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Master degree

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Master degree thesis

Forecasting model analysis for aesthetic component production in fashion market

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Heartly to my family.

ABSTRACT

The fashion market involves worth trillion of USD all over the world, and just in Italy worth about fifty billion euros. In Europe the market is divided in supplier countries and important brand headquarters country. Italy is one of the most important supplier countries with highest employment and export level. It is dominated by small and medium enterprises which have enjoyed a rapid growth. These SMEs have now production management and monitoring issues. The thesis has been carried out in Goretti S.r.l. company, one of these SMEs

Goretti S.r.l. implement time relief to control production cost with latent purpose of creating reliable quotes, then not subjected to uncontrollable variables.

The system currently in place is unreliable (it may have considerable shifts in production phase), it does not allow the creation of a historic data storage with a strong statistical basis and therefore it does not permit the creation of a forecasting model. It is necessary to purify the data from endogenous and exogenous factors that hinder their interpretation.

To create a forecasting model first step is to elaborate a solid statistical data storage. A benchmark technology has been selected and based on this a data collection started using Bedaux chronotechnical technique. After the collection of considerable amount of data it was run the analysis of the database to select proper data.

Data were reworked with mathematical and statistical instrument to extract relations among them. A model was created to forecast the machining time based on parametric input data obtainable from software used. Finally the model was tested and verified with empirical method on real machining process

CONTENTS

ABBREVIATION INDEX

.xdd: file extension;

μ: average value;

σ: standard deviation;

β_i: i-esm regressors;

a: Boolean variable value;

AT: assigned time;

ATECO: attività economiche;

b: coefficient attributed to the specific (then edges and fillets, curves, straight lines);

CAD: computer-aided design;

CAM: computer-aided manufacturing;

CC: carbon copy;

CNC (or NC): computer numerical control;

CSF: critical success factors;

ELM: extreme learning machine;

EU: European Union;

$Expected_{NT}$: the expected normal time, output of the model;

F_i: i-esm factor of the cronothecnical technique;

GDP: gross domestic product;

GM: grey model;

HR: human resource;

ISIC: international standard industrial classification;

ISTAT: istituto nazionale di statistica;

j: stitches feature group (then edges and fillets, curves, straight lines);

L: leather;

LF: levelling factor for each sub-phases;

LVMH: Moët Hennessy Louis Vuitton;

M_1: add-on for unexpected;

M_2: add-on for fatigue;

M_3: add-on for physiological needs;

MTM: methods-time measurement;

N.A.: not available;

n: parameter for power model;

NACE: nomenclature statistique des activités économiques dans la Communauté Européenne;

NT: normal time;

O: oval;

$\bar{P}$: average pitch (calculated as the average of all the reliefs);

P: Bedaux pitch relieved

P: Padded;

PC: personal computer;

P_N: normal pitch;

PPM: punti per minuto (stitches per minute);

PPS: punti per secondo (stitches per second);

RAM: Rodella Automatic Machines;

S.r.l.: società a responsabilità limitata (Ltd: limited liability company)

SKU: stock keeping units;

SME: small and medium enterprise;

ST: standard time;

$\bar{T}$: average time (calculated as the average of all the reliefs);

T: time relieved;

TMU: time measurements units (1 TMU=0.036 sec);

TTM: time to market;

U: upper;

UN: United Nation;

USD: United States Dollars;

VS: versus;

WT: weighted time value of each relief (weighted on pitch);

WS : weighted stitches used as auxiliary variable;

d: difficulty index which is used as weight for the number of stitches;

s: number of stitches;

$speed_{group}$: average speed of a products group;

x: number of pins.

CHAPTER I INTRODUCTION

The thesis project has been focused on the development of an original method for a manned CNC working station machine time forecasting. The project was carried out in a company operating in the fashion market *Goretti S.r.l.* locate in Serra de' Conti (AN). Focus of the study was a benchmark technology, a sewing machine called *Three head Rodella* of the *Rodella automatic machine*. *Rodella* is a three heads machine, with a two axis control each head. The market in which the company operates is a very peculiar market and the machine is developed by a high specialised small company. Then it is needed a research about the state of the art to know what studies about the time forecasting for CNC machines in the fashion market have been carried out and which solutions were found.

Literature data testify, the machining time forecasting is an important aspect in an industry. It is one of the most important factor to determine a semi-finished product or a finished product cost[1], scheduling system and production plan[2]. Furthermore it is necessary to forecast machining cost because "cost information should be promptly provided to product designers[3]" in this way the designers could intervene and chose the best design in order to reduce cost, cost communication delay causes later design changes and then higher costs[3]. It means that the study of a machining estimation process is focused on the market requirements and furthermore is strongly needed to a company for a better management.

It is also important a focus on the market which is a very particular one. Lots of studies about fashion market focused on the social and the psychological influence of the fashion, such as work focused on trans-cultural fashion choice[4]. The last decades of previous century and the first of this one has seen a strong targeting of two topics:

1. Demand forecasting;
2. Supply chain.

These two topics are very important in a so unique market and strictly related. The demand is highly uncertain and the market competitive. These factors result in the "need to "refresh" product ranges[5]" and therefore increasing the number of *seasons* which are the period for each entire product class substitution. Traditionally the fashion market had four seasons[6], but now some companies (as *Zara*) has about twenty seasons[6]. These increase frequency which cause the need of shorter lead time, along with the competitiveness of the market have effect on the management of the supply chain. This kind of link between demand uncertainty and supply chain brought some

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[1] Nazi, Dai, Balabani, Seneviratne; 2006; "Product cost estimation: technique classification and methodology review; *Journal of manufacturing science and engineering*

[2] Changquing, Yingguang, Wei; Weiming; 2013; "A feature-based method for NC machining time estimation"; *Robotic and computer-integrated manufacturing*

[3] Jong-Yun; 2002; "Manufacturing cost estimation for machined parts based on manufacturing features"; *Journal of intelligent manufacturing*

[4] Wills, Midgley; 1973; "Fashion marketing; *Allen & Unwin*

[5] Cristioher, Lowsin, Peck; 2004; "Creating agile supply chains in the fashion industry"; *International journal of retail & distribution management*

[6] Hines, Bruce; 2007; "Fashion marketing, contemporary issues"; *Butterworth-Heinemann*

research group to analyse the problem starting from demand forecasting and other ones starting from supply chain. An important study[7] relieved a forecasting method based on extreme learning machine (ELM) and grey model (GM) the second one is mostly used in the fashion market due to its well performing with low data amount. These two methods were melted in an hybrid model because the time required to execute demand forecasting are quite long for single product. In fact the analysis must be carried out on a single product because of the high number of different colour shades, different styles and great number of Stock Keeping Units (SKU). The model created resulted in an average error of 44% in different condition, which itself testifies the difficult condition in which forecasting are done.

Other papers manage the supply chain issues. In this case the different approach brought to study both the supply chain strategy and supply chain portfolio. It has been demonstrated that at Italian level, it is possible to divide the portfolio based on three characteristics:

1. Product characteristics;
2. Brand characteristics;
3. Channel characteristics[8].

Even if the division was verified at local level, some other scholars consider appropriate focusing on supply chain strategy more than portfolio. An interesting point of view was expressed by Christopher, Lowson and Peck: the introduction of agile supply chains in the fashion industry. In fact the same Cristopher stated "today competes the supply chain, not the company" which has a strong impact on the actual fashion market. Studies as already described, strongly depend on market demand forecasting, while the approach proposed by "Creating agile supply chains in the fashion industry" is different. Because of the fragmentation of demand, the being an open system mostly dominated by chaos and because also modern technique are not able to well forecast the future demand, it is suggested to resign the idea of forecasting and embrace the idea of "real time" demand[5] where the product is create, manufactured and delivered only when and in the quantity required. The attention of managers should be focused on lead-time reduction reducing then the inertia of the company. This can be obtained through different ways: reducing batch size, ability to recognize customers taste change, concurrent engineering and the increase of use of CAD/CAM software (then converting quickly idea into tangible product). The high control on the factors that true the reduction of lead time are higher control over the production: concurrent engineering can be helped by the forecasting of time, which in turn can be implemented through CAD/CAM software. An higher awareness of the production capability of a company lead to proper answer to market change or client request.

Big fashion brand started to understand the potentiality of the market in which where not interested before and try to understand and satisfy the request of this segment in the way they are used to operate. Other brands (such as *Zara*, H&M…) instead are already operating in this market with an agile strategy and it is reasonable to expect big fashion brands to adopt this strategy too.

