Supervisors question in which they are requested to order three factors respect to the importance they give to them in managing their teams. It is therefore a rank-order scale measurement technique[30] that provides for Supervisors to be able to establish a preference order among the team management factors. This is a scale conceptually simple where Supervisors implicitly compares all pairs of alternatives to comparison. They are therefore forced to discriminate between similar and potentially related variables. The possible interdependencies between communication, control and collaboration will be explained in the commentary of the results (Chapter 5 and 6); it is now hypothesized that the relations between classes of non-equivalence and strong ordering are valid. The question was asked in the form of an interview and not a questionnaire to remedy the great disadvantage of rank-order scales: in fact, in this case, the measurement of an emotional variable is imposed and discrimination is forced on the three factors, without considering the level of importance. The

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[30] The main reference in the techniques of evaluation of what is precisely called "attitude" or “deportment” is the Chapter 4 of “*Dai prodotti ai servizi, Le nuove frontiere per la misura della qualità*”, Franceschini F., UTET. The attitude is defined as a perceptive mental process of individuals, based on knowledge, evaluative and action-oriented, which takes place with respect to an object or a phenomenon. The main deportment components are:

- The cognitive one
- The emotional one
- The intentional one

The characteristic or attribute, to which is addressed the measurement of the attitude, is called “psychological object”. The first step towards the deportment measurement is the collection of individuals evaluations. The attitude measurement scales can be classified into two major categories: Single-Item Scales and Multi-Item Scales. The first use a single scale, as the rank-order scale. In this type of scale, if the classes are: x_a , x_b , x_c , $\dots$, x_i so the relationships between classes are: $x_a \neq x_b \neq x_c \neq \dots \neq x_i$ and $x_a > x_b > x_c > \dots > x_i$. The main advantages are the implied comparison between all pairs of alternatives by the evaluator and the fact that the interviewee is forced to discriminate between objects as a “buying decision”. The disadvantages are that there is no level of satisfaction evaluation (the solution adopted in this thesis consists in asking at the beginning if the attitude is negative or positive towards the considered objects) and that the number of products that a person is able and willing to order is limited.

first element could have the meaning of least not useful factor or most useful factor. It is very difficult to think that a Supervisor of an automotive factory could actually find not useful the team communication, the team control and the team collaboration at the same time, however, to be rigorous on the method, it cannot be ruled out anything in the hypothesis phase. The fact that the question has been designed in an open form is precisely the purpose of confirming that the Supervisor has a positive attitude towards these three factors in the management of the team.

4.4. Typifying the possible organizational benefits

To carry out the research in the plant, it is first necessary to define the results that are expected to be obtained. The thesis has started with the exposure of the digital project whose technical aspects have already been widely studied and, applying it with the WCM methodology, now intends to investigate the impacts at management and organization level; by slightly expanding the boundaries of the discussion, it will be possible to model the organizational benefits that all the digitalization concept can provide the "Premium" facilities in the Assembly Shop quality control system. Since this is a project that aims to eliminate paperwork activities by making them digital, it is indispensable that the implementation of the innovative system will save time for the Team Leaders. This time saved is obviously translated in monetary terms, and a preliminary analysis of the cost benefit ratio (B/C ratio) in Paragraph 3.3 has been carried out in this regard. However, digital projects and, more generally, Manufacturing 4.0, are aimed at generating wider benefits by changing the way in which management works inside the plants. As listed in **Figure 38**, the introduction of technologies first ensures greater collection, maintenance, correctness and availability of data and provides tools that make communication more effective and accurate. In this paragraph, the author merely suggests that these benefits indirectly result in better coordination and hence greater alignment between the various hierarchical branches in automotive companies' organizations. It is also assumed that changes in the rewarding system may occur, in particular in the incentive procedure: the fact that a tedious and manual activity is made now digital and automatic, of course, changes the timing and effort of Team Leader in thus, opening up to the Supervisor the possibility of assigning members of their teams to new activities that will then be evaluated and monitored differently.

Question 2 of the interview to the Supervisor aims to better define the differences between three very similar factors and to study the differences. *A priori* the student cannot understand if there is any interdependence between team collaboration and team communication. Is a Domain team (formed by one Team Leader and six operators) that collaborates well inside itself also good at communicating with other teams? The fact that Team Leaders of a Ute communicate well between them helps Supervisors in managing the Domains under his control? These two questions are just two of the many that the reader could argue for by dealing with a potentially very wide topic, whom boundaries should be well defined. At present, the author only points out to the reader that **collaboration within a team** is manifested by 6 operators and 1 Team Leader in the Domain team and by 5 Team Leaders and 1 Supervisor in a Ute team, but however, is a factor strongly influenced by the figure of the operator and, to a lesser extent, by the role of the Team Leader. **Communication between teams** is an exclusive competence of Team Leaders, supervised by the top management. Finally, **team control** concerns the Supervisors on all Domains and, to a lesser extent, the Team Leader on his Domain. Therefore, Team Leader is the central figure that can affect all the three factors, while the Supervisor manages two of them and the operator mainly affects just the collaboration.

Improvement or changes in	Collaboration within the team
	Coordination between the process stakeholders
	Team supervision and control
	Easiness, accuracy and timeliness of communication
	Clarity of information
	Alignment between the different team members
	Integration of works with new role emerging
	Rewarding system (incentives)

Figure 38: the main organizational benefits that the thesis research expects to demonstrate about the digital automation projects.

For these last reasons, it was then decided to integrate the interviews of the Team Leaders with the opinion of some line operators and in particular the Deliberations operators[31], who manage a little bit more the Upstream Check problems than the other operators in the Assembly Shop line: this decision is justified by the fact that, in order to investigate the alignment of the organization[32] and about the possible benefits in terms of accuracy and timeliness of communication, it is not sufficient to engage in researching only two hierarchical levels (Supervisor and Team Leader) and it is essential to involve the lowest organizational level of the plant that can contribute with its own work experience on the line. Chapter 6, with reference to existing literature, will examine more delicate topics such as the discussion of the integration of some roles within the organization of production automotive factories.

Finally, the discussion of the results of the interviews of Chapter 5 requires the specification of the different types of communication present in the plant:

- ✓ Physical or "hot" communication
- ✓ Mobile phone communication
- ✓ Digital or computerized communication

The first occurs when two or more company employees meet physically in a place to exchange opinions or information. This type of communication requires the physical movement of people who in some factories can take a long time. To give an example, the Mirafiori Assembly Shop area (in which two cars are produced on two different lines, one mass market and one Maserati of luxury market) takes up much more space than that of other plants that contain only one production line. It also takes the form of daily meetings of update between the Assembly Shop Team Leaders: this meeting is called Daily Improvement Meeting[33] (DIM) and takes place with staff entities such as Plant Quality. Telephone communication guarantees, with respect to computerized communication, a more immediate and easy verbal clarification, but does not allow to communicate if one of the stakeholders is occupied. Digital communication, on the

[31] Remember that the Deliberations (also called Quality Gates) are listed in Chapter 1.2.
[32] One of the "Management of commitment" (managerial pillar) criteria analyzed in Paragraph 4.1.
[33] This type of meeting is part of the hybrid approach outlined by the Project Management literature: this approach is halfway between "Waterfall" and "Agile" and is aimed at prioritizing the essential features, increasing the engagement of the Team Leaders and pushing their iterative approach; it is very similar to the Daily Scrum Meeting proposed by the "Agile Project Management" approach.

other hand, in very general terms, guarantees that the email, the notification or the signal sent will be received by the recipient when he will use the reference device.

5. Discussion of the acceptance in the "Premium" plants

The Attachment 6 contains two sheets in Word format containing respectively the interviews given to Team Leaders and Supervisors. In the first paragraph of this chapter, the discussion will refer to the first survey, while instead the second will refer to the second one. In general, the interview with the Team Leaders was more focused on the technical part of the project and therefore on the use of the tools, especially the mobile terminal, on the line during the Upstream Checks; the analysis conducted on the Supervisors focuses on more managerial and team control aspects. In this chapter, some of the phrases expressed literally by the respondents during the research will be written in italic handwriting.

5.1. Team Leaders interviews

After conducting the interviews, it is possible to say that the sample of interviewees is statistically significant for Supervisor and Team Leader (including Team Leader of Deliberation) compared to the Mirafiori plant population. It is true that also the plant of Agap[34] was involved, but it could be declared that the survey has taken place just in a single plant, including for half a day Agap only to confirm that the employees between the various "Premium" plants do not reason in a totally different way: this assumption is intended to justify the non-random and distorted sampling to study the Team Leaders and Supervisors attitude[35] in the "Premium" plants. Before starting to deal with the results of the interviews completed at the Mirafiori and Agap sites, it is necessary to state that 30% of the Team Leader interviews were conducted with the concurrent presence of operators, so the responses have been supplemented with the opinion of some of them who have attended the interviews: their participation cannot however be

[34] The Grugliasco plant is a car factory located in the municipality of Grugliasco in the province of Turin; built in 1959 by Bertone, it has been owned by the FCA Group since 2009.
[35] The attitude is defined as a perceptive mental process of individuals, based on knowledge, evaluative and action-oriented, which takes place with respect to an object or a phenomenon.

considered statistically significant, but just useful in order to enrich the analysis of managerial impacts. This research phase can in any case be considered concluded because:

- The percentages of interviewees are statistically significant[36]
- All the Ute of the Assembly Shop were involved in the investigation
- None of the 40 interviews that will be submitted in the thesis (30 Team Leaders + 10 Supervisors) are incomplete: they had all the expected duration
- The Team Leaders sampling also includes those of all Assembly Deliberations:
    - Trim 3 or Selling,
    - Chassis 1 or High Mechanics
    - Chassis 3 o Low Mechanics
    - Final or Assembly Deliberation
    - Doors, although it is a non-institutional Deliberation proposed in Mirafiori and in few other plants

Firstly, two questions were asked to the Team Leader about the current situation (As Is), especially what is currently being considered about the reaction system and if there are communication problems between the actors of the Upstream Check. The first obvious result that emerges is that the problem exists: the proposed analysis of the managerial, technical and organizational impacts of the project is justified by the fact that 73.3% of Team Leaders (22 out of 30 respondents) firmly state that the Upstream Check they perform, characterized by Reaction Sheet and paperbacks, could be greatly improved. The intolerance towards this system is reflected in some of the adjectives or descriptions associated with it by Team Leaders, as "*obsolete, complicated from a procedural point of view and too expensive in temporal terms*". It can therefore be said in extremely general and still relatively cautious terms that, consequently, digital innovation consisting of the automation of the process is well received in the factory. However, the results of the interviews show that only 35% of Team Leaders argue that "*there are communication problems in the management of reaction systems such as Upstream Check*"; anyhow, as it will be discussed later, this result suffers Team Leaders scarcity of perceiving the

[36] See "Franceschini F., Advanced Quality Function Deployment, St. Lucie Press/CRC Press LLC, Boca Raton, FL, 2002" and "Grazia Vicario, Raffaello Levi (2014), *Metodi statistici per la sperimentazione*, Casa Editrice Esculapio, Bologna".

problem as well as to think that there may be a more effective and less expensive alternative system in terms of time. In the survey of Supervisors, not forgetting what was said about the evolution of roles in Paragraph 4.1, the current difference between the two roles will emerge markedly: the Supervisor, by managing a set of Domains and therefore a group of Team Leaders, has a more relevant experience with the digital tools and a better perception of the needs of the line and can evaluate in a more global way the management system in terms of efficiency of communication and collaboration within the team and between the teams.

One factor which must not be overlooked in the application of digital systems, not only in this thesis but also in more general terms, lies in the fact that automated systems often tend to eliminate human contact, in particular the already mentioned mobile phone communication which consists in telephone calls between Team Leaders who operate in the Assembly Shop line. Analyzing the answers gathered to the second question, 55.8% of Team Leaders notes that "*often, in order to fully understand the anomaly found at the origin of an Upstream Check, it is also useful, sometimes indispensable, to have a telephone verbal consultation*". The total elimination of such contact would therefore not be desirable to maximize the acceptance of innovation within the factory. It should therefore be clarified that the Upstream Check automation project does not have the purpose of eliminating the "clarifier" telephone contacts, but merely reducing them or at least reducing the need for them. Summing up what has been declared and stated during the first two questions of the research in the plant, it has been recorded the Team Leaders "ex ante" need to implement a new system that:

- provides the information that the Reaction Sheet is opened in a timely manner;
- enables faster control "*in order to leave the Domain as short as possible*";
- do not delete the telephone comparison system;
- enables "*a faster closure of the Reaction Sheet than the current paper procedure*" that forces the Team Leader to transcribe everything from paper to system;
- involves more directly in the process the so-called Technological Gatekeepers, who have a good ground in certain issues and to which everyone turns to solve specific technical problems;
- allocates immediately the anomaly to the correct Domain;

Lastly, the discomfort inherent the difficulty in eliminating human errors has been expressed. In this regard, the second phase of step 4 of the Workplace Organization technical pillar comes into play: the goal of this phase is to map operators, assess whether it is the case of having advanced level operators, to understand whether there is a gap in knowledge or less. Then it is necessary to form them and verify their learning and confirm their "membership class". In order to better analyze the human error and to understand whether it is a Man or Method problem, there are two tools, one consequence of the other. The first is the Twttp (The way to teach people): it simply checks if the operator has the skills needed to perform a particular operation. It comes in the form of an interview with 4 questions. If Twttp does not find any shortage or gaps of training, next step is to proceed with the Herca (Human error root cause analysis), which is made up of a series of questions and serves to identify any other possible causes of human error that are not related to the lack of competence of the operator: then continue with the formulation of solutions. It is in the application of the Herca that Team Leader requires greater support: they declared they would like to "*have more support from the staff or rather receive more training to expand their skills in order to be able to manage all the anomalies of all 4M and 1D autonomously*": this statement will be crucial during the Chapter 6 to discuss the integration of roles within the organizational structure of the automotive plants analyzed. One last "ex ante" need arises in the necessity to work more on prevention than on reaction: in order to satisfy this need, however, it is desirable to enter a broader discussion about the current gap in the main business vision that will be thoroughly analyzed in Chapter 7, when the author will discuss the evidence that many projects are still aimed to improve just the reactive phase in the anomalies resolution.