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[7] Tsan-Ming, Chi-Leung, Na, Sau-Fun, Yong; 2013; "Fast fashion sales forecasting with limited data and time"; *Decision support systems Journal*

[8] Brun; Castelli; 2008; "Supply chain strategy in the fashion industry: developing a portfolio model depending on product, retail channel and brand"; *Production economics journal*

The agile strategy in a market where suppliers, brands and final customers cooperate and are linked in a such deep bond makes more sense if all the level operates with the same strategy. The emerging trend therefore, is an unique network platform where all the information is stored (virtual integration[5]), to which every component of the supply chain have access and can operate, from the retailer to suppliers; in this way the needs of warehouse is reduced and the communication inertia decreased because each suppliers know at which level the stocks are and can start producing products only when needed. In this case the brand operate exclusively as director of a theatre play[5]. To know when the product will be on the market and backwards when the production would start, the manufacturing time forecasting is essential for the brand, furthermore it is needed to control where the order is and at which production step it has been machined. In this way the control over the production of the brand is large and the freedom of suppliers is reduced but in this way, because of reduced inertia, there is an enrichment of all supply chain. To have a competitive advantage with respect to competitors it would be a good practice starting the use of forecasting time model. The state of art did not return any article concerning machining time forecasting model in fashion industry neither related market but it returned the importance of this practice. The possible reasons are:

- The information are considered industrial secret by companies which therefore abstain from disclose;
- The company operating in the market are usually small company and therefore do not have enough knowledge in house to develop such model and prefer methods based on past experience ("far from being an accurate estimation[3]");
- The subject is an highly industrial process and therefore slow-drying to studies because low interest.

The highest probability is the second option, supported by data later exposed and by practice currently in use in the company.

The analysis was then carried out on machining time forecasting model starting from the state of the art. The highest number of papers discuss time estimation for milling or drilling and this because "milling is the most important and widely used operation to obtain dies and molds[9]". For this technology already exist numerous software, sometimes implemented in the CAM software or in some case external independent software (*Vericut*, *Costimator, Digifabster…*). NC machining time estimation methods are divided in four categories[2]:

1. Estimation based on material removal rates;
2. Estimation based on NC program (then feed rate and length of the path);
3. Estimation based on NC program and machine characteristics;
4. Artificial intelligence based estimation methods.

All authors agree in stating that the software are not always able to estimate precisely the machining time for milling: they use a fixed feed-rate which instead in reality suffer of oscillations which depends principally from:

1. Mechanical limitation: inertia;

[9] Coelho, Fagali de Suoza, Roger, Rigatti; Lima Ribeiro; 2010; "Mechanistic approach to predict real machining time for milling free-form geometries applying high feed rate"; *Journal od advanced manufacturing technology*

2. Electronic limitation: machine does not reach acceleration and deceleration as fast as required[9].

Therefore, the most useful software became ad-hoc software created for specific machinery with specific studies. The study [2] relieved a commercial software error on a specific machining of about 30% against an error of about 4% of proposed method; study [[10]] report an error of commercial software of about 57% against an error of about 7% of the here proposed algorithm.

All forecasting methods studied where or features model or mechanistic models. The analyst voluntary skipped analytical method because of their “great difficulty in gathering all required information of machine9”. Then method studied have a similar structure based on three levels which will be here reported with the terminology of study [2]:

1. Data preparation level: preparation of data for machining time forecasting;
2. Data level: where data prepared in previous level are codified in order to be communicated between different software to allow the computation of the method. linking computer aided design with computer-aided process planning[11];
3. Data calculation level: forecasting machining time based on data received from data level.

The data level can be omitted in some condition: when the translation from a software to another is done by operator (e.g. simply compiling an excel form) or when the operations are carried out inside the same software. Software used in chip removal machines are usually more sophisticated than the one the sewing machine is using: the control for this machine needs to be in two dimensions and therefore *Rodella* is six axis machine; for the aim of the project, it is interesting to understand which data are used (collected) to estimate time (level one) and in which relationship these data are linked to obtain the model (level three).

Data preparation level among all above mentioned collecting data methods can be classified into two groups: data common to all the models and specific parameters evaluated for each models. Generally it is possible to find the specific parameters in all the models unable to perfectly integrate, because of complexity or strategical choice, information coming from different software and therefore must rely on derived data. Common data required are:

- Geometry information: volume to be removed, area to me polished, length, height…;
- Cutting information: material removal rate, feed rate, tools…;
- Material information: which material, which shape....

Then specific parameter can be found in models: especially in feature-based model. In this case primarily features are defined and then group the product with same feature together and estimating similar machining time or the machining time of the specific feature was defined and then applied to every similar feature[3]. This principle is very similar to the *group-technology* approach principle.

[10] So; Jung; Park; Lee; 2007; “Five-axis machining time estimation algorithm based on machine characteristics”; *Journal of materials processing technology*

[11] Maropoulos, Baker, Paramor; 2000; “Integration of tool selection with design Part 2: Aggregate machining time estimation”; *Journal of materials processing technology*

In some other case a parameter indicating the machine limitation is introduced considering specific condition for which the model was created[9]. The indicator is a sort of representation of machine ability to operate specific machining and it is a machine characteristic (i.e. the indicator does not change, changing the condition, for a machine). For analogy it is possible to create an indicator for each product which represents the difficulty of machining the specific products, which indicators became a product characteristic.

Furthermore there are models in which the validating products need is high and the requirement is extended to a versatile way of carrying out it. In this case it is possible to adopt a Boolean validation method which consist in the presence or absence determination of specific characteristics[11].

Attention then was set on data grouping. In fact due to the large amount of data companies today held, there is the need to identify specific parameters which help to determine which model is more appropriate for a specific situation. And a last important aspect is the aggregation of forecasting: in fact even if "simple approach are considered robust, […] averaging statistical approaches leads to improvements in predictive accuracy[12]" due to the decrease in noise output.

All the relevant information relieved from papers were implemented in the project done in *Goretti S.r.l.* in order to have a valid basis on which create a model. In fact a model created deals with *group-technology* principle as by Wills *et al.* paper [3]; an index which indicates the difficulty of each product (as proposed by So *et al.* paper [9])was introduced in two models and the definition of the index was based on a Boolean evaluation[11] and finally, once the model verification will be carried out, it will possible to evaluate aggregation of forecast[12].

This thesis will be structured as follow: *Chapter two* deals with the external market conditions and their consequence on the company internal environment; *Chapter three* treats the design of experiments; *Chapter four* covers results and discussions and finally *Chapter five* handles the conclusions.

[12] Kourentzes, Petropoulos; Trapero; 2014; "Improving forecasting by estimating time series structural components across multiple frequencies"; *International journal of forecasting*

CHAPTER II THE COMPANY AND THE MARKET

An important step to understand the work done during the thesis period is to explain the market in its macro components and dynamics, then drop these mechanisms inside the company reality and finally analysing the company's surrounding circumstances to understand its own dynamics. Because of this an initial and brief analysis will be run on what the company do as product. Then the attention will be set on the market, and therefore the parameter to define the market; once the market will be define it will be possible to analyse it from two prospective: one from an economic point of view and a second from the dynamics of the market (supply chain, organizations, products monitoring…). Finally, it will be inspected how these market characteristics are found inside *Goretti S.r.l.* and how the company works with respect to these.

Goretti S.r.l. is a textile company which operates in the luxury fashion segment. It is located in *Serra de' Conti* (Ancona, Italy). The company handles the application of decorations on shoes and accessories for luxury fashion. The segment in which *Goretti S.r.l.* operates requires high ability of adaptation to stay competitive with the market maintaining profits and high-quality standard. Due to this particular approach the company owns avant-grade technology such as: laser cutting and engraving, water jet cutting, VAT photopolymerization. Water cutting is principally used for material which can suffer odour or burns due to laser cutting; VAT photopolymerization is used instead with rapid prototyping purpose, laser cutting is used to cut textile material and laser engraving is used to decorate materials. To maintain the high standards required by the market, the raw material must be of high quality too, this why company uses: rhinestone (as *Swarovski*), studded and pearl of high-grade. In particular rhinestone and studded can be applied for fusible, rivet or stapled (samples in Figure II.1)

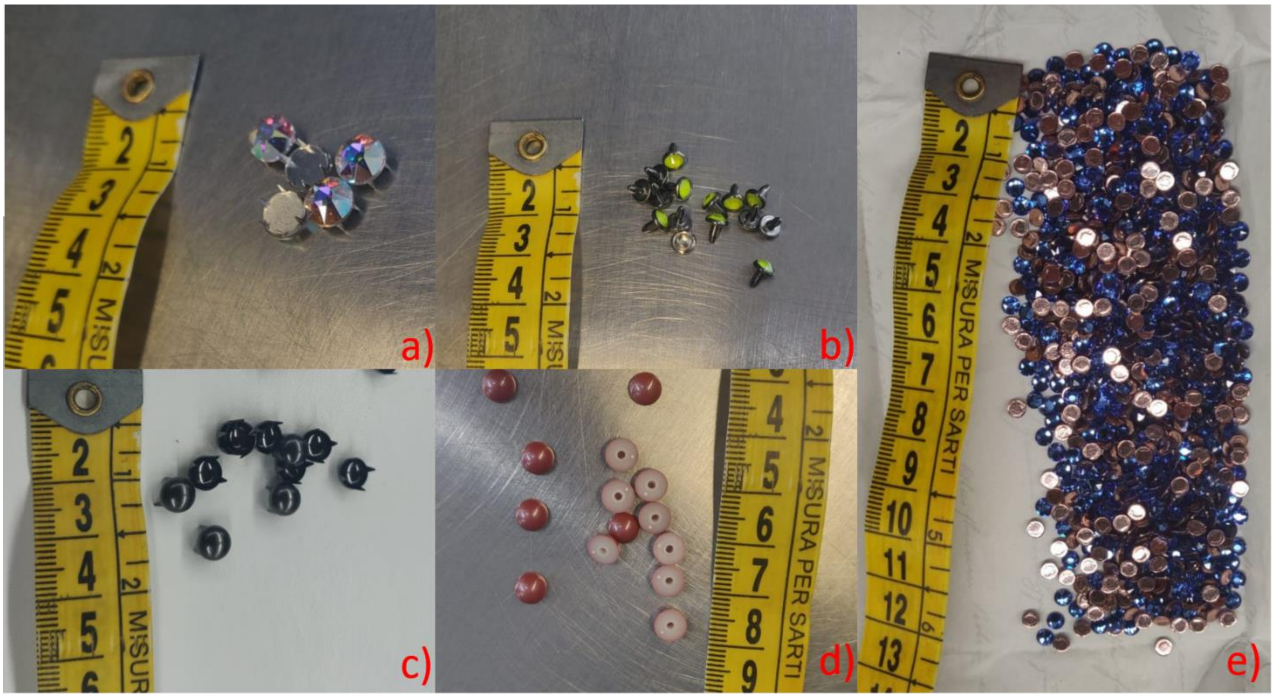


Figure II.1 a) they are Swarovski strass stapled; b) they are rivet; c) they are studded stapled; d) they are ABS studded; e) they are Swarovski fusible rhinestone.

2.1 MARKET EVOLUTION AND DEFINITION

Luxury fashion market, is a luxury market with very specific mechanisms and dynamics. It is crucial to follow how this market evolved and works to better locate *Goretti S.r.l.* inside it. The first step to understand the market it is to identify the market. Therefore, as it is luxury market, a first analysis will be run on the definition of the term. Luxury emerged since the Palaeolithic era and since that to the ancient world luxury was strictly related to the sacred practice and to the elevation of leaders of clans from other people. A symbolic example are the represantation of Gods is reported in Figure II.2.

Figure II.2 In the left. Athena Parthenos: it is the statue of Athena placed in the Parthenon (Athene, Greek). It was twelve meters high and covered of fourty tonnes of gold. In the middle[13]. Toilet of a roman lady; in ancient Rome, robes were clothes used to represent the nobiliar familiy. Robes had drapes and were made of precious yarn of linen[14]. In the right. Amulet representing "djed" pillar, symbol of Osiris, made of faience[15].

Luxury concept evolved during ages until now passing through the middle age, to the modern concept of luxury. It would be superfluous and inappropriate to thoroughly analyse all the evolutions in time and space that the luxury concept has had. Nevertheless, it is important to understand in the modern world what luxury is to better determine the market and its clients. A very important change in the luxury market happened during the industrial revolutions (particularly during the second, 1870). Luxury goods were items with precious material, high quality standards and high cost for the wealthy class, because of these products were hand-made by artisans, then every product was unique and require long time for the development. During the second industrial revolution, the introduction of automatic and semi-automatic machineries in the luxury industry totally change the artisans' approach to the market. Many factors fit together: the new production capacity brought by the automatic machineries increase the number of product an artisan was able to produce, at the same time the sales required to economically sustain the machineries increased and the cost of the luxury products (and then the price) decreased. In this way, during the decades luxury became a product that highlight high quality and standards, a *status symbol* but at the same

[13] John Leonard; 2019; "The Truth Behind the Lost Statue of Athena and the Virgins of the Parthenon"; *Greece is*
[14] "Toghe, tuneche e gioielli nel mondo romano"; *Capitolium*
[15] 2018; "Museo Egizio"; *Franco Cosimo Panini Editore*

time affordable for a large customer base. In this evolution the brand acquires a very important and relevant meaning to broadcast some specific value.

- What emerge from the analysis of luxury term that it is difficult to define what is and therefore it is difficult to define a market based on luxury definition. Therefore a better approach could be the one of defining the characteristics a luxury product should have. A very important representation of the luxury product characteristic is given by *Emanuelle Riguad-Lacresse* and *Fabrizion Maria Pini* in "*New luxury management, creating and managing sustainable value across the organization".* They collected various analysis done by distinguished academics and created a list of Critical Success Factors (CSF) a company must have to deliver a luxury product:
- Premium quality product: it can be obtained both by using high quality raw material and using advanced manufacturing technology;
- Expert human resource (HR) in manufacturing high quality product: this CSF represent a sort of transmission from artisans to the modern world;
- Exclusivity of the product: for example producing small lots;
- Emotional appeal: the user of the product is not only interested in the product by itself but also in the experience around it (*atelier* experience for example);
- Brand reputation: brand acquired a very important role in a product expectation; therefore company should pay particular attention associating its name to a luxury standard;
- Recognisable style: which helps costumers recognizing the brand without any logo;
- Origin country with strong reputation heritage: it helps the customers trusting the brand reputation;
- Uniqueness of product: each product should be different from the other due to, for example, small imperfection when the production is more than one unit;
- Superior technical performance: principally for luxury product in technical sectors but it can also indicate durability of a good;
- Creation of lifestyle for the costumers that use the product[16].

What clearly emerge from the analysis is that cost do not influence the luxury perception of a product. What strongly influence the luxury is the perception in terms of *touch and feel* and emotional perception that the client has for the product. At the same time the consequence of the CSFs for this sector lead to high production cost and then high cost. These circumstances allowed a new evaluation of luxury product also from a client point of view. The shift that came out can be seen at the beginning of the twenty century in French where the fashion started to move from tailored clothes to "haute couture" do ready-to-wear[17]. The evolution of this concept brought to the modern representation of luxury where not only well-established brands are able to create fashion products, but also relatively new brand such as Balenciaga or Off-White.

[16] Emanuelle Riguad-Lacresse, Fabrizion Maria Pini; 2017; "New luxury management, creating and managing sustaibable value across the organization"; *Department of Economics Caledonian University, Kingston Business School Kingston University*

[17] Diana Crane; 1997; "Globalization organizational size and innovation in the French luxury fashion industry: production of culture theory revisited"; *Poetics, Vol 24, pp. 393–414*

CSFs can be applied to important fashion brands *in toto* and to suppliers of brands for what concerns CSFs of production. To guarantee that the study done really interest *Goretti S.r.l.* it is useful to test if the company has the CSFs of interest. A supplier is required to produce (or sale): high quality product, expert HR, exclusivity of products, brand reputation, important origin country and uniqueness of product. It is possible to find these CSFs in *Goretti S.r.l.* too.

- Premium quality product: *Goretti S.r.l.* uses high standard raw material such as *Swarovski* or other crystals responding to specific European standards,
- Expert human resource (HR): most of the company employees worked on the fashion market for most of their working-life (this also because the geographic area is strongly specialized in the production of footwear)
- Exclusivity of the product: the production request for *Goretti S.r.l.* rarely overtake five thousand units;
- Brand reputation: the reputation of a brand is a very difficult evaluation process which must take into consideration different aspects. It is possible to assume as a qualitative measure of reputation the fidelity that clients has to *Goretti S.r.l.* and the name of clients that the company has (such as *Gucci, Luis Vuitton, Bottega Veneta…)*;
- Origin country: it is well known that Italy represent an icon in the fashion market; furthermore the region geographic territory which *Goretti S.r.l.* operates is divided in district (Figure II.3), and *Serra de' Conti* is inside footwear district.

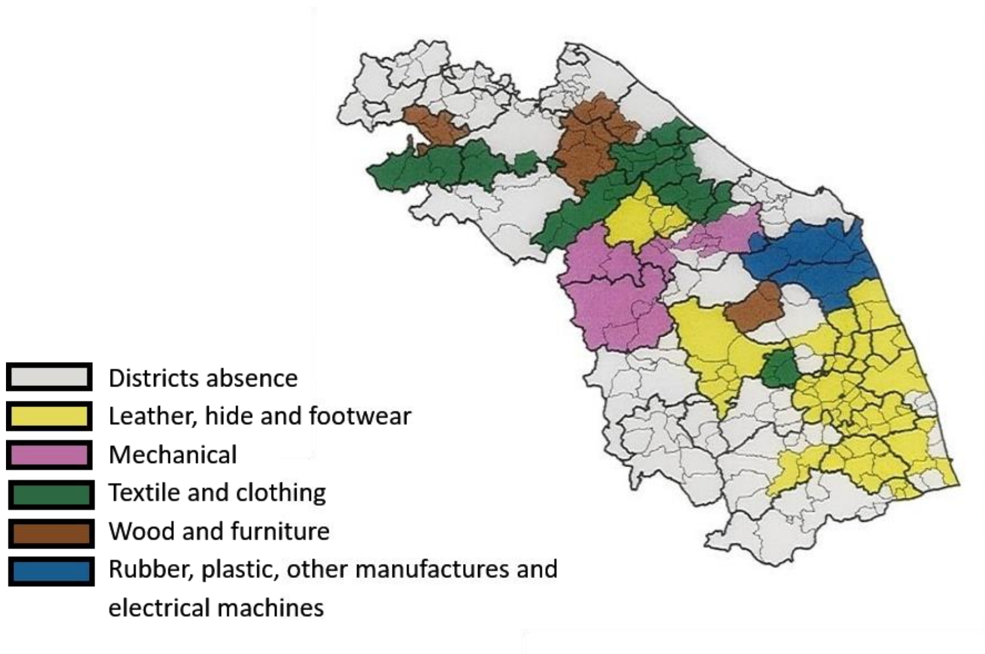


Figure II.3 Representation of Marche district. The legend represents the district sector focus[18]

- Uniqueness of product: each product is worked both automatically and manually, it is normal to have small differences between one product and another (for example, small variations in colour shades, small variation in the position of strass…)

[18] 1991; *ISTAT*

Now it is the possibility to define the market as the group of companies which possess the CSFs listed above. This definition of the market is a clear simplification of what could be a very complex and deep analysis but nonetheless it is still valid. Because of the definition of the market and once attested that *Goretti S.r.l.* bears the characteristics of a luxury product company (i.e. it has the CSFs listed above) it is possible to conclude in which market the company operates and the characteristics of the market (such as value, supply chain, value added…).