After explaining in detail the operation of the new digital system that is about to be implemented, it has been asked to the Team Leaders which three top benefits (question 3) this system would bring in their opinion: after this general question, however, it was asked more in detail if the interviewee felt that this innovation could generate benefits in terms of time saving and communication efficiency (question 4); these two are in fact the two benefits the author had said to expect in Paragraph 4.3: this question referred to all three types of communication because it was not possible to exclude one of them in the hypothesis phase. Fortunately, all respondents (100% of the sample) already said in question 3 (the first general one) to expect at least one of the two hypothesized benefits. Furthermore, the answers meet all the "ex ante" needs emerged previously, except for the last two: according to the WCM methodology principles, the

Technological Gatekeepers must be the Team Leaders themselves, who, by filling their gaps through a better training[37], must become the real knowledge guarantors of the process, Domain and single operations in them; as far as the correctness of the anomaly assignment to a Domain is concerned, the speech should be extended to the reliability of the informative plant systems as MES, which this paper has only partially dealt with in this chapter, to not overwhelm large and long discourses that this thesis does not propose to deal with. All other needs are satisfied; in general, the main benefits, which are reported by at least 60% of the population involved in the interviews are:

- time saving during the Upstream Check, in communication times, and in compilation of Reaction Sheets: *"this time can of course be employed in a productive way in other activities"*;
- practicality of the tool, so convenience and simplicity of execution of the process with less procedural complexity;
- due to the two above, an increase in the number of anomalies effectively solved and more effective solutions found: these advantages are beneficial to the Plant Quality and are partially induced by the fact that the new system would allow to check immediately, recovering in a faster manner the cars to be repaired;
- easy online management of Reaction Sheets;
- possibility "*to let the systems talk between them, making them communicate easily and effectively*";
- "*if the system really learns from several Upstream Check historical data, an improvement in the allocation of the timing to the correct Domain"* with time savings for Supervisors and Deliberation Team Leaders.

Later, it has been asked to the interviewees (question 5) if they would suggest some improvements to the solution adopted. The answers to this question has embraced a lot of interesting aspects that will be presented later, not just in this paragraph, but even a little further on. Then, since Team Leaders will also be those who will perform the Upstream Check method, it has been wondered (question 6) which ones they would prefer as a mobile terminal to control

[37] In this sense could be useful to apply the **Allocation of high qualified people to model areas** and **Competence of the organization towards improvement** managerial pillars concepts.

by interfacing with MES type systems. As can be seen in the Attachment 5, questions have been posed openly without any suggestions, in order to allow the Team Leader to think in ideal terms. However, according to what has been claimed in the "Hypothesis and attitude evaluation method" paragraph statements, this is the only statistically treatable question in the Team Leaders interview. The answers are listed in the **Table 6**: it is noted that the tools suitable for doing this task are the tablet or mobile phone that are properly connected to the mobile terminal, allowing the Team Leader to instantly communicate to the system the successful control on each potentially defective car.

Table 6: results of question 6 of Team Leaders interview.

Tool→	**Mobile Phone**	**Tablet**			**Bracelet with bluetooth**	**Paper Reaction Sheet**	**Total**
Number	One per TL	One per TL	More than one per Ute	One per Ute	One per TL	One per check	
Team Leaders	13	8	3	4	1	1	30
Total	13	15			1	1	30
Percentage	43,4%	50%			3,3%	3,3%	100%

Note, however, that the average age of the respondents, and therefore of the Mirafiori Team Leaders representative sample, is 48.6 years: the average age of Team Leaders in the "Premium" factories of FCA is 45,9 years. It is therefore evident that the proposed survey is slightly influenced by the average age of the Mirafiori plant, which is a bit more "old" than other factories in southern Italy[38]. So, it is necessary to specify that a research conducted in a plant characterized by a greater number of young and graduate Team Leaders would have led to pretty different results; in particular, it would introduce more innovative proposals such as the bluetooth bracelet that in this research cannot be taken into consideration since expressed by only

[38] These data were collected from the official FCA website dedicated to company employees.

1 Team Leader on 30 (so only by the 3.33% of the chosen sample). This proposal can eventually be included in the answers to question 5, therefore as a proposal for improvement to the solution adopted. Anyway, after the investigation it is suggested that the system should be implemented on the mobile phone; the reasons that encourages who writes to support this statement are essentially three:

- ✓ there is a benefit in terms of cost savings since Team Leaders are all already provided with a mobile phone, while the tablets are only present in 10% of the locations[39];
- ✓ the percentage of responses to the tablet is not significantly higher than that for mobile phones, and more than one of such answers are not consistent with the number of tablets to be used for the Upstream Check activity in each Ute;
- ✓ in open answers, 46,7% of respondents expressed the desire to use "*as few as possible different devices*"; since the mobile phone is indispensable for the reasons previously expressed on the need for verbal communication, it is desirable to implement the new system on that device.

As supposed before, from a managerial point of view, emerges the need to empower the operator in case of Man and Method defect: answering question5, some Team Leaders suggest[40] that the Reaction Process should be carried out by the operator himself who has committed the mistake "*to thoroughly understand the causes, in order to make him stimulated to complete his training where necessary and above all so that it is encouraged not to commit again the error*"; this latter aspect is the first of many ideas that will bring the thesis to deepen, albeit not in detail, the changes in the incentive system that derive from digitization and automation projects.

Ultimately, it must be pointed out that 17% of Team Leaders express some perplexity and some skepticism, as a result of past experience, that the system implemented can effectively improve MES knowledge about the process as a machine learning system[41].

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[39] Essentially in the Domains where the dashboards and the doors of cars are mounted.
[40] Remember: the opinion is supplemented with that of the deliberators.
[41] This aspect to be analyzed would require a lengthy study on non-treatable topics in this thesis, with the involvement of the ICT office and with a further research phase that would be out of context and purpose of this paper.

5.2. Supervisors engagement

At the beginning of the Supervisors survey, before discussing the Upstream Check digitalization project, two questions were asked: first, they were required to express what they think about the current paper reaction system; their answers to the first questions were much longer, detailed and exhaustive than the Team Leaders ones. The expected time was 15 minutes for both Team Leaders and Supervisors: the first ones respected that time, the seconds were often prolonged up to 25 minutes of interview. This evidence demonstrates the hypothesis of the greater engagement and perceptual capacity of Supervisors in innovative and digital matters.

The results of question 1 show that the Supervisors find the system "*as a necessary and indispensable reaction to Quality Control anomalies along the line*", but also believe that "*the current system is obsolete and can be improved by implementing a digital system*"; the present system "*entails considerable loss of time and difficulty in communication, especially when the Sheets are opened by the 'Bollino Verde' and when the Upstream Checks and, as a consequence, the Reaction Sheets, are closed*[42]*"*. According to 40% of the interviewed Supervisors, it is also imperative that "*those who perform the checks know perfectly the process and their Domains, so it would be advisable to improve the formation of the new inexpert Team Leaders*". They also believe that, in identifying the root cause, it is important to have more support from the staff entities. The 20% of respondents (so just 2 Supervisors) feels that "*the current Reaction Process would be very effective if applied in accordance with the rules, but sadly it is not always seriously involved: the problem lies in the attitude and in the fact that people who work in the line do not really believe in all the tools provided by the WCM methodology*". In this regard it is conceivable that within the "Premium" plants there is a lack of implementation of the managerial pillars. The problem of lack of motivation is caused not only by the age of some operators, by the end of career, but also by the history of continuous improvement methods that have always died in a short time[43]. The pillar that should look at this aspect is the **Management of commitment[44]**:

[42] Remember that the two are not the same thing: see Paragraph 3.1.

[43] TPM in Fiat Group lasted about 10 years and it has been applied mainly in the mechanics (engine and transmission production). WCM is a reality that has been stable for 10 years now. However, it is a methodology that requires a very high level of detail: for example, the ability to collect and process data at the workstation level is often required. However, the risk is that systems are not always adequate, that databases are not updated and maintained effectively.

this defines criteria for top management to align the organization in using the methodology. This is clearly a *conditio sine qua non* to make things happen in the plant. In the "understanding of problems" and "leadership" of the Supervisors, instead, lies the great responsibility of middle management. A single Supervisor who does not believe in the methodology has devastating effects on the line, because he negatively affects several Team Leaders teams below him. In fact, these intermediary roles between operators and top management have to involve operators (**Motivation of Operator** pillar). Interviews show how many people are involved and engaged but employ little effort and commitment in problem solving because they are poorly trained on the tools or because they are poorly trained on the WCM methodology they see as extra work. Invoking the speech introduced in Paragraph 1.1 about the Audit system, all the pillars need to grow together. A low level of a given pillar is a "boulder" that weighs across the organization and pushes the entire management down.

Before the explanation of the innovation on the Upstream Check, Supervisors have been also asked what they consider to be more important within their team between the effectiveness of communication, the collaboration within the team, and the team control. The results of the sorting carried out by the 10 interviewed subjects are presented in **Table 7.** Obviously, a higher score indicates a lower importance to the factor.

Table 7: results of question 2 of Supervisors interview; the number indicates the rank position of the given factor, while the Roman numbers indicate the number of Team Leader interviewed in order.

Interviewee \ Factors	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**TOT**
Communication effectiveness	2	1	1	3	1	2	1	2	1	2	**16**
Collaboration within the team	1	2	2	1	2	1	3	1	3	1	**17**
Control over the team	3	3	3	2	3	3	2	3	2	3	**27**

[44] Already introduced in Paragraph 4.1.

The interesting outcome is that Supervisors believe that with effective communication and strong collaboration within the team, the issue of Supervisor control would almost be resolved by itself, or at least would be extremely facilitated. In this result lies the first point of reflection on the integration between the roles of the Team Leader and the Supervisor amply discussed in literature[45]: in order to facilitate the task of supervising the Team Leaders, it is therefore essential the collaboration but, above all, that the communication is timely and effective.

Proceeding with the research results presentation, answers to question 3 indicate that the Supervisors, after knowing the digitalization project, believe that "*the effectiveness of the already mentioned digital communication and time savings are the two main benefits of this innovation: information is immediate and timely, and above all it would be visible to all the Team Leaders of the line, who would then capture the news in real time, reacting immediately; the time savings will be realized by eliminating time spent on the phone to identify and alert the responsible Team Leader*". As mentioned above, it is not taken for granted that the Deliberation Team Leader is able to immediately identify the responsible Domain: the most relevant example concerns the assembly of electrical wiring harnesses that in all plants involves many adjoining and often adjacent Domains and involve operations overlapping between Domains; in this case, it often happens that, when a Reaction Sheet is opened, *"Team Leaders start to free themselves from the responsibility for generating the defect on other Domains, resulting in Upstream Check allocation problems"*. The Team Leader would therefore have more time to use in other activities, and the responses show that one of the activities "*that are currently not being carried out accurately and which is not completed using enough time*" is the creation of a project to find effective countermeasures: with the automation, the Supervisor would allocate Team Leader saved time to focus on activities to solve the problem of identifying anomaly root cause and countermeasure.

In addition to the benefits in terms of timeliness and punctuality of communication (question 3 and 4), 70% of Supervisors believe that this innovation would also improve control over the team precisely because (60% of respondents) "*send notifications and collaborate would be simpler*

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[45] For example, see the article "*Group leaders and teamwork in the over-lean production system*", Nobuyuki Inamizu, Faculty of Business Sciences, University of Tsukuba, Tokyo, Japan, Mitsuhiro Fukuzawa, Faculty of Economics, Seikei University, Tokyo, Japan, Takahiro Fujimoto and Junjiro Shintaku, Graduate School of Economics, The University of Tokyo, Tokyo, Japan, and Nobutaka Suzuki, Graduate School of Medicine, Kyoto University, Kyoto, Japan.

with this digital tool". It should be recalled that the proposed analysis concerns the only reaction system designed to solve the defects found: it would be inappropriate and too brave to claim that this elaboration proposes a solution that can improve the internal digital communication effectiveness of the entire quality control management system.

As already shown, the new digital system would be placed in the context of machine learning tools: after every single Upstream Check is completed, the system always learns better the structure of the process and improves its ability to trace the line and allocate anomalies and responsibility to the right Domains and Team Leaders: Supervisors believe, in this regard, that "*it is imperative to create an orderly data collection containing a history for each event or anomaly, so that there is always a reference to be consulted before dealing with a problem*" (question 5). On this topic the reader is required to wait for the discussion about the machine learning implementation steps that will be illustrated in the last chapter of the thesis. From a functional point of view, the system should also be able to alert all Team Leaders when Reaction Sheet is opened: this functionality would be indispensable for the Team Leaders of the Finals, who daily detect "*communication problems despite the innovative tools available in the plant. Having real-time information would let them to have their process under control and would allow them to get involved immediately if a serious problem (such as a Priority 1) is detected upstream, for example in the Chassis or in the Trim. This new tool would increase collaboration, enabling colleagues to be more informed about events and Assembly Shop process*". Finally, 80% of Supervisors believe that digitization would boost the Upstream Check process, with obvious improvements on the Occurrence and Release tool efficiency (see Paragraph 2.3) and with the possibility of extending the tool also for cases not related to Upstream Checks standards (question 7), so even if it is not a Priority 1 failure, or a repetitive anomaly (three cases in the *biorario* or 5 cases in the shift).