2.2 MARKET EVALUATION

In order to have a view of the market size, here revenues will be analysed specifically for the fashion market. Because the company operates in Italy then Italian market will be took in consideration initially and then it will be inspected the influence of Italian market in European one. Finally a look will be given to the worldwide market. Difficulties defining luxury bring to different definition of the luxury market and therefore it is difficult to identify data with a homogeneous and logic basis which allows comparable data. Therefore there is the need of a standardized definition of the market which still allows to get hold of valuable data, with homogeneous basis, but still in accordance with the definition given above to luxury goods. United Nation (UN) created in 1948 the first edition of the "*International Standard Industrial Classification"* (*ISIC*) which s a classification of economic activities with the purpose of divulge at international level comparable statistical data about economic activities. The last revision of *ISIC* standard was accomplished in 2008. In order to be compliance with this standardisation *European Union* (*EU*) modified the old version of the "*Nomenclature statistique des activités économiques dans la Communauté européenne*" (*NACE*) of 1970. The Italian body in charge of converting the European standard in domestic ones is the "*Istituto nazionale di statistica*" (*ISTAT*) which transforms *NACE* standards into "*Attività economiche*" (*ATECO*) standard, the last revision of this standard create a new one called "*ATECO 2007*". *ATECO 2007* standard divides the economic activities in seventeen "Sections" indicated by a capital letter (from A to U) reported in Table II.1; each section is then divided in "Divisions" (a progressive number for each division of the same section), each division is divided in "Groups" (indicated by the number of the division plus a dot plus an incremental number) and each group in "Classes" (indicated by the group name plus a progressive number). An example of nomenclature is give in Figure II.4.

Table II.1 Economic classification of activities "Ateco 2007"[19].

ATECO 2007	
Sections	Descriptions
A	Agriculture, ladle farming and fishing
B	Mining activity
C	Manufacturing activity
D E	Electricity supply, gas steam and air conditioning. Water supply, sewerage, waste treatment and sanitation activities
F	Buildings
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
I	Accommodation and catering services
H J	Transport and storage Information and communication services
K	Financial and insurance activities
L M N	Real estate activities Professional, scientific and technical activities Administrative activities
O	Public administration and defence; compulsory social insurance
P	Education
Q	Health and social care
R S	Arts, entertainment and entertainment Other service activities
T	Activities of households as employers of domestic workers; production of goods and services undifferentiated for own use by households
U	Activities of extraterritorial organisations and bodies

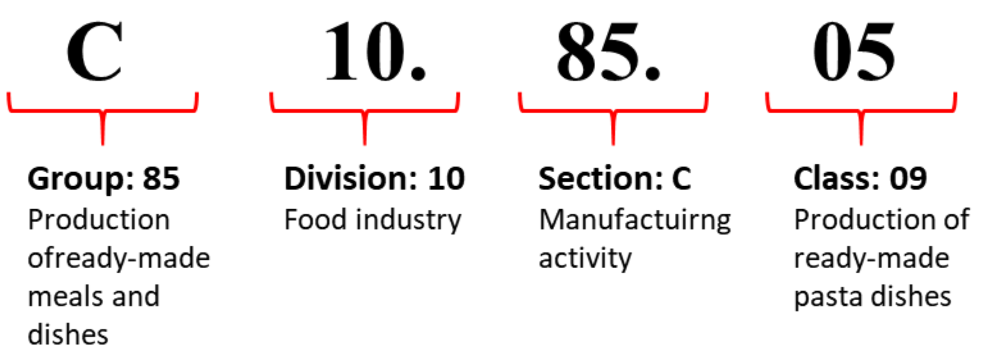


Figure II.4 Schematic representation of indication for a specific economic activity: production of ready-made pasta dishes.

The code selected to statistically evaluate the market, from an economic point of view, include three different division of the same section, section *C manufacturing activities*:

- *C13: Textile industry;*

[19] 2009; "Classificazione delle attività economiche Ateco 2007"; *ISTAT, servizio produzione editoriale*

- *C14: Confection of wearing articles; confection of leather and fur articles;*
- *C15: Manufacture of leather articles or similar.*

In this way, the classification selected, respect the definition of luxury good based on CSFs and at the same time are comparable data. It is true that these date do not fully analyse neither the fashion luxury market nor the *Goretti S.r.l.* production items (such as accessories, jewellery…), but at the same time it is a good benchmark to have a comprehensive view of the fashion market which is principally driven by these three categories. Nevertheless the same approach was used by *Monte dei Paschi di Siena* in a 2017 presentation by the department of "*Studies and research*" analysing the fashion Italian market[20].

2.2.1 ITALIAN MARKET

ISTAT provides data from 2011 to 2019 excluding the current year for obvious reasons. Here a summary of data collected *and* graphically represented in Figure II.5*.* There is also a representation of the growth of the Italian market in Figure II.6*.*

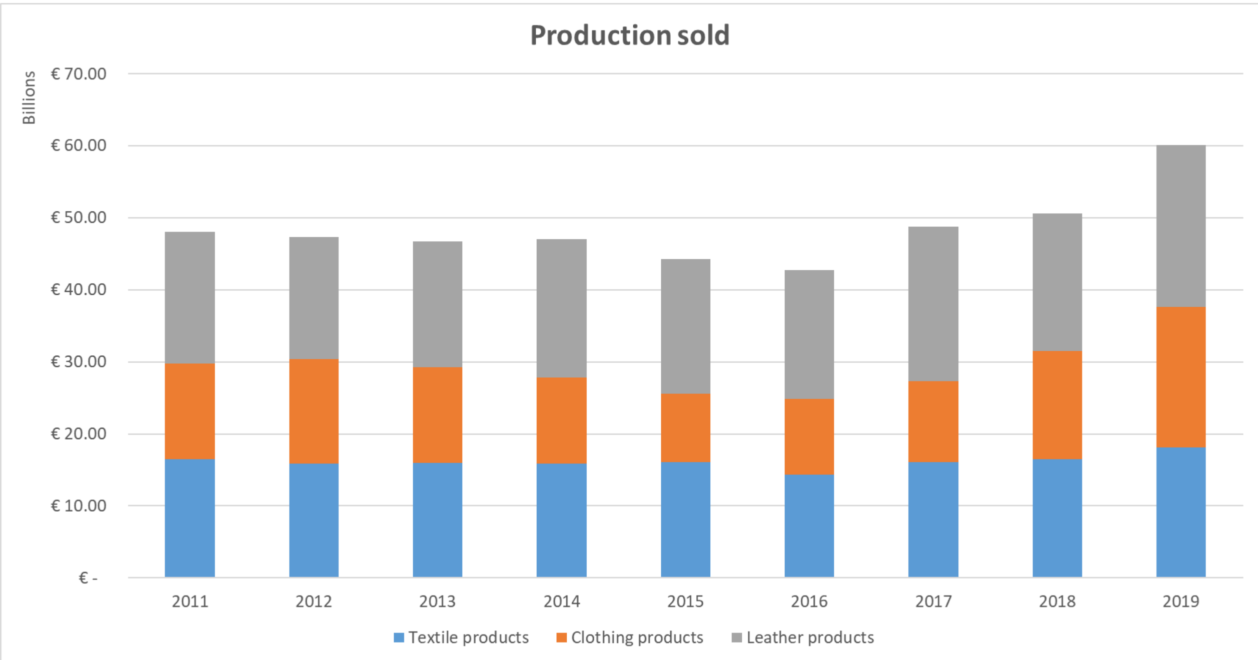


Figure II.5 Graphical representation of Italian market for production sold in fashion industry classified on the three different economic activity analysed.

[20] Paolo Ceccherini; 2017; "L'industria italiana della moda: analisi del settore tessile, abbigliamento e pelle"; *Servizio Studi e Ricerche Monte dei Paschi di Siena*

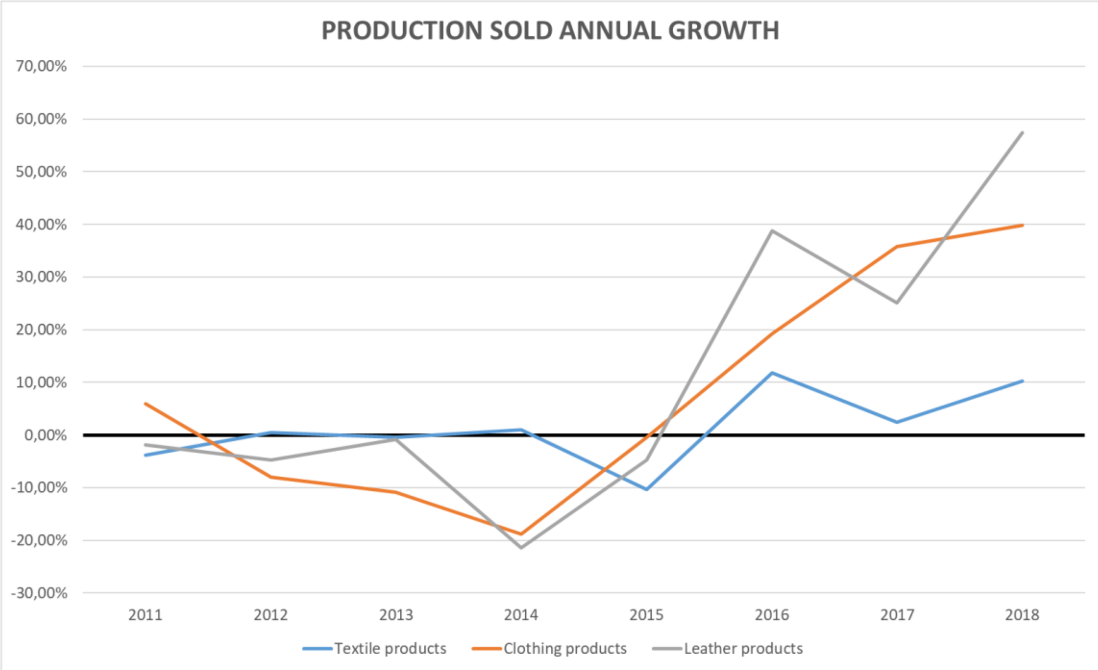


Figure II.6 Representation of the yearly growth of the Italian fashion market from 2011 to 2018 in terms of production sold (based on previous year). It represents the trend of the three different economic activities considered.

These data are confirmed by another independent carried out by studies area of *MedioBanca* in February 2020 which for the period 2014-2018 report very similar data[21]. The analysis is run on aggregated balance sheet of 173 firms located in Italy (registered office) with a minimum turnover of 100,000,000.00€ in 2018, data reported are compared to ISTAT data in Figure II.7.

[21] 2020; "Focus "aziende moda Italia" (2014-2018)"; *MedioBanca*

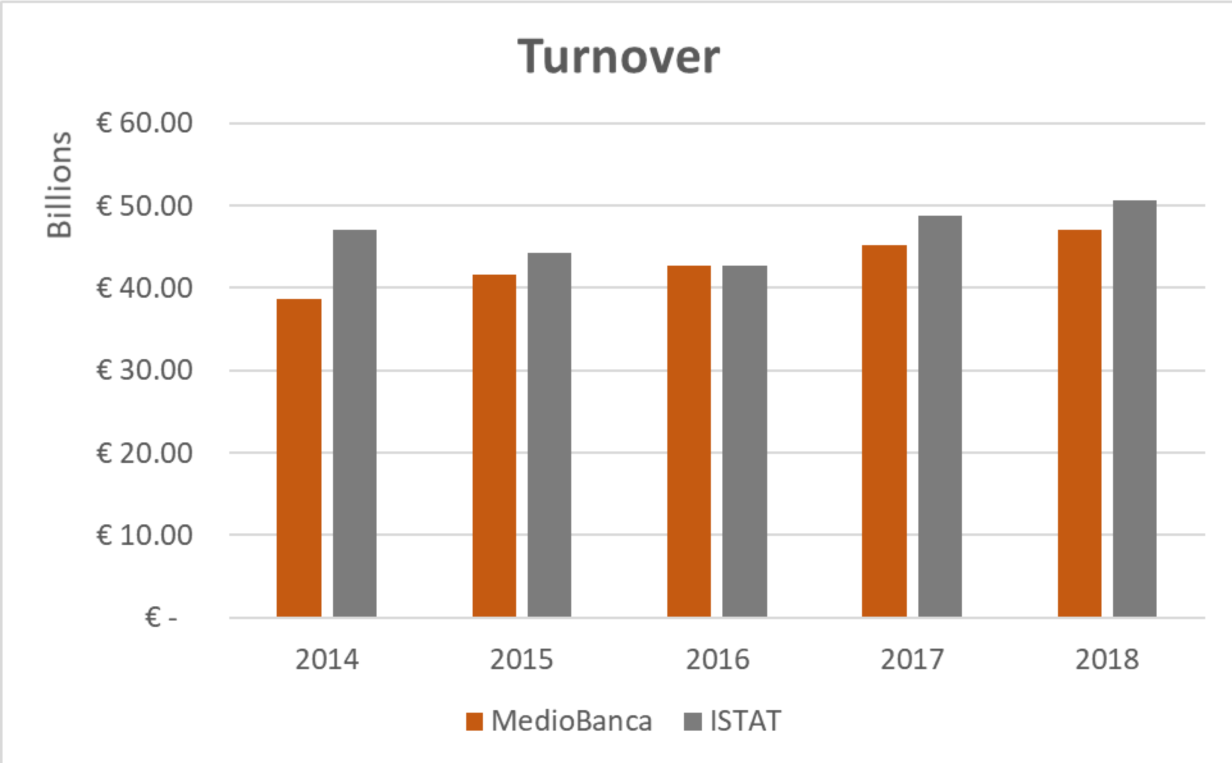


Figure II.7 Comparison between data collected by ISTAT and another indipendent source (MedioBanca) on turnover.

What emerge from the analysis is that the fashion market is a very important market in Italy. In 2018 with about fifty billion turnover it influenced for 1.2% the Italian gross domestic product (GDP). It is useful to investigate deeper the market in which *Goretti S.r.l.* operates, that is to say the small and medium enterprises (SME). *Confartigianato,* which is the Italian trade association for artisans representation, reported a study on the fashion market in 2019 where wrote a focus on SMEs. In Italy SMEs operating in fashion market are 55,491; and only considering SME, employees amount to 311,697 workers[22] (Figure II.8).

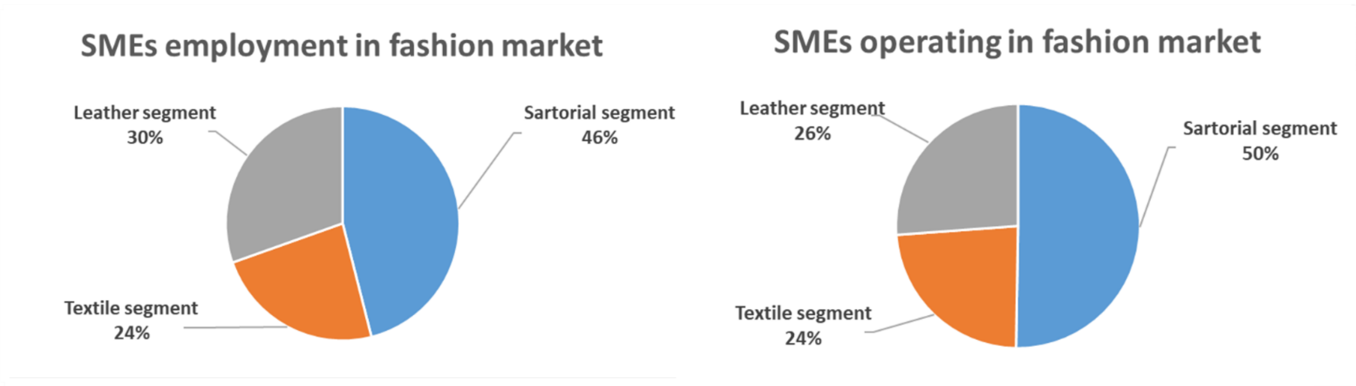


Figure II.8 On the left a representation of the employment in fashion market divided by economic activities. On the right the amount of SMEs operating in fashion market divided by economic activities.

[22] 2019; "STUDI – Moda, punto di forza del made in Italy grazie a 79 mila MPI che danno lavoro a 372 mila addetti. L'artigianato della moda fattura 21,3 miliardi di euro e genera 6,1 miliardi di valore aggiunto"; *Confartigianato Imprese*

The numbers above reported place Italy as first country in Europe for workers number in these three sectors. In particular, the region in which *Goretti S.r.l.* is located (*Marche*) is second placed in Italy for workers quota: 6% against 7.5% of Tuscany and 1.8% of national average.

It is possible to understand how a negative performance in Italian fashion market can create crisis in terms of Italian GDP and occupation. Here it is why there is apprehension for 2020 year. In June *Unicredit* run an investigation to detect the effects of Covid-19 on this fundamental market. What emerged were two hypotheses defined "*Soft*" and "*Hard*" (Figure II.9). In both case fashion market will suffer a strong and important setback loosing from 17% to 25% in terms of turnover. The "*Soft"* scenario forecast a loss 17.5% with respect to 2019 turnover but with a strong restart in 2021 which will bridge almost completely 2020 losses. The "*Hard*" *scenario* instead forecast losses for one fourth 2019 turnover (25.4%) and two different restart in 2021: the first one called "U-shaped trend" where the restart will be constant and a second one called "W-shaped trend" in which the restart will swing around an average value.