About the role of the Team Leader that Supervisors discussed answering to question 6, the 60% of Supervisors believe that "*innovation would facilitate the task but would not change the role*": 40% of the sample state that "*the Team Leader would have more responsibilities and would acquire a more autonomous role; it will thus be a step towards autonomous Domain management, where Team Leaders would increasingly acquire the responsibility of line management. Team Leaders will initially be subject to greater control as Supervisors would be* *alerted in real time by the Reaction Process system; however, such greater control would lead to make Team Leaders making more responsible; Upstream Checks along the line would always be performed and thus will increase the commitment of the people in the Assembly Shop Unit"*. Ideally, then, the factory would only be able to move forward with teams of "blue collars": this is the real revolution of WCM.

Lastly, the author wants to mention a suggestion received by several Supervisors and Team Leaders to implement a new feature in the project: "*it would be useful to notify on the Operator Terminal not only the details of the defect and the Upstream Check with the cars CIS to be controlled, but also the last point useful in the process to check and repair the defect, in the cases it is covered with an Assembly Shop mounting operation of another Domain*" (the cables represent the most significant example because their operations involve several workstations and are overlapped between consecutive Domains); note that this functionality is currently only applicable by linking a cover operation to a workstation, but it would be better to link it to an Operation Card[46]: in the first case, if it changed saturation within the plant and the operations were modified between the various Domains, this would generate inaccuracies in the indication of the last useful checkpoint for the Team Leader. The optimum procedure would in fact see the Team Leader resolve any anomalies as soon as this is reported, but in practice it is obvious that this additional functionality would allow the Team Leader to better manage his time by immediately performing the Reaction Process, if the last checking point is near, and at the same time allowing him to cope with some possible clutter in the Domain by postponing the Upstream Check in the event that the last checkpoint is far away.

6. Organizational influence on the plant structure

After presenting the results of the research carried out in the reference plant, it is possible to continue with the analysis of the influence of digital projects on the organization within the plant, taking as an example the project analyzed in detail until now. In the last paragraph it has been demonstrated that Supervisors do not consider that the role of the Team Leader could change, but rather improve or be easier. However, this statement could be contradicted and denied by the

[46] Remember: it is simply a sheet where is shown the correct operation procedure with OKAY/KO pictures.

Supervisors themselves: it has been recorded from them that "*this project improves communication and collaboration within the team and therefore, with such improvements, control over the team is basically no longer necessary*". This chapter is entrusted with the task of assessing whether eliminating the team control problem is sufficient enough to support the future integration of the figures of Team Leaders and Supervisors that has extensively proposed in the literature[47]. It will again be necessary to refer to the history of the organizational structure, illustrating the role of new roles not yet mentioned in the discussion: in particular the PPS (Product Process Specialist) is the ideal role with which the Team Leader figure could be horizontally integrated "*expanding its skills by becoming more flexible and ductile to the needs of a 'Premium' plant*", as gathered during the interviews.

6.1. Results discussion: the WCM influence on behavior in the Plant

From a behavioral standpoint and attitude, Japanese methodologies, and in particular WCM, have introduced the ideology of continuous improvement into productive plants; in the previous decades, the process and the product were well-defined: the operator had only to carry out the task assigned to him without mistakes. He could not afford to propose suggestions or to deal with activities that were not assigned to him. Now it is understood that if it does not improve the process, this risks degrading; then if it boosts in an organized way then performance can also grow. Initially, there were three macro-areas or Departments: production, technical services, maintenance (see **Figure 39**). These were separate environments without horizontal communication. As the reader can see in the framework shown in **Figure 40** to communicate from a macro-area to another one it was necessary to move from the bottom to the top, so it was unavoidable that the information passed through top management and crossed the information flow into the other macro-area from managers to the lowest levels: this system showed obvious inefficiencies in terms of company alignment.

Nowadays, thanks to the new matrix organization, the uniqueness of the command has disappeared and opportunities for developing functional and product skills are provided. The problems now consist in balancing the powers and the highest costs of communication and

[47] See again the note number 44.

coordination[48]. The discussion about the Technological Gatekeepers presented in Chapter 5 is clearly linked to this new organizational structure: those figures could not exist in the old organization since horizontal communication flows were not facilitated in that situation.
As already written in Chapter 4 the Supervisors, in Toyota mentality, should not work on the production line. Since 1990, many studies have examined the work team in the production line of the Assembly Shop. At first, the Toyota Production System and the Lean Production System as sources of Japanese automobile companies' strength have attracted widespread attention (Berggren, 1993; Fujimoto, 1999; MacDuffie et al., 1996; Ohno, 1988; Womack et al., 1990). With this trend as a crucial point, a surge in interest in the team as the new system of work organization has occurred (Appelbaum and Batt, 1994; Benders and Van Hootegem, 1999; Cutcher-Gershenfeld et al., 1994; MacDuffie, 2002; Morita, 2008). The tasks that the lean work team of the Domain must achieve are as follows: at first, it is required to perform the standard work, to stop defective products from flowing to the next process stage (to stop the production line and immediately deal with the defective products) and to be responsible for the multi-stage process. Second, the Domain team must determine the real cause of the detected anomalies, revise the standard work through Kaizen activities and quality investigations and develop multi-skilled workers through job rotation (Monden, 2012)[49].

[48] The differences between the various organizational structures and the relative advantages and disadvantages have been studied in the following courses of Management Engineering Master Degree in Polytechnic of Turin:

- "Strategy and Organization" (Prof. Paolucci E.)
- "Project Management" (Prof. Rafele C.)
- "Innovation Management and Product Development" (Prof. Cantamessa M.)

[49] See the already mentioned article "*Group leaders and teamwork in the over-lean production system*".

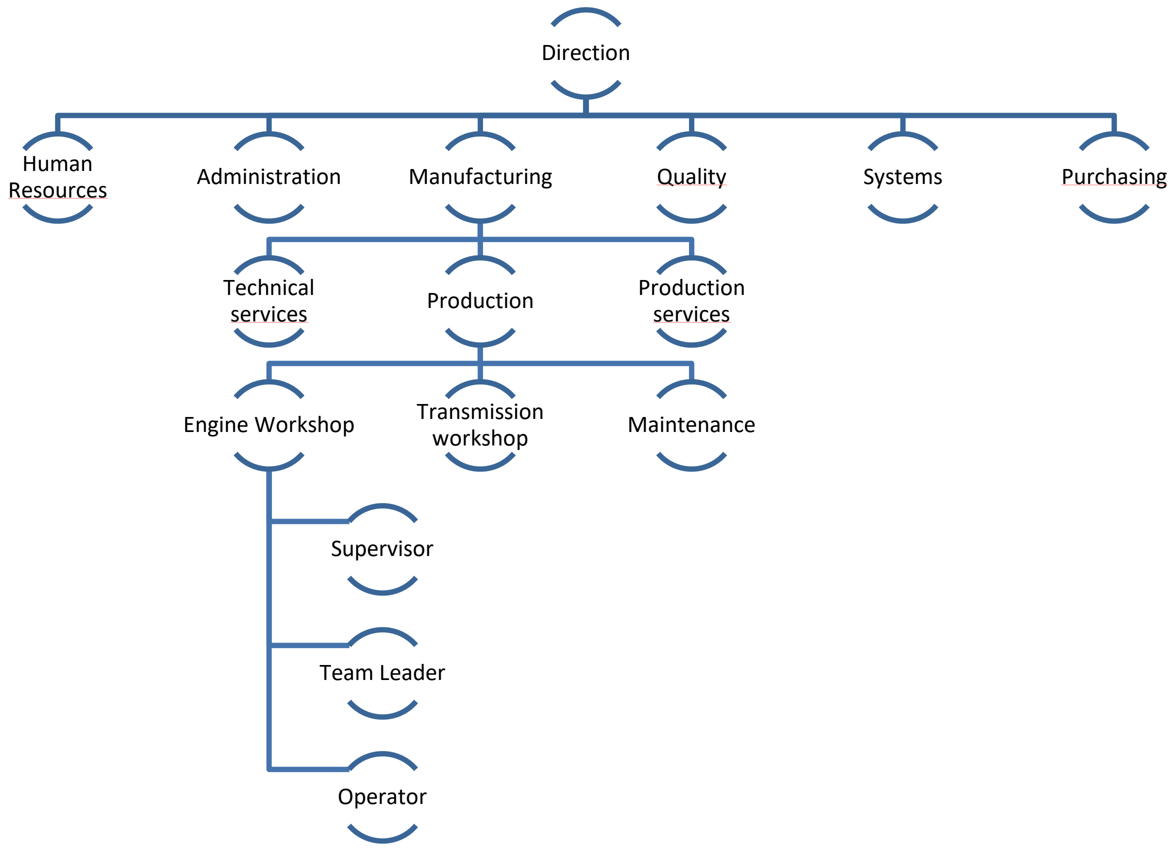

Figure 39: a complete functional view of the "Premium" plant organization with the different offices detail.

The factors that brought to this organizational change were basically the following:

- Technological development.
- Critical Unions[50] relations; in fact, from 1960 to 1980, the factory suffered from such problems, so it would have been better to work with fewer people to have less Union problems.
- Safety and health; automation was born in Paint Shop and Body Shop where the safety and health conditions were worse.
- The will of the company to pursue innovation.

[50] In Italian this word is usually translated as "*Sindacato*".

As mentioned in Chapter 4 (Paragraph 4.1), productivity was initially not improving because there was an organizational problem in managing all the inconveniences and setbacks listed above. This is how the so-called Integrated Factory was born: it was a pronounced organizational and methodological revolution focused on the culture of continuous improvement (from 1989 onwards), accompanied by digitization. As already introduced before, this process of rise came to fruition with the application of some Japanese methodologies, among which the one that lasted longer before the WCM advent was the Toyota Productive Maintenance. The TPM method was born in capital intensive areas and lasted from 1990 to 2000. WCM is now 7 years well established in FCA plants as manufacturing methodology.

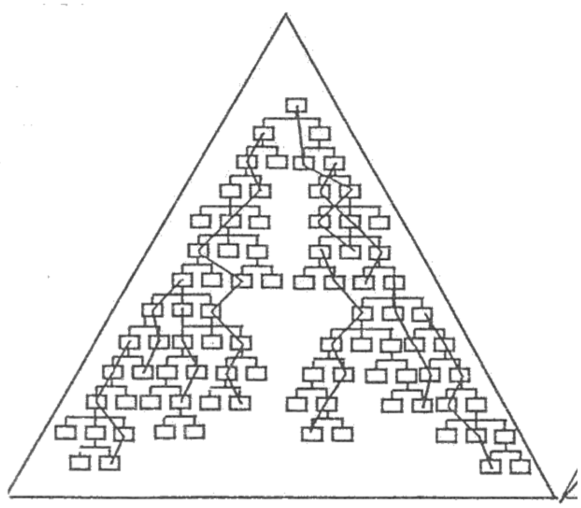

Figure 40: this picture shows how, with the old organization, was difficult to communicate from a macro-area to another one: it was necessary unavoidable that the information passed through top management to flow into the other macro-area.

Before proceeding with the discussion, it is necessary to illustrate the complete organizational structure within the production plant at "white collars" level. As can be seen in the **Figure 41**, in addition to the already mentioned Shift Managers and Supervisors, who are part of the Production Department, there are in fact other important roles belonging to different branches and more precisely to the Product Department and the Maintenance Department. The Product Improvement Manager (or PIM), who supervise about 10 Product Process Specialists (or PPSs), is the head of the employees specialized in the resolution of vehicle technical issues. As far as maintenance is concerned, there are three different figures: a single Professional Maintenance

Manager or PMM supervises about 6 Professional Maintenance Specialists or PMSs and about 10 Maintenance Leaders or MLs, who handle maintenance of vehicles and machines belonging to the productive process[51].

Continuing the discussion started in Chapter 4 about the new structure, other organizational changes at the launch of the Panda in Pomigliano in 2011 were the assignment of PPSs to certain areas and the assignment of maintainer management (PMMs) directly to the Units. Such roles obviously include an expertise and a list of skills that are far different and much more specific than those required for Team Leader. In fact, PPS and PMS are "white collars", generally graduates, and are required to know in detail all the manufacturing process and product (PPS) and all machines (and therefore all Machine defects) in the process (PMS and ML). Specifically, PPS advances in an organized and standardized process and product improvement (with Team Leader support, of course). About these figures, the elaborate has not talked about so far because they are roles mainly about capital-intensive areas such as Body in White and above all the Paint Shop, where the machines number is larger than the Assembly Shop area. From 2010 on, there have been more specific changes to the organization:

- the old figure of the Manager of Production Engineering was eliminated;
- the figure of the line technician has been merged with that of the specialist and the product definition process;
- the Production Manager and the Operational Manager (an old role) have been merged in a single role;
- as mentioned, Team Leader position was further re-evaluated.

[51] Remember from Paragraph 1.1 and Figure 1 that two of the WCM Technical pillars are Professional Maintenance and Autonomous Maintenance which, contrary to this thesis topic, involve the capital intensive areas such as the Paint Shop.