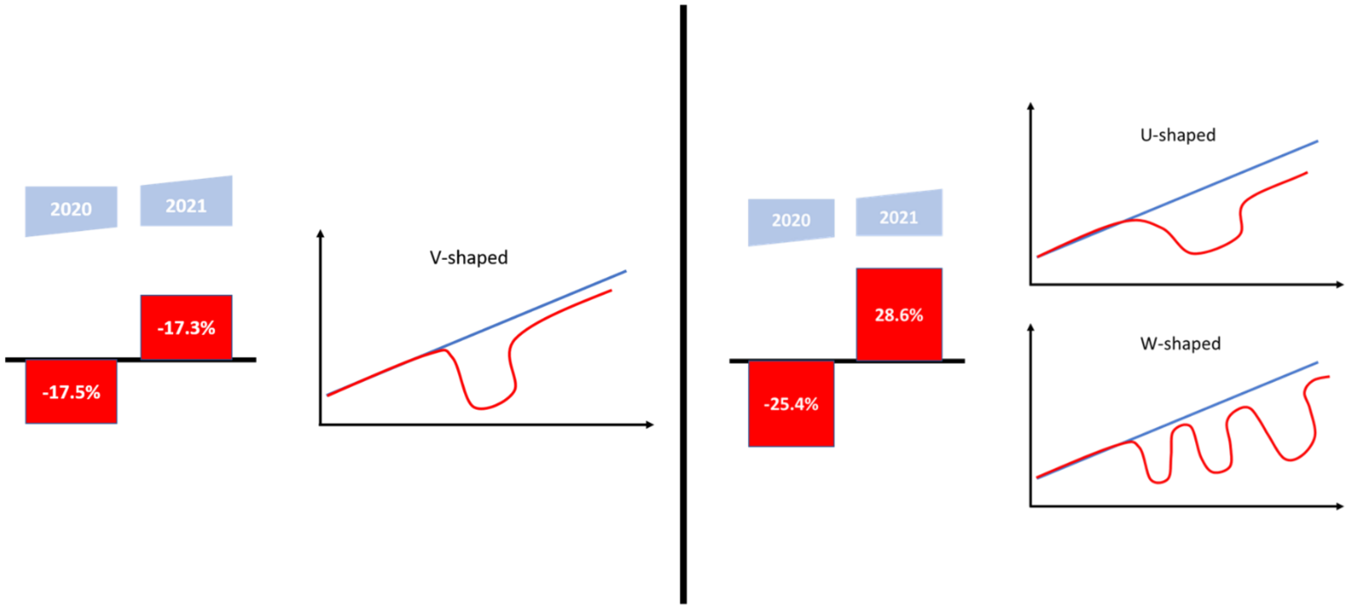


Figure II.9 Graphical qualitative representation of two possible scenarios on market trend for 2020 and 2021. On the left the "Soft" scenario and on the right the "Hard" scenario[23]

In September *Confindustria moda* (which is an Italian industrial organization aimed to protect and represent firms focused on fashion sector), analysed Covid-19 effect based on the real turnover data obtained comparing the first trimester of 2020 with first trimester of 2019. What emerged from the analysis is that 86%[24] of companies working in fashion market suffered a decrease in turnover, 14% of companies instead were able to has a turnover growth or maintain it constant. Analysing the companies that suffered turnover decrease (so the 86% of fashion companies) the result is the one reported in Figure II.10.

[23] 2020; "The Italian way"; UniCredit

[24] Cornaz; 2020; "Settore tessile-abbigliamento-moda: crolla il fatturato"; *Corriere Nazionale*

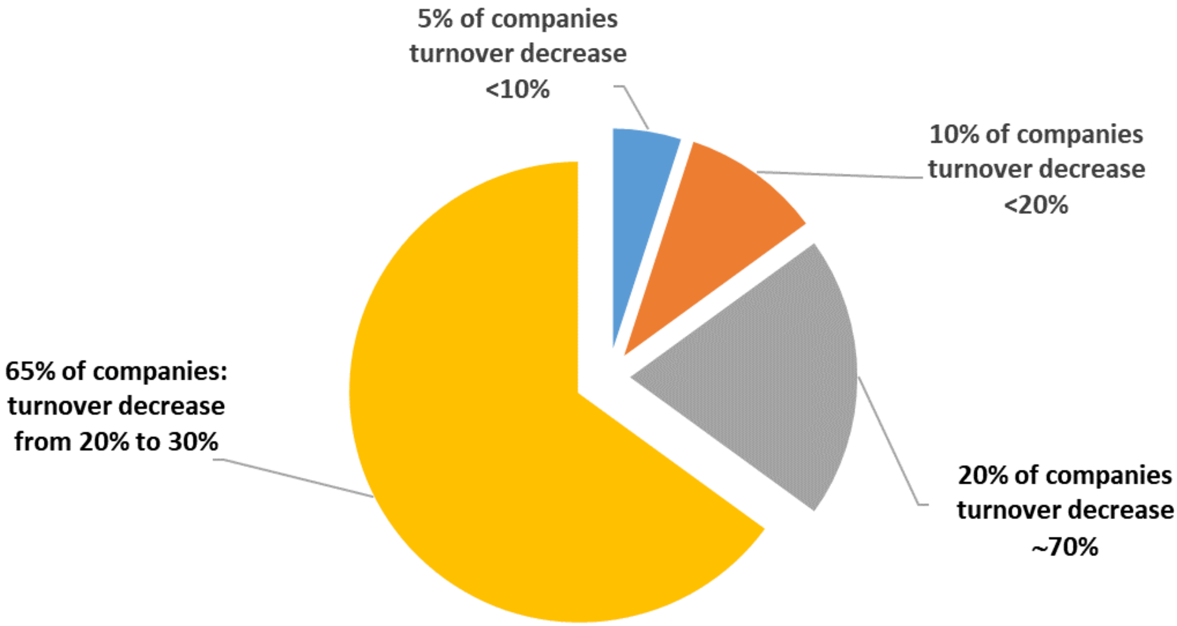


Figure II.10 86% of companies operating in fashion market reported a decrease in turnover. Based on data collected, decrease is distributed as shown.

Based on these data, *Confindustria moda* forecast a decrease of 39% on turnover for 2020 second trimester with respect to 2019 second trimester.

2.2.2 EUROPEAN MARKET

The importance of fashion in the Italian market has been clearly stated but it is useful too precisely locate Italian market in the European context both to place Italy in an international market and to evaluate the influence of European market on communitarian decision. An important role in recording market data is played by *Euratex* which is the European apparel and textile confederation aimed to represent the market and coordinate different country company in a community setting. *Euratex* creates each year a report anayzing the condition of the market and it makes public the document. It was possible to create the table below collecting data emerged from the analysis of these reports about turnover in textile and clothing of European market is reported in Figure II.11.

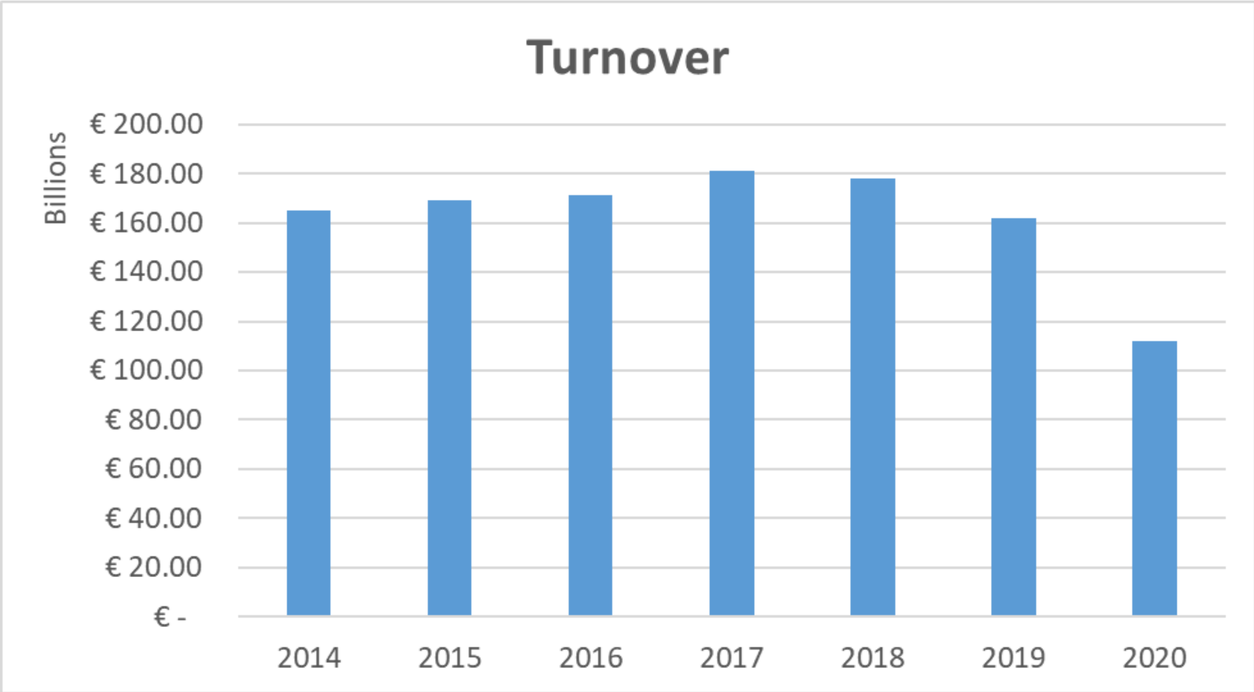


Figure II.11 Turnover data of European fashion market.

Italy in the big picture of European market covers an important role: the companies acting in the textile and clothing market in Italy are more than forty thousands and the second highest number of company in the same sector is held by Czech republic with more than ten thousands (and less than fifteen) companies. According with this data Italy bears also the highest number of employees which, together with Romania Poland and Portugal, it accounts for more than the fifty percent of all European market[25]. Italy comes out as the biggest producer in Europe (followed by France and Germany)[26]. A very important aspect to understand the validity of Italy inside the European apparel market is import/export analysis. The first 2019 European importer in apparel sector is Germany with a nineteen billion of import it constitute the 23% of all European import. Italy set in fifth position with eight billion of import, so 10% of European apparel import, it is interesting to highlight how the first eight country for import amount represent more than the 75% total European apparel import. About export instead Italy is the leader with twelve billion of export, about 34% of all Europe (followed by Germany with 16% and then Spain with 15%)[27]. Finally the European market total net sales: in 2018 France guided the list accounting for 34.6%and then Germany and Spain. Even if Italy is not on the podium of net sales, it is clear from the analysis that Italy represents strength in the European luxury market. An important dynamic of the market must be highlighted: France is the first European fashion market country for net sales and turnover but this has an interesting motivation. The power of France is determined by the presence of big fashion group (LVMH which is the biggest fashion group in Europe with about forty-seven billion of sales) but low level of production. Italy is exactly the other way around: there are not big fashion groups but high production companies[28].

[25] 2019; “Annual report 2018”; *Euratex*
[26] “Internal market, industry, entrepreneurship and SMEs: textile and clothing in the EU”, *European commission*
[27] 2020; “Where do our clothes come from?”; *Eurostat*
[28] 2020; “Report on large Italian and European fashion companies”; *Area studi MedioBanca*

At European level the Covid-19 pandemic will have a negative effect. *Euratex* carried out a forecast on 2020 year based on survey submitted to companies. The impact on turnover is forecast in a negative fifty billion euro, as to say a degrowth of 30% of the market turnover with respect to 2019 turnover. This negative effect on market value will surely have an impact on employments level: in the survey *Euratex* submitted to companies for the question about measures to stem losses, 73% of interviewed company replied that they would opt for a reduction of workforce[29].

2.2.3 WORLD MARKET

The attractivity of the market at Italian level and the importance of the market at European level is evident. Now it can be useful to test the capability of domestic market from a global point of view. *Common Objective* is a network for the fashion industry. Analysing *Common Objective* report came out that the world market value for fashion retail is about 1.78 trillion USD. It represents an increase of market size of about 14%[30].

The association *International apparel federation* (*iaf*) mission statement is to unite stakeholders of fashion industry from all over the world with the aim of creating (or making) stronger the supply chain. The association also takes care of creating statistics on the global market. At this level the small reality of Italy competes with giants such as the USA, China, India; this must be taken into consideration when analysing the result of statistics. A first look should be given to the apparel markets dimension given by the retail sale price. The first important market in 2016 is (not surprisingly) China, followed up by the USA and Germany. Italy maintain an important sixth place in a global environment.

Another very important index of the wealth of a market and of its strength is the exports. A marked simplification to describe the relation between exports and market wealth is that higher is the exportation of a country and stronger is the market (graphical representation reported in Figure II.12). What came out from statistics is that Italy, until 2012 was the second country in the world for export. From 2012 to 2014 it still held the second place but together with Bangladesh and then in 2015, caused by a fall in exports, Italy drop from second to fourth place after Bangladesh and Viet Nam. This is reported in the graph below.

[29] 2020; "Euratex activity update: June 2019-June 2020"; *Euratex*

[30] Clare Lissaman; 2019; "The size of the Global Fashion Retail Market"; *Common Objective*

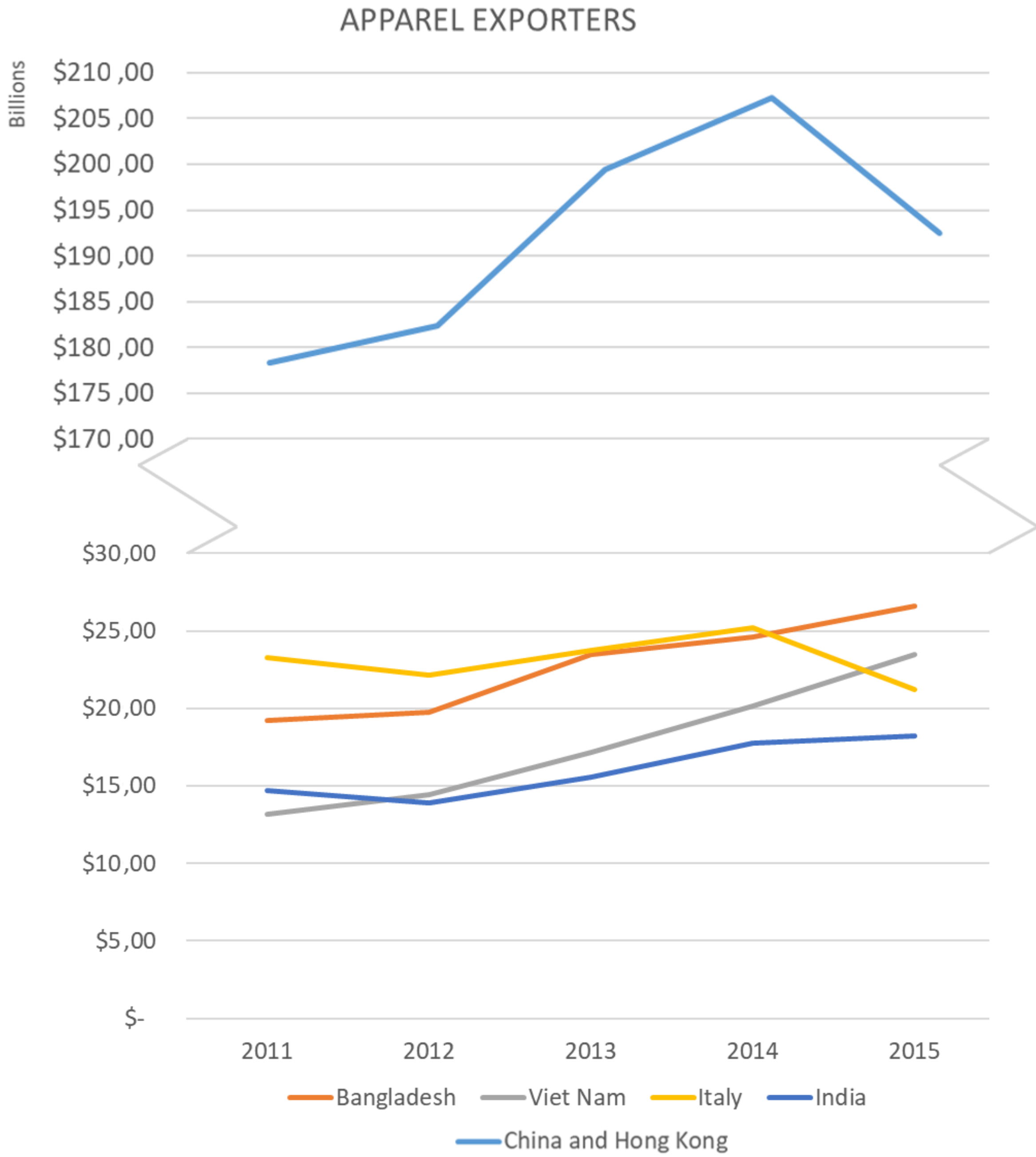


Figure II.12 Marked exportation value for each country in the apparel market as production exports.[31]

Some trends characterize the global market in pre-Covid period and trends in 2020, which now will be analysed. *McKinsey Global Institute* create an annual report on fashion market wealth and trends which may help understanding better the market. What results from the last analysis of 2019 is that already (in 2019) there were indicators that suggested a slowdown of the fashion market in the world, this because fashion market is entering in a period of changes. In fact, what is happening is the construction of a new paradigm, an indication of this event is big brands started to destroy their business models. The drivers of this change are two: younger market looking for innovation and improvement in digital area. What came out from a *McKinsey Global Institute* market research is that young people prefer small brands, with a story to tell, to big and established brands. This change

[31] 2016; "Industry statistics"; *International apparel federation*

brought big players (and therefore the highest share of the market turnover) to change their view and approach to the market, hard to do in a big company, and therefore there is instability in these companies which brings to an obligatory brake to the market[32]. Logically no one expected Covid-19 pandemic, therefore in next years there will be the possibility to control if the emerging paradigm resisted to the pandemic or if the old one did, there is also a third option where a new paradigm emerges. In accordance with this analysis and the driver of change on digital area, it is possible to spot a new and future trend of this market: analysis tools. In fact the possibility of collecting data and analysing them help companies controlling cost and customers satisfaction. *Goretti S.r.l.* is perfectly approached to this scenario as it is trying to create tools that help management monitoring the company. Because of this shift toward monitoring a more relevant role will be hold by cost: cost of material, labour cost and others. Chinese market suppliers find difficult to adapt to this new approach of the market (due to government policies) and therefor global market is shifting the supply of materials to other countries. This way brings India, Viet Nam and Bangladesh to acquire more client and grow their influence in the global market as share of it in terms of exports[33]. Another important trend related to digital area is the digitalization of the retail market itself, which is shifting from the big companies' atelier to the easiest and better accessible online store.