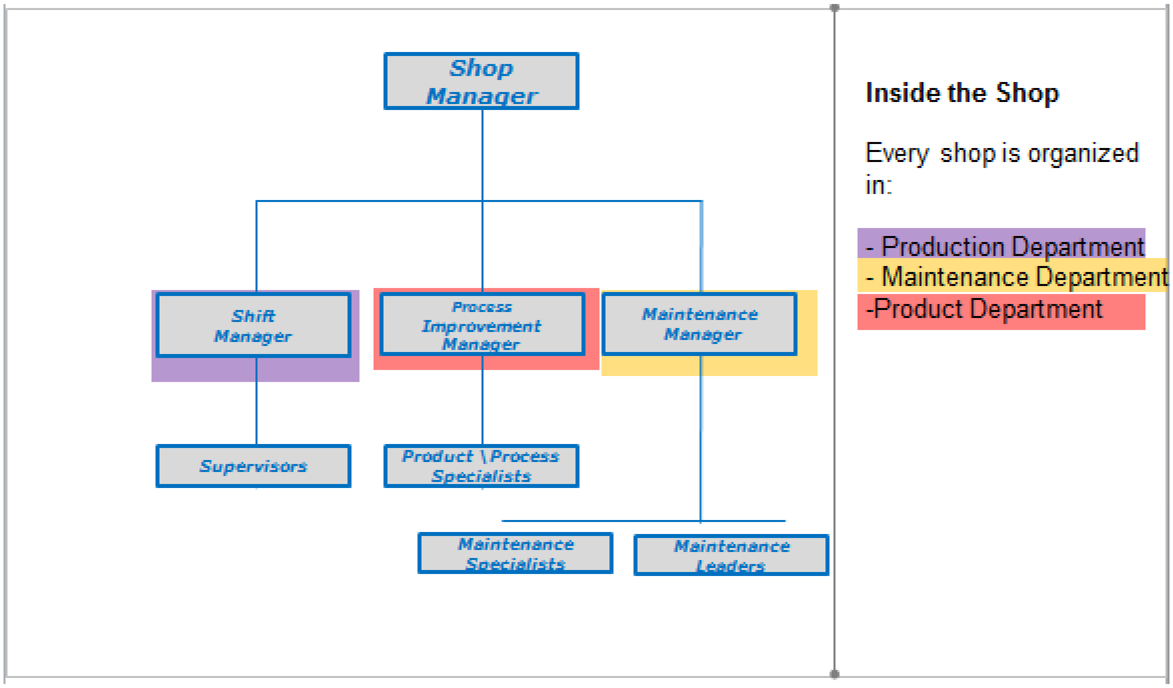

Figure 41: detail of the organizational hierarchy of the Maintenance Department and the Product Department; the Production Department structure is shown in Figure 2.

A more streamlined Unit structure has been created and multi-functional professional roles interact with the crucial production team (1 Team Leader and 6 operators). Just to make the structure even leaner and to create professional figures with multifaceted roles and skills, it is possible to study the possibility of further integration between the roles described up to here in the thesis. The next paragraph will take shape the topic, outlining the main implications and the thesis contribution to the pros and cons of it.

6.2. Pros and cons of integration between work roles

More precisely, interpreting what has been declared by the individuals interviewed, it is possible to outline two types of integration of roles:

- ❖ Horizontal integration
- ❖ Vertical integration

The first results in the integration between the Team Leader and the PPS and has never been proposed in literature; as suggested by the Team Leaders sample, it consists in expanding the skills of the Team Leaders themselves and that should make:

- the organization leaner
- the people more flexible and interchangeable
- the personnel more trained

The integration between Team Leader and PPS is already practically habitual: the fact that these two figures are one a "blue collar" (the Team Leader) and the other a "white collar" (the PPS) is not a problem: from one Ute to another there can be different defect modes and procedures, but essentially the Supervisor could act as a glue. The real problem, as mentioned before, is that the PPS works on the central turn, while the Team Leader has two, sometimes even three working shifts. Nowadays the Supervisor fulfill the function of connection and link between the various shifts. In the case of computer integration system through tools as tablets, smartphones[52] or other, this digital flow of information may occur automatically and in real time even without people talking directly or through the Supervisor. It would be desirable on the system to access to a "map" of areas and issues of responsibility between PPS and Team Leader, and all this already exists from a practical point of view in the “Premium” plants. When a problem occurs, the Team Leader and the Supervisor must intervene and try to buffer the problem, then the PPS interferes in a future prevention viewpoint, when he has been warned of the anomaly. With a computerized system everything would be more secure, standardized and fast. The contribution of this thesis is to clarify the pros, which could bring to define the integration as "desirable" by the Team Leaders, and the cons: as already announced during the presentation of the chapter, during the interviews it was recorded that Team Leader would like to *“obtain more support from the staff or rather receive more training to expand their skills in order to be able to manage all the anomalies of all 4M and 1D autonomously*”; since they are very prepared on the Man and Method anomalies, it is clear that the reference is to the poor preparation on the defects of the Material and, in particular, the Machine zones; this fact should not surprise the reader since, as already mentioned, Machine anomalies in the Assembly Shop are very rare; however, in the

[52] See the investigation results in Chapter 5 (Paragraph 5.1, Table 6).

World Class optics this cannot justify a lack of preparation on this subject, and it is also worth remembering that the increasing of flexibility between the roles aims to make the Team Leaders interchangeable between the various Units, so they have complete preparation on discrete flows both in labor intensive areas and capital intensive areas.

A second debatable integration of roles within the automotive organization after the advent of Manufacturing 4.0 is that this thesis defines "vertical" between the Team Leader and the Supervisor. Although also the one between Team Leader and PPS is an integration of figures between different hierarchical levels, in this case it is analyzed the flexibility of a role that is the direct leader and referent of the other. As already shown above (see Figure 2 and Figure 3), the Team Leader is directly supervised by the old "Capo Ute", now become Supervisor; Chapter 5 has analyzed the results of the interviews designed and created in Chapter 4: Supervisors were defined as skeptical about a possible role change in Team Leader, but have admitted that "*if the digital and mobile phone communication between the various Domain teams is effective and if internal collaboration persists, then team control is much easier, if not even superfluous*". The question of the digital communication has already largely debated the unquestionable benefits that digitalization of the line leads, particularly with the implementation of projects such as the automation of the Upstream Check and the pursuit of a strategy aimed at continuous innovation. With regard to the second question, that of team collaboration, the thesis will use the results that have emerged in publications and previous articles[53] to this analysis: it has in fact been proven in the past that collaboration in corporate production contexts is more likely and more effective among people of the same hierarchical level rather than between people of different levels. To give an example, it is more likely that a Team Leader is more available to help another Team Leader than a Supervisor who is not his or her direct referent. Moreover, it is really unlikely and unconvincing that a Supervisor would spend his time helping a Team Leader of a different Ute. This discourse is part of the debate on managerial conflict that characterizes organizations all over the world and is a difficult subject to fight for all companies.

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[53] See "A case study of virtual team working in the European automotive industry" from International Journal of Industrial Ergonomics, the research article "Formal and Informal Hierarchy in Different Types of Organization" (Thomas Diefenbach, John A.A. Sillince, 2011), "Sustained Product Innovation in Large, Mature Organizations: Overcoming Innovation-to-Organization Problems" (Deborah Dougherty, Cynthia Hardy) and "The Hidden Power of Social Networks: Understanding How Work Really Gets Done in Organizations" (Robert L. Cross, Andrew Parker from Harvard Business Review Press, 2004).

Therefore, this discussion now has three elements which could be intended as pros of the hypothesis of future integration between the roles of the Supervisor and the Team Leader following the digitization of the line and, more generally, the advent of Manufacturing 4.0:

1. A digital information system ensures faster and effective digital information in the form of mail, notification or alert between the team of the plant (demonstrated in Chapter 3).
2. Collaboration in the Ute team would be more effective if carried out by Team Leaders alone than by 5 Team Leaders and 1 Supervisor[54].
3. Domain team control is superfluous if the conditions set out in points 1 and 2 are met (demonstrated in Chapter 5)

However, Team Leaders said they did not want to eliminate verbal communication. In interviews they referred to cell phone calls, but it is clear that the implementation of digital systems can also damage the so-called physical or "hot" contact. In particular, it is evident that the DIMs, previously introduced, could be criticized because they force Team Leaders to walk for a long time to have a physical consultation. However, it is undeniable that the Daily Improvement Meetings guarantee the "*indispensable verbal clarification*" that the Team Leaders claim they want.

It is now necessary to understand whether deleting control work on the Domains is sufficient enough to suppose the Supervisor figure should become more flexible and willing to perform other activities or if their tasks are actually deployable between the Team Leaders: therefore, a more precise and detailed presentation of the role of the Supervisor is needed. In particular, it is possible to better define and clarify the role of the Supervisor in the so-called “Over-lean” production[55] in a dynamic context, referring to some empirical analysis over time with productive changes[56]. There is a type of teamwork and Supervisors behaviors that can be called

[54] See note 52.

[55] In the Japanese article mentioned above, the Supervisor figure is called "Group leader". The paper simply summarizes that the so-called “Over-lean” production happens when:

(1) The Assembly Shop plant productivity rapidly improves and the number of multi-process handling workers does not increase.
(2) Job rotation and multiple skills development became difficult.
(3) Supervisors spend more time working on the line and devoted less time to tasks such as Kaizen outside the line.
(4) When Team Leaders Domains cause delays, the number of operators in the line at that time decreased and the tasks in each station increased to its maximum.

[56] See the already mentioned article “*Group leaders and teamwork in the over-lean production system*”.

"Over-lean". As already explained in Chapter 1, the Lean Production system is one of the four methods which have flown into the WCM methodology: it attempts to achieve both high productivity and high quality by eliminating buffers. "[…] *Lean team activities can be divided into the following two categories: on line activity and off-line activity. The first type of activity involves performing only the standard work, eliminating the defective vehicles from the line to the next Ute. The latter activity includes determining the real cause of the detected anomalies, revising the standard work through Kaizen activities. "Over-lean" production prioritizes the on-line activities over the off line activities in order to overcome the resource (Manpower) shortage. The "Over-lean" mode is considered to be the result of a rapid increase in production that exceeds the limit of production capacity"*. Under these circumstances, Supervisors and their Domains teams cannot help but adapt to this difficult condition. "Over-lean" mode has strengths and weaknesses: the strength is that a very high improvement in productivity can be achieved in the short term; the weakness is that this mode runs counter to flexibility and long-term capability building because of the shortage of Kaizen activities and multi-skilled workers. Hereafter, a large, rapid environmental fluctuation can occur, such as a market oscillation. The "Over-lean" mode must correspond to a short-term and rapid production increase. In this mode, Supervisors can execute direct tasks in the production line. Note that the explained line activities and off-line activities are already partially in the hands of the Team Leader.

After defining exhaustively the possible implications of the role of the Supervisor, in its modern conception, it is possible to outline the problems that such integration could cause. In the first instance, it should be clarified that, according to the opinion of WCM DC Specialists and taking advantage of the insights offered by the interviews presented in Chapter 5, there are at least three structural factors in the cars industry to be considered before hypothesizing and define as advantageous and beneficial the integration of managerial roles:

1. Complexity of product and process
2. Volumes and low Takt Time in the mass market plants
3. High product and process variability

The problem 1 of process and product complexity can be solved through two tools: learning economies and concurrent engineering; the combined and protracted use of these tools could lead to the joint design of "Premium" processes and products that would greatly improve the variability (problem 3) that needs to be handled today in factories such as Mirafiori. Note that the survey was carried out in a plant that has the strange feature of producing simultaneously a "Premium" product (Levante) and a "mass market" product (Mito). This factory therefore suffers inevitably the difficulties due to the fact that the Levante is the first luxury product that the plant has ever manufactured. It is therefore legitimately likely that in other historically "Premium" factories the learning economies are definitely in a more advanced stage. The problem 2 claimed by the Specialists does not exist within the thesis perimeter because this analysis is limited to only "Premium" factories that are characterized by very high Takt Time (about 6 minutes) versus the significantly lower ones (less than 2 minutes) of “mass market” products. The last problem has emerged from the Supervisors and Team Leaders research; the author has already pointed out and underlined that, during the interviews, the Supervisors have shown better intuitive and reflexive capabilities in optics for continuous improvement and in optics of digital innovations, probably because they manage a set of Domains and therefore a group of Team Leaders, so they have a more relevant experience with the digital tools and a better perception of the needs of the line and can evaluate in a more global way the management system in terms of efficiency of communication and collaboration within the team and between the teams. The open point that this thesis leaves to future researches concerns precisely the doubt that this greater managerial capacity of the Supervisor is still indispensable within a quality control system of a labor intensive automotive area. However, these studies will have to be performed and confirmed after the implementation of a significant number of digital tools with the WCM methodology.

Lastly, the choice of WCM as a new production model has given various ideas for renewing bargaining: first, the rewarding system is built on the dynamics of the efficiency gains generated by WCM. The challenge is to read new professional skills in a lean context, where hierarchies are reduced. Important is the new role of the Team Leader who cannot behave like the old role and, at a lower level, the engagement of operators in suggest improvements; however, participation in the suggestion system has two issues: first, only 40.3% of the “Premium” plants operators has received feedback on the suggestions provided[57]. The second critics are related to

[57] “*Le persone e la fabbrica, Una ricerca sugli operai fca-cnhi*”, Luigi Campagna, Alberto Cipriani, Luisella Erlicher, Paolo Neirotti, Luciano Pero.

the rewarding system and the expectations that workers come to receive on awards for the ideas provided. Only 24.4% of workers has claimed to receive or have received prizes deemed appropriate for the suggestions provided. The high difference between the percentage of respondents who are advancing ideas of continuous improvement and those who receive feedback or awards may have different causes, which indicate a company difficulty in managing the generation and knowledge management processes effectively. This may be due to the still too marked distance between the lowest level (operators) and managers (from Supervisors up). It is therefore evident that the advent of WCM has already revolutionized the rewarding system of the organization and that the affirmation of Manufacturing 4.0 and digital projects will involve a further modification: in the case discussed by the thesis, the Team Leaders now have more time to devote to the research activity of root causes of defects and to the study of effective countermeasures; it is therefore clear that they will be evaluated differently, so a significant award to Team Leaders is desirable, if they will identify a greater number of effective countermeasures in less time.

In essence, the role of the Supervisor is to manage production and monitor the entire line of competence; he is responsible for the production of the reference part. Eliminating this role would not be cautious and would risk bringing the plant to the old Pomigliano structure where a single manager was not able to manage a large number of workers: as a result, the operators were less motivated to make suggestions and to communicate with the higher levels. Regarding the horizontal integration, it is known from the literature that in Japan in the "Premium" plants there is a cross figure that deals with the “Premiumness” (it is like a Super Team Leader) and is responsible for ensuring that production is done respecting the product. It can undoubtedly be useful to have Team Leaders who in some Domains have great expertise both on the product and the process. The Supervisor instead has the role of fluidifier and must have control of a limited stretch of line.

Recapitulating everything that has been analyzed in this thesis about the two organizational figures investigated, it is possible to list the benefits and disadvantages (**Table 8**) they receive with the implementation of this innovative project that is part of the process of the automotive plants digitalization trend.

Table 8: list of benefits and disadvantages for Team Leaders and Supervisors induced by the Upstream Check automation project; the pros and the cons are divided into macro-points.

	Topic	Team Leader	Supervisor
Advantages	*Time savings*	Fast Upstream Check completion with the mobile phone than the current situation which forces the Team Leader to write on paper all the succeeded controls.	Immediate anomaly allocation to the correct Domain.
		Well-timed closure of the Reaction Sheet than the current paper procedure that forces the Team Leader to transcribe everything from paper to the computer.	
		More effective individuation of the provisional countermeasure thanks to the system suggestions.	
	Digital (or computerized) communication	Prompt notification of the Reaction Sheet opening.	Accurate and well-timed information to the Final Ute alerted in real time by the Reaction Process system.
	Simplicity of execution of the activity	Practicality of the tool thanks to the connection between the mobile phone and the Operator Terminal.	Thanks to the data collection it is always available a reference to be consulted before dealing with a problem.
	Control over the team		Easier control thanks to the digital communication and to the collaboration within the Domains teams.

	Topic	Team Leader	Supervisor
Advantages	*Control over the team*		Alignment between the Domains team members. Coordination between the process stakeholders, so to be involved immediately if a serious problem (such as a Priority 1) is detected upstream.
Critical points	*Physical and mobile phone communication*	Risk of elimination of the verbal contact through the mobile phone.	
	Rewarding system	Alteration of the incentives system within the Domain team.	Changes in the Team Leader performance evaluation.

Summarizing what has been argued in the first six chapters of the thesis, it is also licit to state that this work has added the following contributions to the existing literature:

A. A clear and detailed definition of the roles of the Supervisor and the Team Leader within the automotive realities in the luxury vehicle market.
B. The demonstration of the benefits in terms of time savings and timeliness and accuracy of information that are guaranteed by digital projects in the "Premium" plants of the automotive industry; it has been also argued that the time saving guaranteed by the digital projects will bring the Supervisors to allocate more Team Leaders time to the analysis activity of root causes of anomalies and to the research of effective countermeasures.
C. An assessment of the overall positive acceptance of digital projects within these plants by the two organizational figures of the Supervisor and the Team Leader.
D. A discussion of the pros and cons of the possible vertical and horizontal integrations of roles within the organization of automotive production plants.
E. The demonstration that the digital tools do not facilitate the physical communication between the organizational levels: the "hot" or physical communication occurs in certain

meetings such as the DIM (Daily Improvement Meeting), which is partially weakened by the advent of digital tools; however, digital projects applied with the WCM methodology help to find data, thus improve information and can speed up the timeliness of information, because the organization is able to find more precise and faster data.

The last chapter, starting from the project analyzed, will define the general pros and cons of the digitalization of the production lines of the industry analyzed and will outline the next steps of digital projects, specifying that they should be oriented towards a more preventive and not just a reactive approach to deal with the quality problems found in the automotive plants.

7. Conclusions and next steps

Currently, the automotive companies are working on many projects like the Upstream Check automation; but in a continuous improvement optics, the WCM methodology expects that processes always improve not only in a **reactive** way, but also in a **preventive** and a **proactive** one. Therefore, it is necessary to reduce more the probability to generate the defect in the station (**Occurrence**) than the probability to release the defect from the station that generated the issue (**Release**). Clearly, an automatic operation generates less defects than a manual one: a machine could be set to not even start the operation if it realizes that this one is wrong. The Mistake Proof or Poka Yoke is usually created with an automatic tool which substitutes a manual operation and which can figure out that an operation is wrong, for example reading the CIS identifier with a barcode. It obviously can avoid a lot of anomalies, but it is costly to implement: the automatic tool must in fact communicate with the plant informative system, letting it to collect all the data and track all the operations. All these reasons have brought the automotive industry to implement in the last decade more automatic production systems. They generate an enormous amount of data that must be computerized through the digitalization of the line and managed by an organizational role as the Supervisors' one. In conclusion this thesis states that digital projects have recorded a good acceptance within the plant because they present more pros than cons. At the organization level they bring benefits in term of:

- *Time savings*
- *Digital communication*

- *Simplicity of execution of the activities*
- *Control over the teams*

Anyway, there are also some critical points because, as emerged in the interviews, for every digital project it must be studied the possible negative impact on:

- *Physical and verbal communication*
- *Rewarding system*

The thesis goal has been reached, but now it is important to discuss the possible evolutionary scenarios of the automotive plants, in term of global digitalization and continuous improvement.

7.1. Digital lights and shadows

To conclude the treatment, the author now intends to extend its scope of discussion and to model in broader terms the general benefits that digital projects such as the one analyzed could entail in the future. To discuss the lights and shadows that characterize digital systems, it is possible to start from the analysis of existing information systems, in particular MES, and from all the information systems that characterize the automotive production plants in the luxury vehicles industry: initially, from 2012 to 2015, these systems were used in a traditional way, but after some time it was noticed that they collected exorbitant amounts of data from the production line; therefore the new challenge consists now in finding the value of this amount of manufacturing data. Nowadays it has known within the automotive companies that such data have a huge potential value, in fact numerous *ad hoc* studies have been carried out since the 90's in the literature[58] to understand how these provide important information. For example, in the context of a labor intensive reality as the automotive Assembly Shop, it is possible to calculate work cycle times immediately without timing them as it is done now, or to perform complex calculations on the variability of processes automatically: in the case of the Upstream Check it is possible to calculate the reaction time, and in this thesis it was found that with this system the Team Leader reacts in an extremely faster way, so that the reaction time has therefore been

[58] See for example "System and method for monitoring information flow and performing data collection", Charles George Johnson, Bernard S L Renger from At&T Corp, 1999.

reduced. In the last few years the main problem has consisted in not being able to extract the value of these data because, although the staff offices possess the business skills and the technical manufacturing skills, there was not the ideal Information Communication Technology structure to bring out the value and optimize it[59]. Given the current situation, it is important to clarify that digital must be applied after the process is already sufficiently streamlined and lean, so it is necessary to continue this additional challenge. In the context of the Internet of Things, introduced in the first paragraph, it is important to connect all the devices (see **Figure 42**) of the plant: it has been calculated that in the FCA global plants there are about 20 TB[60] of data collected by all these devices.

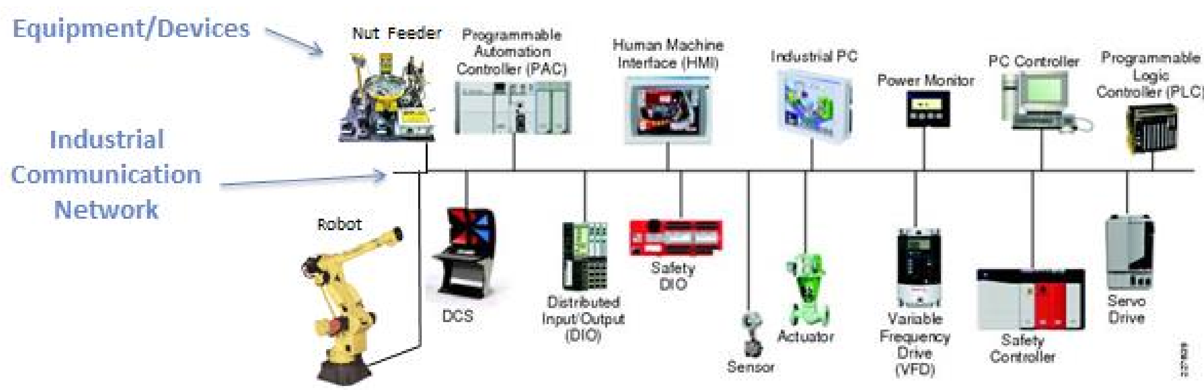

Figure 42: a FCA computer devices and tools overview; these details have been collected from Chrysler.

However, these digital systems have numerous question marks or, at least, open points that represent potential shadows or brakes to the future of Manufacturing 4.0:

❖ As mentioned above, it is necessary to have optimized processes as an *ex ante* condition, therefore in the As Is situation (**Figure 43**) the plant must already have significantly attacked the losses and have already strained flows. It is useless, if not harmful, to digitalize non-optimized processes.

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[59] Remember that during the research 17% of Team Leaders expressed some perplexity and some skepticism, as a result of past experience, that the MES system could effectively improve its knowledge about the process as a machine learning system.

[60] The terabyte or TB is a multiple of the unit byte for digital information. The prefix "tera" represents the fourth power of 1000, and means 1012 in the International System of Units (SI), and therefore one terabyte is one trillion bytes.

- It is also necessary to have trained staff, to have the right people who are aware of the potential of change (**Allocation of high qualified people to model areas** managerial pillar), who are interested in digitalization and are aware of the tool (**Commitment of the organization** managerial pillar).
- It is also necessary a giant effort to connect all these data (20 TB), because today the automotive groups still work with proprietary systems, and not with the more efficient open systems. On one hand the factories must understand what is contained in the TB and the plants organizations must try to increase them, to analyze them continuously, to study their correlations and, with them, must improve the processes involved and facilitate connectivity within the plant.
- It is then necessary to make the old devices useful, functional and compatible with the new paradigm, otherwise they can be a brake and make the extension of the digital slower.
- Finally, it is important to resume the communication speech related to the plant introduced in Chapter 4 and discussed in Chapter 5 and 6. It is necessary to distinguish between three types of communication:
  - Physical
  - Verbal
  - Digital

  As already mentioned, digitalization improves the timeliness and accuracy of information, but can have different effects on different types of communication; the advent of digital communication through the devices illustrated above could have a negative effect on physical communication (for example the Daily Improvement Meeting), while on the verbal one (by telephone) it could have it and this would be, according to the Team Leaders interviews, very harmful for the management of Quality Control activities such as the Upstream Check. It is therefore important to discuss whether these communication types give real added value to the plant.

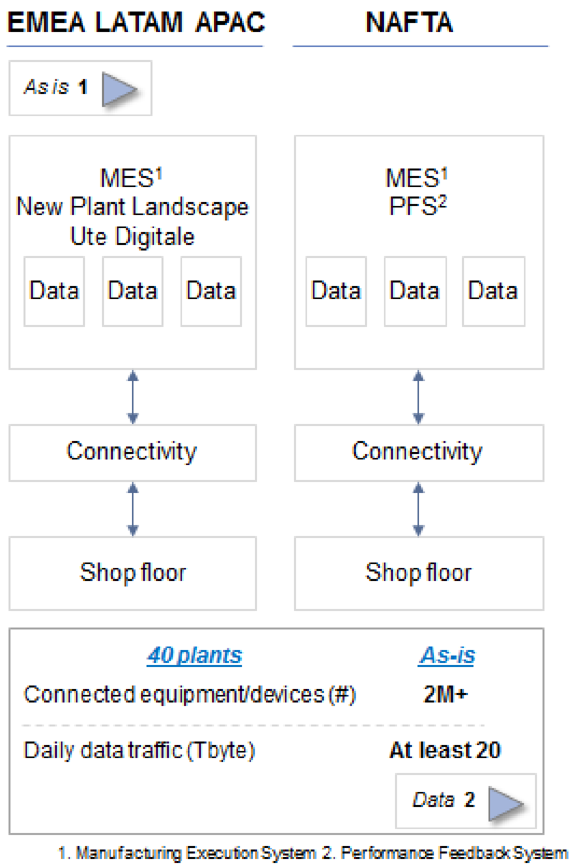

Figure 43: graphical framework of the As Is situation where it is clarified that the systems which collect data need a powerful connectivity tool to be linked to the Shops of the three Units.

It is clear that in terms of alignment of global companies such as FCA, telecommunication and digital communication are essential and of primary importance, considering elementary factors such as the time zone and the distance between countries such as Italy (Fiat) and United States (Chrysler). The balance between the two companies after the fusion has led to significant benefits, allowing each company to take a cue from the other company systems to improve their weaknesses[61]. However, it also caused the alignment of some offices that now have weaknesses in both the original sub-companies. The current ICT landscape suffers from some limitations to which a digital system could remedy. There are some good digital examples in plant execution

[61] The thesis has already mentioned:
- the MES system, which was implemented by Fiat, inspired by the old Chrysler system called PFS;
- the system called "Caps" that asks questions in the "CPA end of life" and, after the answers, releases as output an anomaly value: the system was developed by FCA and Chrysler jointly after the fusion.

processes that can be used as benchmarks, but the data collected and the business intelligence are confined within closed systems. The landscape of FCA ICT systems, which is aligned to that of other OEMs, includes heterogeneous solutions across Regions, specifically:

- ✓ EMEA/LATAM/APAC based on Windows server
- ✓ NAFTA based on mainframe and midrange

So, a huge effort is needed to connect shop floor devices and gather data for analytics: the reader can notice as the plant is relied today on proprietary communication protocols, which result still far away from the open ones. The deal which has brought to the 4G connection sharing between the states of the European Union is the most relevant current example to follow to implement open systems.

Theoretically, a step ahead in digital Manufacturing 4.0 requires to:

- ✓ Increase significantly the amount of data collected
- ✓ Simplify and enhance connectivity
- ✓ Facilitate data gathering from many different sources

Open platform is key for a digital landscape as the NPL. As shown in **Figure 44** it allows to exploit the applications that make up the goal of the new vision; the system gets and processes the data, the app lets the plant distribute information bringing everything back to the line. Apps are supposed to support use cases to reduce waste and create value, so it is crucial to apply advanced analytics and machine learning systems and to use data provided by the platform; the open platform itself collects data from the devices previously illustrated and also from legacy systems, so results indispensable for the company to organize data in interconnected databases and to enable easy apps administration. About the connectivity, protocols are selected to standardize communication, while the network infrastructure is able to support a large amount of data, to define rules for data transmission and to manage independently increased data transfer. Lastly, gateway filters and sends data from sensors to open platform and commands from apps to devices, while sensors acquire data from one or multiple devices (brownfield or greenfield) in the Units lines.

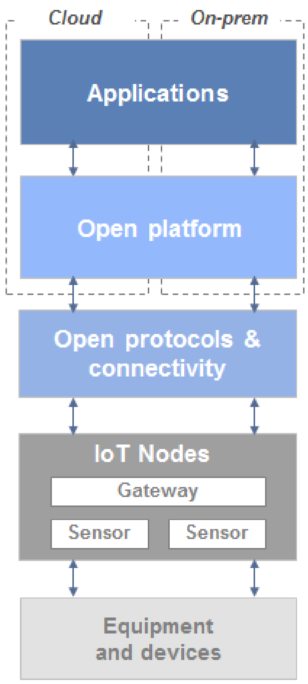

Figure 44: apps support use cases to reduce losses and generate profit; the open platform collects data from the devices; the connectivity standardizes the communication; the network infrastructure supports a large amount of data management; gateway sends data from sensors to open platform.

For the applications it is desirable a co-development deal to enrich FCA internal capabilities. As is known from the theory of management courses, the skills of companies influence decisions to establish or not a partnership[62]. The co-development agreement consists in financing the Research and Development activities of one of the potential suppliers of open platforms; this may imply a more focused agreement on one of the three following factors:

- sharing of future revenues;
- division of investments;
- sharing the benefits of innovations in the form of spillovers.

[62] Other possibilities for agreement are: **business acquisitions** that are influenced by overlapping targets and buyers, so that if there is high overlap then there is little diversity between companies, the risk of conflicts is high and good absorptive capacity is needed**; joint venture** with capital subscription and compliance with alliances, in this case it is necessary to evaluate the size of the companies involved and the complementarity of the objectives; the **strategic alliance** aimed at creating value with company shareholdings; investment in **internal Research and Development** which is a risk because the investor does not always get more; the **hiring of experts** is a hybrid solution between business acquisition and internal Research and Development; to **outsource research and development** to consultants, smaller companies, non-profit research centers or research and development units of competitors paying for solutions or results; **acquisition of licenses** to develop skills after incorporation; **total outsourcing**.

The choice depends on which of the three elements constitutes the greatest source of uncertainty. For the open platform instead, after the requirements definition, the typology of the partner could influence and determine the type of agreement. The author has performed a secondary research on the market about the potential suppliers of open platform. **Figure 45** details a list of potential candidates for the partnerships, detailing the pros and strength or at least the current status of the company. Finally, the connectivity needs a selection of best-of-breed technology players on specific industrial topics for deep knowledge and quick adoption.

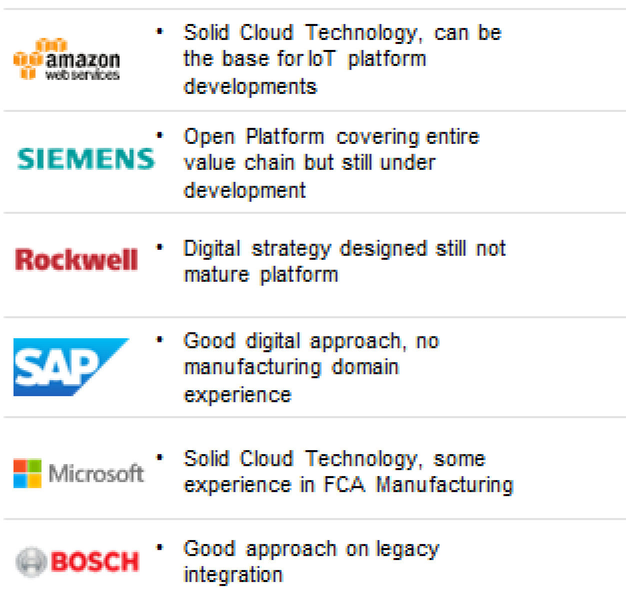

Figure 45: the list of the most powerful and equipped potential open platform providers with a brief strong points explanation.

7.2. Next steps of the digital projects

Finally, to delineate the future of digital projects of the automotive realities, it is necessary to perform some reasoning on the logic of the improvements to be made to the production line. Currently, the manufacturing offices are working on many reactive projects like the Upstream Check automation: they result useful for the plants, because they serve as a further protection for the customer, since the Quality Gates are often unable to detect all the defects. However, in a continuous improvement optics, the WCM method expects that processes always improve not only in a reactive way, but also in a preventive and a proactive one. Therefore, referring to the O&R tool explained in Paragraph 2.3, it is necessary to work more on the Occurrence and not just on the Release (see **Figure 46**) of the defects. For example, in purely theoretical terms, the preventive resolution of one anomaly per day in an automotive "Premium" plant as Mirafiori, could result in 250 permanent countermeasures at the end of the year for 250 different defects, assuming 250 working days per year. Today's tendency is to temporarily resolve anomalies, without focusing on the prevention. It is then a priority to bring processes to a continuous improvement status with WCM methodology application.

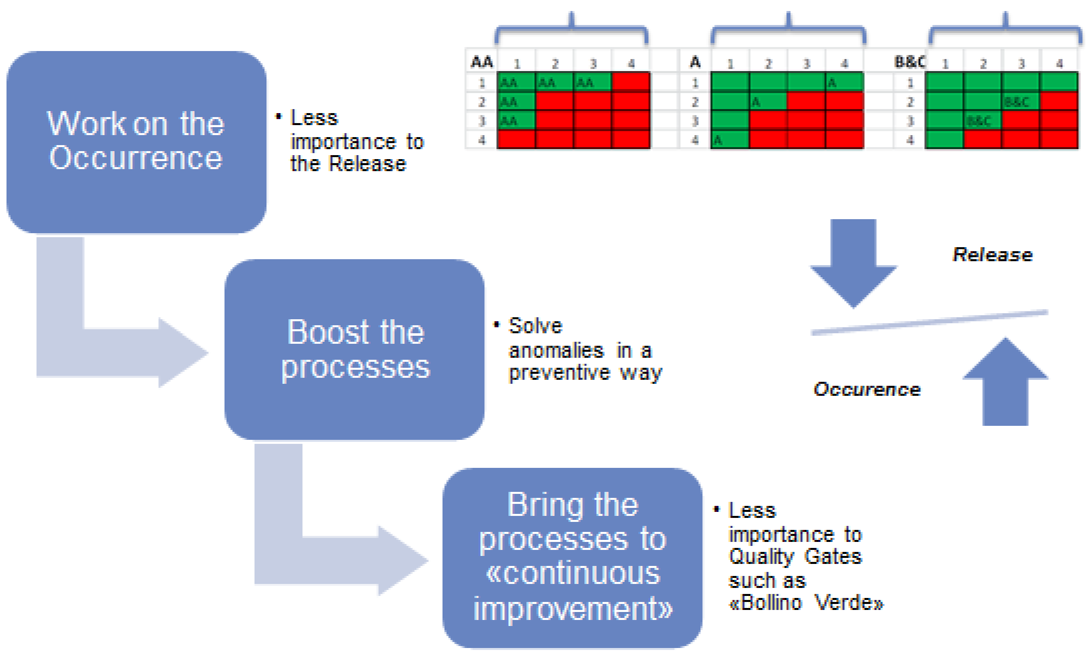

Figure 46: this image displays the basic general steps to bring the processes to a continuous improvement status; it is indispensable to work on the occurrence of all the anomalies (AA, A, B, C) avoiding that they even may happen.

Once the general objective has been defined, it is necessary to clarify the steps to be completed in the context of digital projects, which therefore include the exploitation of the computerization of the line. First of all, it is necessary to resume the discussion introduced in Paragraph 1.3

regarding the meaning of the term "digitalization" in its present sense. In the global automotive industry there are nowadays two currents of thought: the first one considers that it is possible to speak of digital even when simple computerization operations of the line activities are carried out; the latter argue instead that a project can be considered digital only if it provides an artificial intelligence that learns and is able to realize certain activities alone, without external inputs as the ones that Team Leaders send from the mobile terminals. This analysis will not dwell on the discussion of which of the two definitions is correct, but will now clarify that, to implement the Upstream Check automation, the plant will first need to perform activities of simple and basic computerization of the data and documents of the totem inherent Quality Control and, only later, it will be important to equip the system with its own intelligence that allows it to support the Team Leader in the complete execution of the analyzed activity.

First of all, implementing a full line digitalization, it would be possible to create a link between the systems as MES and the Domains QA Network[63]. The QA Network shows the workplaces where the anomaly could be generated and the ones where it could be detected. The Upstream Check can clearly start only from one of the points where the defect can be detected. With the digitalization all the workstations are connected to the informative system, so the starting point of the Upstream Check could change in the sense that it could already start from, for example, a previous Double Check[64].

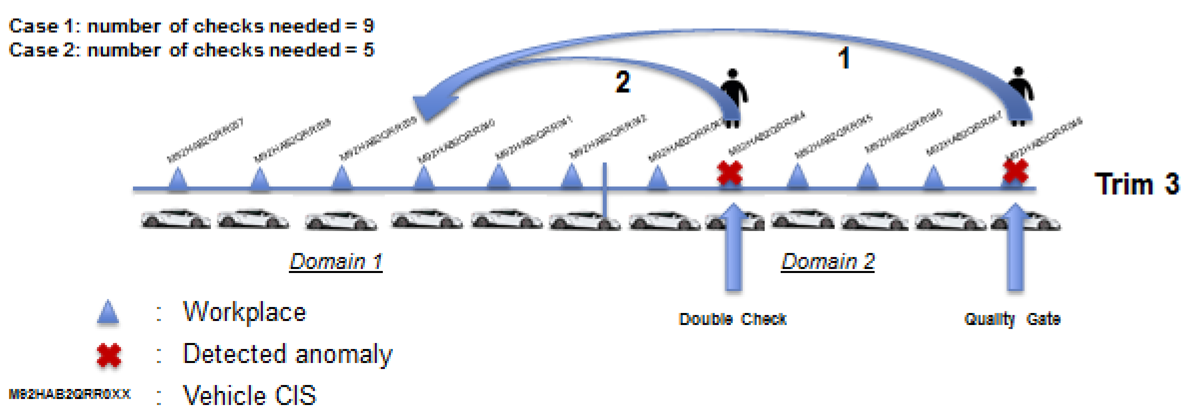

Figure 47: graphical illustration of the benefits of computerization of the line.

[63] Remember what has been explained in Paragraph 2.3.

[64] The Double Check is a double control that takes place along the line: usually the first check is carried out visually or sensorially in the workstation where the defect can be generated, while the second check (also visual or with a sensorial tool) is always placed in a different and subsequent workstation, before the defect is eventually covered (therefore before the gray boxes in the QA Network) and before the Quality Gate.

When the Trim is not traced by the information system, this detects the need to perform an Upstream Check only in conjunction when the anomaly arrives at the Quality Gate (see the example shown in **Figure 47** of a Trim 3 Upstream Check). Vice versa, when all the workplaces of the Assembly Shop line are in contact with the plant system, the Team Leader of Domain 2 of Trim 3 can warn the system that an Upstream Check is necessary (for example due to the detection of a Priority 1) already in the workplace where the Double Check is present, allowing the Team Leader of the Domain 1, which caused the defect, to control only 5 vehicles instead of 9.

So, the Upstream Check would be less demanding both in terms of time needed and in terms of number of controls; the defect would be detected earlier and controls would be faster; tools such as Twttp and Herca would be also applied sooner and in a more effective way. The process becomes more objective to detect problems, and this will, in the first instance, increase the number of defects: this result (illustrated in the **Figure 48**) should not surprise the reader because logically if there are more "eyes", it is advisable to detect more defects.

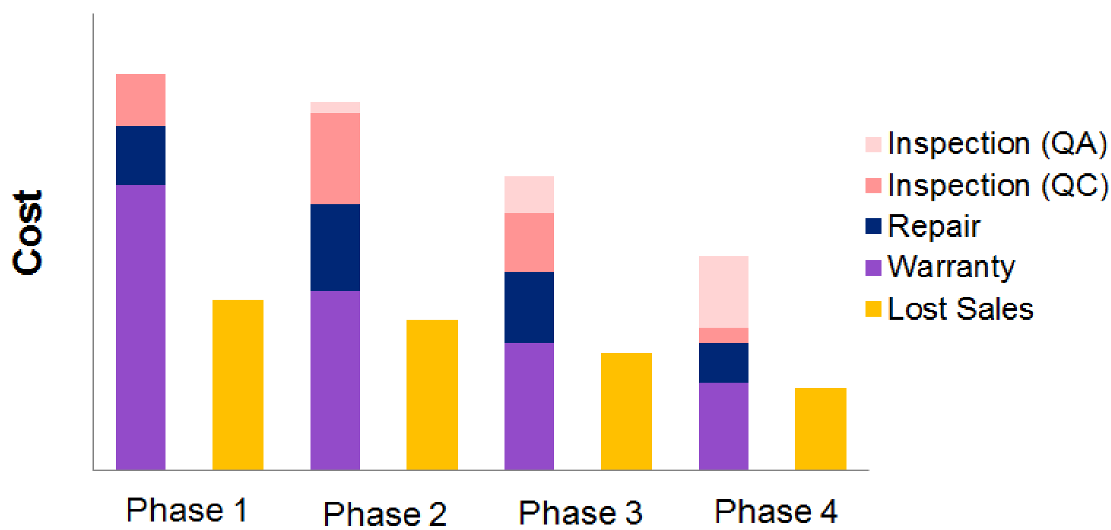

Figure 48: in order to reduce more and more sales losses and quality costs, first of all the reduction of warranty costs takes place between phase 1 and phase 2. Between the phase 2 and phase 3 the costs of inspection are significantly reduced (Quality Control), while between the phase 3 and the phase 4 the repair costs percentage is decreased; at the end the plant records that the missed sales and the total quality costs have been cut down and a high percentage of these concern the costs of inspection relating to Quality Assurance.

What happens in terms of costs can be summarized in four phases:

I. First phase: lower outgoing costumer costs but higher control costs in the plant process ("if I increase the number of eyes, then I see more problems").
II. Second phase: reduction of non-quality costs by acting in a preventive way and boosting the process.
III. Third phase: reduction of inspection[65] Quality Control costs.
IV. Fourth phase: the warranty and the repair costs keep becoming lower and will continue to decrease in the future.

However, as it is easy to understand, all the speech presented so far is aimed at the progressive improvement of the reactive activities within the plant. This, as illustrated, is certainly advantageous for the Quality Control system, but the aim of the chapter is, as already announced, to lead the process to prevent the expected problems and those not foreseen so as not to even have to react to the detection of defects. Thus, the Upstream Check does not have to be just an extra job to reduce the Quality Gate effort in repairing anomalies: in this case, as emerged in Chapter 5 during the analysis of the answers to the interviews, Team Leaders would not be willing to carry out the Reaction Process, losing a long time to do a hard job that the Quality Gate should already do. So, this tool is useful for the Assembly Shop if it also helps to understand the defect root cause, to determine an effective provisional countermeasure and to boost the process. The issue now consists in establishing how to make the automation beneficial and profitable for these activities.

[65] Where the inspection cost calculation is performed as follows:

$$Cost\ of\ Inspection = (N^{\underline{o}}\ of\ manpower)(monthly\ hours)(Taxes/h)$$

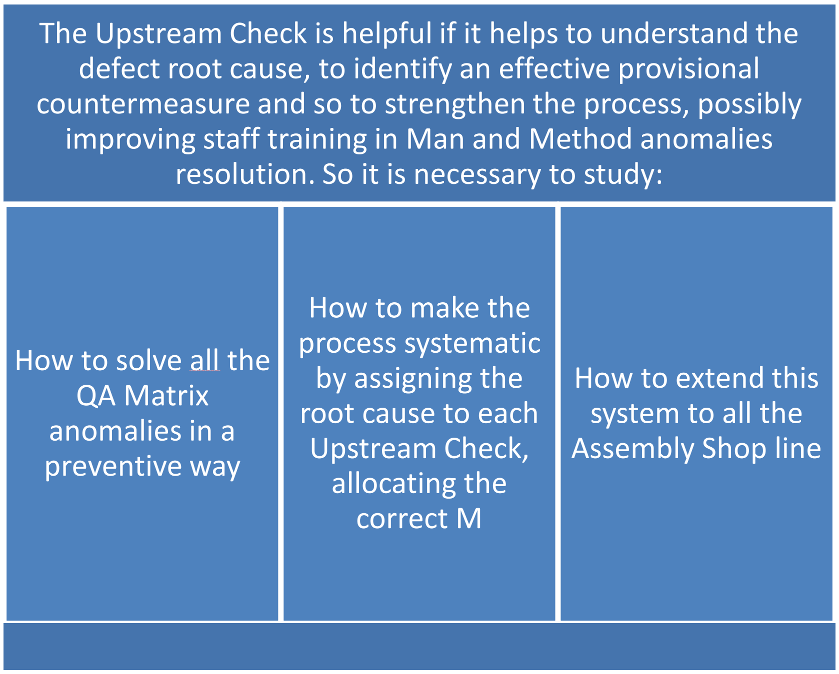

Figure 49: the statement written above involves a series of questions and problems to be addressed that are not trivial to solve either from a conceptual point of view, or from a practical point of view; in fact, it is now necessary to define and extend to the whole plant a systematic procedure to identify anomalies, understand the root cause and resolve them by implementing countermeasures that prevent that type of defect from happening again.

To answer the three questions posed in the **Figure 49** it is necessary to refer to the learning ability of the information system of the plants: therefore, emerges the need of a machine learning system. It must already know the possible countermeasures to a defect, suggesting and giving to the Team Leaders a short list of possible types of provisional countermeasures. All of them must be not only reactive but also preventive. If the Quality Gate detects an anomaly that is not yet mapped with a countermeasure, then a new one must be inserted in a QA Network. The digital system has to become a "pool" of information, so that defects can be blocked as much as possible.

What has been said refers to the phase of prevention of defects already known within the company production sites. From a proactive perspective, it is necessary to prevent anomalies that have never occurred; the activities that are indispensable to carry out consist in:

- ❖ taking what it has been already studied or found in other plants;
- ❖ blocking what it is detected on the line;

- ❖ talking with staff entities (Manufacturing Engineering, Technology…) about the conditions (or Machine values) that produce always the same effects and might generate not yet known anomalies;
- ❖ taking action against everything that might happen, reasoning on how the operations are carried out and on what defects they could generate.

As already mentioned, the proactive activities deepen more with the O&R tool than with digitalization. It is necessary to think of an operation that is carried out in a certain way and what consequences it might generate and, in this sense, the digital is the perfect tool to get the information immediately. However, another help could come from the so-called Lesson Learn[66], that is supposed to be a list of documents which help the production in the preventive phase, but should also have a proactive undertone. The term Lessons Learn is broadly used to describe people, things and activities related to the act of learning from experience to achieve improvements. The idea of Lesson Learn in a generic organization is that, through a formal approach to learning, individuals and the organization itself can reduce the risk of repeating mistakes and increase the chance that successes are repeated. To contextualize the Lesson Learn, the reader is provided with an example shown in **Figure 50**: the context is that of the pre-launch, before Job1 (see again Figure 11). The only WCM pillar that deals with the design phase of the productive process is that of Early Product Management or EPM. If a Lesson Learn is analyzed on how the problem originated, then on the process that led to the defect and not on the technical problem, it is so possible to reason in a preventive but also proactive view: starting from the Lesson Learn, it is possible to foresee similar failure modes but on new problems that could happen with the operation of the analyzed process. In general, the opposite concept of anomaly is improvement and if a Lesson Learn is positive, it is called "best practice" because of the improvement implemented; otherwise, if it is negative, it is referring to an anomaly. All the problems and faults are included in the LUA (in Italian *Lista Unica Anomalie*), so this database clearly has priority over improvements. The LUA is a database in which, in this context, there can also be suggestions for improvement that refer to another database called WPI EPM.

[66] The purpose of a Lessons Learned procedure is to learn efficiently from experience and to provide validated justifications for amending the existing way of doing things, in order to improve performance, both during the course of an operation and for subsequent operations. This requires lessons to be meaningful and for them to be brought to the attention of the appropriate authority able and responsible for dealing with them. It also requires the chain of command to have a clear understanding of how to prioritize lessons and how to staff them ("Lessons Learned Handbook", 3rd Edition, NATO, Joint Analysis and Lessons Learned Centre, 2016).

Checklists in general are lists of questions that ask if certain activities have been carried out or if the necessary materials and equipment are available on the line. These are questions asked before the launch, but also monitored *ex ante*. They can come from all the functions (for example, Design, Quality, Logistics and Supply Chain) because there is not yet a database that contains all of them. Each Checklist refers to an activity, so often in labor intensive areas it has an organizational level to which it refers (for example Team Leader or Supervisor), but it can also involve several organizational levels at the same time. In this context the thesis refers to the design and therefore to the pre-launch phase of a product of the automotive industry. A current or past Lesson Learn can become a Checklist, an EPM solution or simply a Lesson Learn for the WCM technical pillar called EPM. EPM solutions consist in technical solutions as product design features; therefore, the Lesson Learn which often arises from a problem, after being resolved, leads to obtain a technical solution that can be used as an EPM solution. If instead it is a procedural or management solution then the Lesson Learn can also end up in the EPM technical pillar.

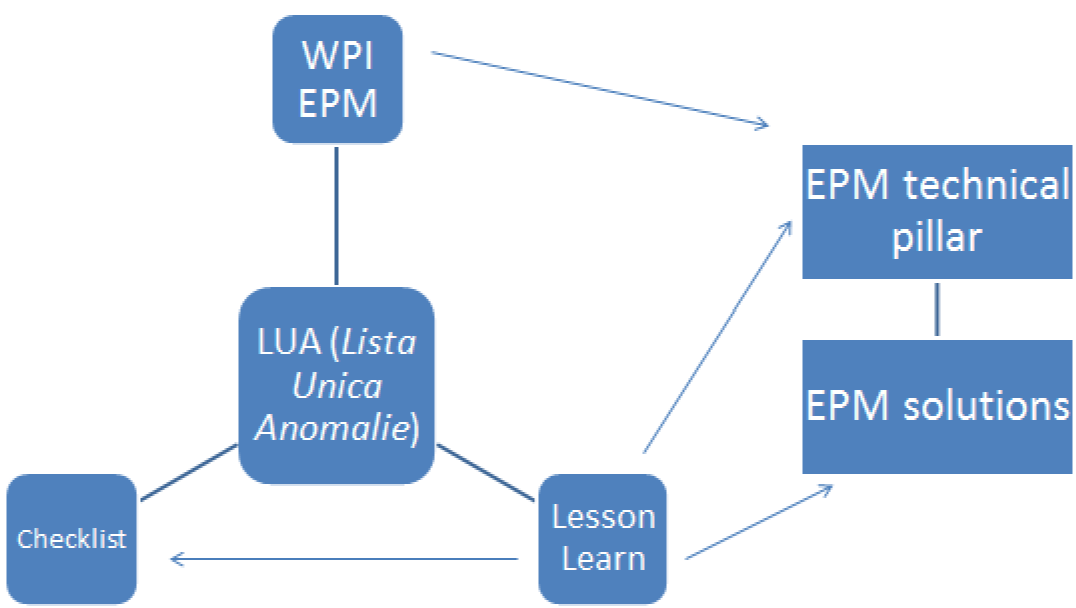

Figure 50: as mentioned, currently there are databases for LUA, WPI EPM and EPM solutions.

The purpose of this discourse is to assert that, in addition to the Occurrence and Release tool, it is possible to have a support in the proactivity phase even from a typically preventive tool, namely the Lesson Learn: starting from a problem already encountered and learned in other reality or other plants, it is possible to think about it and about the operation or process that generates it, identifying similar problems that have never happened and never found that could happen and that need to be remedied. This activity is not yet directly connected with digitalization, and it is difficult to make it automatic. However, compared to the Occurrence and Release, it is an activity that starts from the information present in other plants (the Lesson Learn precisely) that digitalization could undoubtedly in the future make usable quickly and effectively in all the plants of the company. Now, it is time to go back to the project analyzed by the thesis and to outline what are the three fundamental implementation steps (**Figure 51**) to be completed to link the system to the Quality Control totem documents. These functionalities are not peculiar of a machine learning system: so, for now the speech will only refer to the steps related to the computerization of the line.

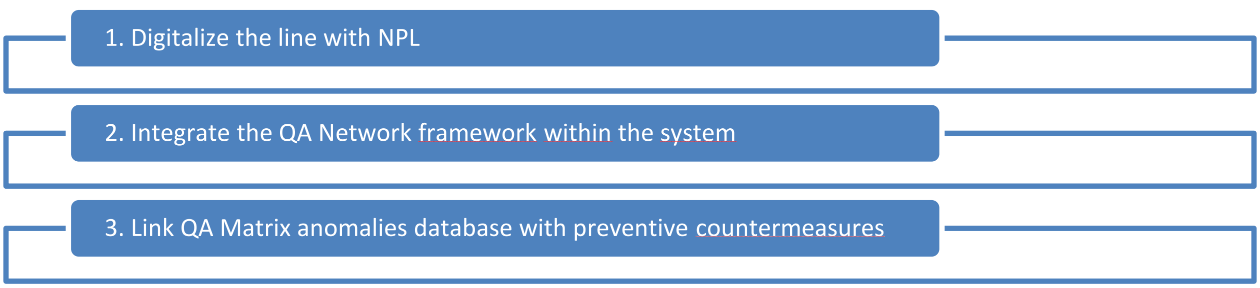

Figure 51: the three implementation steps of the Upstream Check automation in a digital factory.

Digitalizing the line with New Plant Landscape as a simple computerization means that the plant system knows and traces all the defects that are generated by each single operation recorded in the system with the Operation Card. In this way, after creating a link between all the workplaces and the system, it is possible to integrate the QA Networks of the Domains; so, the Team Leaders can update every single day the anomalies and their workplaces of origin and control. Finally, it is extremely important to connect the system to the QA Matrix, thus creating a sort of database, a central core of information that can be used throughout the factory easily and quickly. note that in every step it is important to monitor the process and some KPIs as the already mentioned FTQ In and FTQ Out in all the Quality Gates.

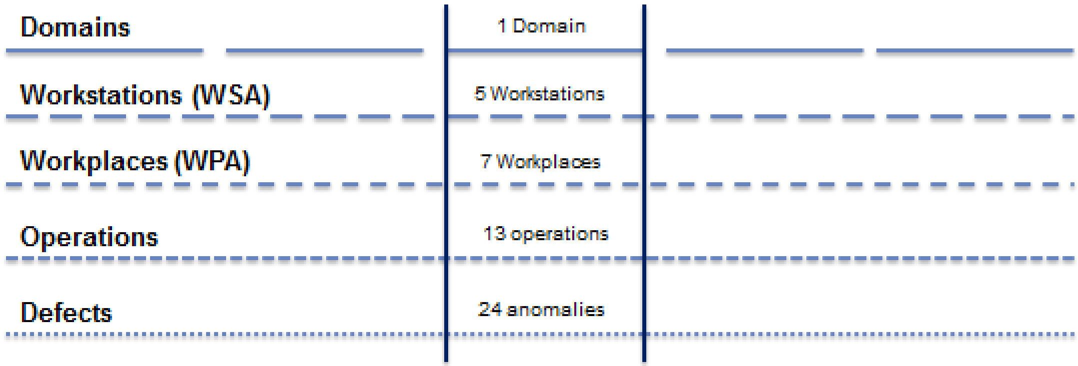

Figure 52: for each Domain the system knows the present workstations, the inserted workplaces and all the operations to be completed within them; to each Operation Card are associated the anomalies that can be generated. There are not only the anomalies already detected in the past, but also those that could happen: these possible defects can be identified with a proactive activity, working for example with the O&R tool. The numerical data inserted in the image are taken from a Trim Domain of a "Premium" plant.

In the example illustrated in **Figure 52** it is shown how, through the information system, it is possible to know which anomalies are generated by all the operations carried out in each workplace. As already introduced in Chapter 1 the workplaces are part of the workstations which belong to several Domains. Domains are associated with groups of six to the Ute (*Unità Tecnica Elementare* managed by the Supervisor) of one of the three main Units (Body in White, Paint Shop and Assembly Shop). As mentioned above, the second step consists in integrating in the system the QA Network document: the system must know in what workplaces of the production line can be generated every single anomaly (red box) and in which workplaces there are controls to detect it and what type of checks they are. As shown in **Figure 53** there are different control types with different symbols: the Mistake Proof prevents the defect from being generated so it works on the occurrence and must necessarily be placed in the workplace where the critical operation that could generate the problem is accomplished; the Error Proof instead prevents the anomaly from being released and can be placed in the Workstation where it is possible to generate the error or, if this is not possible, it can be placed later in the line, even if this obviously forces the Team Leaders to perform the Upstream Checks. However, these controls are effective but usually expensive (Mistake Proof are often automatic controls of digital devices or tools in the line), therefore it is not possible to implement them for every defect. For less risky[67] anomalies, usually softer and simpler controls are introduced: they can be visual, measurable by means of tools or acoustics with alarms that alert the operator on the line.

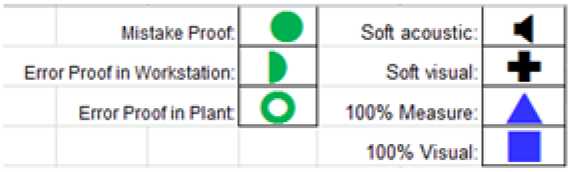

Figure 53: detail of the control type names and symbols.

It is also necessary to keep track of workplaces where the presence of the defect cannot be controlled (grey box) and where the defect cannot be removed due to, for example, mounting Assembly Shop operations that covered it. To have a graphical view please see again the QA Network example in Attachment 3: as the reader can observe the first class AA anomaly ("later battery support, missing assembly operation") is monitored with a 100% visual control in the same workplace where the defect can be caused and has not grey boxes in the line so it could be always checked and repaired in the Assembly Shop line. Moving now the attention on the implementation on an artificial intelligence system it is necessary to establish what it should have as goal and what are the steps of implementation. First of all, it must be able to know the process better through the information provided: at some point the system will become able to allocate the red boxes in the QA Network without human help, indicating in which workplace it has been generated the defect. It is necessary that the system has a history of anomalies that, as mentioned, comes essentially from the QA Matrix registered on the database. Knowing all the operations performed in each workplace, the informative intelligent system must be able to allocate also the anomalies not yet present in the correct workplace of the QA Network of the correct Domain, understanding from the previous anomalies which operation caused the defect or at least what set of operations could have generated the problem. The second step, on the other hand, must consist in supporting the Team Leader in identifying a provisional countermeasure (first level diagnosis) that allows to avoid that the anomaly continues to be generated while the Team Leader performs the Upstream Check. This is the first phase (see **Figure 54**) in which the system, using the QA Matrix, interfaces with the Team Leader, providing and displaying a list of effective temporary countermeasures already applied in the past; the second phase takes place after the Upstream Check and consists in the evaluation of the effectiveness of the temporary countermeasure: if it is

[67] Note that the risk calculation has been explained in detail in Section 2.3

adequate, it is formalized as a definitive countermeasure by updating the QA Matrix and the QA Network, conversely the Team Leader proceeds with the second level diagnosis in which the system collects data from the historical ones and offers a list of definitive countermeasures that it deems appropriate for the mode of defect occurred.

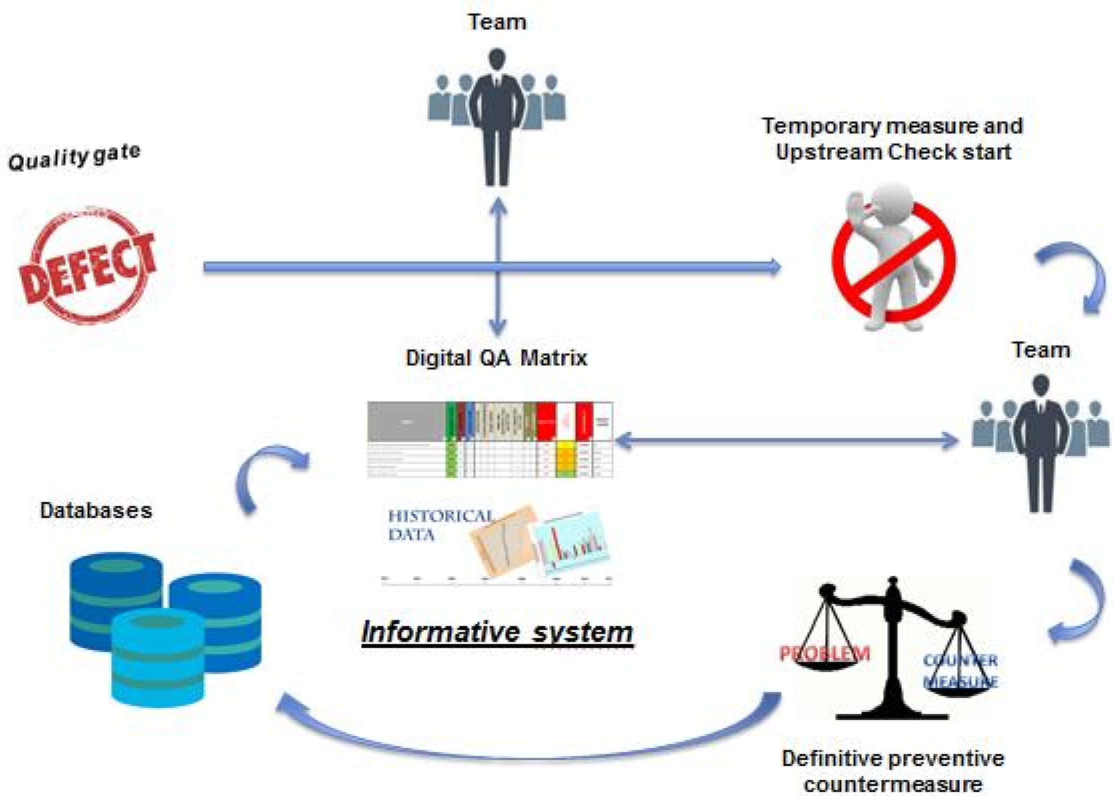

Figure 54: graphic display of the Reaction Process of a plant system equipped with artificial intelligence; when the Quality Gate detects a Priority 1 anomaly or three repetitive anomalies in the two hours or five in the eight hours, it automatically signals that a Reaction Sheet has been opened and offers on the mobile terminal a list of possible provisional countermeasures. After the Team Leader has selected and applied the countermeasure and after the Upstream Check has been performed, the second level diagnosis is carried out with the support of the machine learning system, if the temporary countermeasure proves to be inadequate. After each cycle, the QA Matrix is updated with new defects and any new countermeasures and resolution projects.

The machine learning system must also guide the Team Leader in the correct M identification, suggesting a first level diagnosis, and then show on the mobile terminal the CIS list, indicating the possible workstations where the defect cannot be controlled, taking the information from the grey boxes of the QA Networks; the last steps consists in sending a clear and well-timed notification to the Deliberations Team Leaders or to who can support the Upstream Check, in particular the Technological Gatekeepers discussed in Chapter 4 and 5. A future step, particularly difficult to implement but very useful, would be to integrate the O&R document of every Domain into the system so that it automatically manages the QA Network, which updates and analyzes how it can be reduced the occurrence for each type of anomaly. The challenge that the "Premium" plants must set is precisely that of working on the occurrence, therefore on problem happening, of anomalies: to get to phase 4 of the **Figure 55** it is essential to make sure that the anomalies cannot happen, working on the workstation and continuously optimizing every single operation. It is in fact conceptually wrong to think only of improving plants ability to react to problems more and more, so it is wrong to think that the ultimate goal of digitalization is to bring the system into contact with all workplaces, reacting better (concept illustrated in Figure 47) rather than preventing.

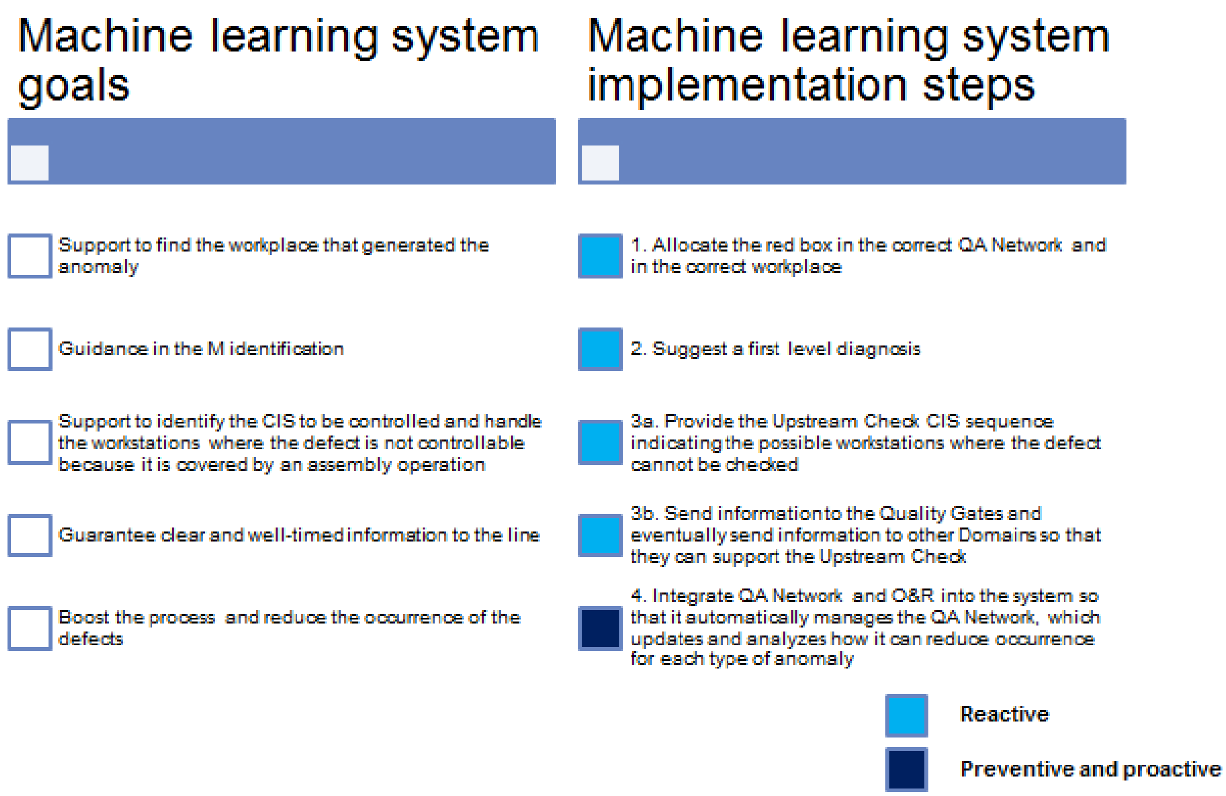

Figure 55: detail of the scopes and implementation steps of the intelligent digital system, with the reactive, preventive and proactive phases detail.

It is therefore desirable that in the future the companies of the luxury automotive industry invest more activities to carry out a more detailed investigation of how to apply digital projects in the labor intensive areas: it is important that they have a positive impact on the internal organization of the plant and that they are applied with preventive and proactive rather than reactive logics.

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