2.3 MARKET DYNAMICS (AND REAL GORETTI S.R.L.'S EXAMPLE)

The importance of the market in terms of economic value as been defined at different layer. Along with this it is fundamental to explain the peculiarity of the market at real functioning of the supply chain level. In order to have a description useful to understand the *Goretti S.r.l.* environment, the analysis will be carried out from a supplier point of view.

The market is still strictly related to what the brand thinks the final client expect from the product and it is a strongly contractors' market. Then it is useful to understand the real structure of the market. A brief overlook can help understanding better the needed further analysis. About the creation of a new product, this is created (directly and only exclusively or not exclusively) by brands. Then brands create an order submitted to a cluster of suppliers directly selected by the brand most of the cases. At this level two option are possible: creating a cluster with a senior assistant or with the brand itself as senior assistant. If it is present, then the communication with brand and between suppliers and the scheduling of the production is upon the senior assistant, otherwise the brand (client) directly schedule the order. Usually the number of suppliers for what concern machining are four or five while materials suppliers are between ten and fifteen (these data are approximation of average conditions).

It is now possible to analyse the supply chain of the fashion system based on a benchmark: *Goretti S.r.l.*. The new product can be created exclusively or not by the brand, this means that brands have designer able to create new product but sometimes it happen that the client take inspiration from suppliers exhibition panels which are sample (in Italian "*campionario*") presentation. In this second case it is difficult that a brand takes as it is the product of a supplier, about for the 99% of cases brands rework this product to add more aspect in line with brand's style. The output of this creative process rarely is a digital technical work but more often is a handmade sketch or a model drawing

[32] Imran Amed, Achim Berg 2019, *et al.*; "The state of fashion 2019"; *Business of Fashion (BOF)*
[33] Sulakshna Sharma; 2018; "Global Apparel Market Outlook for 2019", *Fibre2Fashion.com*

(which is the real case shown in Figure II.13) or, in some cases, just an idea that is communicated to the suppliers.

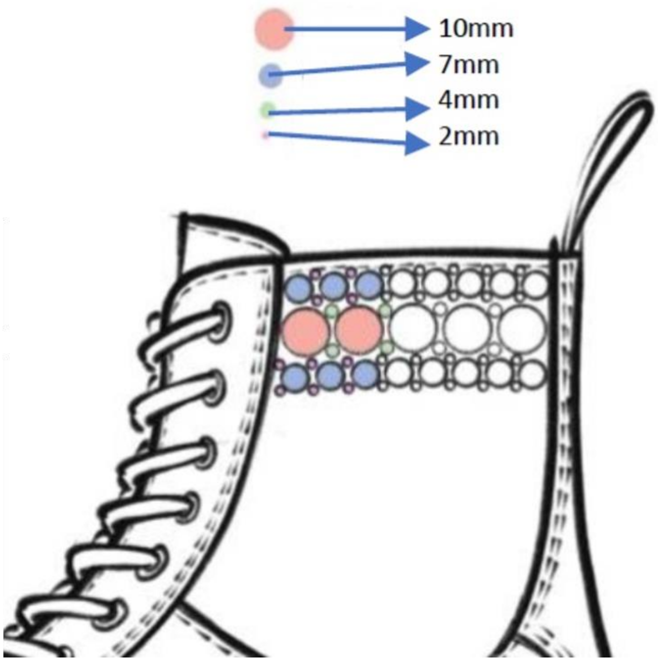


Figure II.13 This is a real example of drawing which a brand created to communicate suppliers what to do. It is possible to notice that here the brand reported the measure of decoration to be used.

After the creation of the model, the brand creates a cluster of suppliers. The companies to be introduced in the cluster are based principally on three parameters: expert in the work, past practices, evaluation of the company. The last parameter is a value given by the senior assistant or, in some cases, by the brand itself, to suppliers; it is used only with some brands. After the selection of companies to be set in the cluster, the brand defines the senior assistant which can be or a supplier or the brand itself. In case of brand as senior assistant then the suppliers will interact directly with the brand which will define the scheduling and deadlines. In case of one supplier as senior assistant instead, it is charged to schedule the production and it act like an agent for the client. The communication of being part of a cluster is divided in two phases: in a first communication the brand notifies to the single suppliers the willingness to produce a specific product, in a second communication the brand notify who is the senior assistant, below there is a real example how this communication occurs (some info are censured for confidentiality obligations).

"as from telephone agreements I send you files for pearls applications for [redacted] *prototype.* [redacted] *[senior assistant, ed.] , in CC, will give you details about pearls' measures and colours. […]"*

Once the cluster is organized the brand can ask for different kind of work such as: orders, production, pre series or other kind of work. In order to do so, the suppliers need to convert the idea of the brand into a digital sketch in modelling office. It is usual to require an order to control how is the real feelings coming from the sketch/idea of client, so after the order is finished the client can ask the same cluster for pre-series and then production. In Figure II.14 a graphical representation of the supply chain above described.

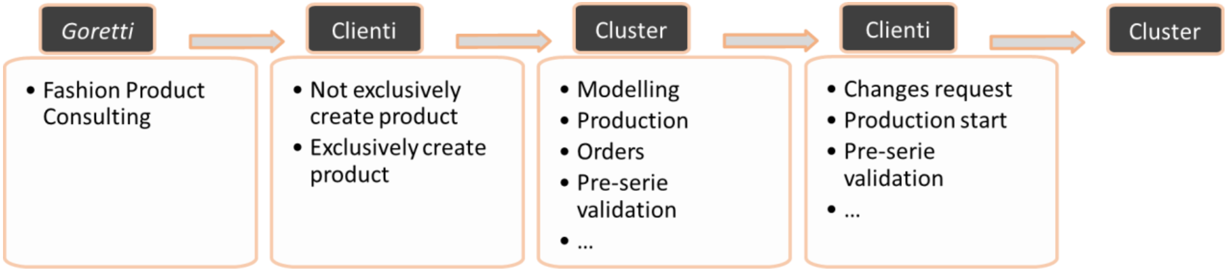


Figure II.14 Graphical representation of a simplified supply chain.

An aspect to analyse in this complex structure are communications. In fact planning an order based on a graphical sketch can easily bring to misunderstanding, delay and poor coordination. Because of this there is a high communication level between suppliers that try to involve clients as little as possible and only in case of problems and misunderstanding. It is possible to say that there is a constant flow of information and communications between suppliers that help planning and monitoring (therefore continuously planning again) the work. The communication between companies in a cluster is limited to the communication with the senior assistant. In fact it is possible that a supplier does not know all the companies in the cluster and therefore cannot communicate with them. In case of important communication a supplier must still speak directly with the senior assistant but can communicate with the brand carbon copy (CC).

The influence of the senior assistant in the production process is very important and of high responsibility. In fact even if the delivery is chosen by the brand, the milestones and delivery of single suppliers are chosen by senior assistant (which must CC the brand). Furthermore the control over the produced pert is upon senior assistant which, in some case, can require delivery to him each supplier product and then himself ships the product to the next supplier. Another aspect that point out the importance of this figure is the possibility of the senior assistant to determine some micro-production phases: even if the brand decide which supplier must accomplish which task, there are some interchangeable operations. These operations are upon the supplier decided by the senior assistant.

A last important aspect is the control over the production. Because of the checkered demand in the market and because of the strong contractor plant that the market is, it is difficult to have forecast or control over production. This mean that the planification done at cluster level trust more the feeling of management that real data. Because of the high experience of companies in this sector, the feeling are mostly spot-on, but there is still the possibility to have a crisis of the production. This may be guided by an overestimation of the production ability of the company (again because an absence of production control), or an underestimation. An important absence on the monitoring of the production process lead therefor to an increase in cost and to a lack of control over the company.

2.3.1 The company dynamics

Goretti S.r.l. place in the market as a SME with a 2019 turnover of about thirteen million and half (with yearly growth rate until 20%); and seventy employees. The company operates with important brands such as: *Bottega veneta, Alexander McQueen, Dolce e Gabbana, Balenciaga, Chanel, Dior, Louis Vuitton* and others.

For what concern supplier cluster, *Goretti S.r.l.* operate in group with an average of four or five machining suppliers. Logically the problem that characterize the market, so the lack of monitoring system, affect the company too. This is represented by the inability to determine the production capacity or the duration in terms of time of an operation. Consequently there are drop-down issues such as the difficulties in scheduling the production or determining the saturation of machinery and operators which may lead to chaotic environment when the production increase abruptly (keep in mind that fashion is a strongly seasonal market). The dimension of the company influence in the difficulties of monitoring: the increase of orders in the last year rendered the old monitoring and management system obsolete and not adapt to the new production volumes. Another important factor is the increase in dimension: the company employed four people thirty years ago and then a strong growth the last 10 years. In this period the employees reach peak of one hundred and fifty people and an average sixty employees. An important indicator of stability of the company is the fact that during covid-19 period there was not a variation in the number of employees.

The changes in the fashion market brought the managers of *Goretti S.r.l.* to particular strategic decision. In fact the company headed in the direction of strong vertical integration trying to get as much work as possible from the beginning of the process to the end. In fact, even if *Goretti S.r.l.* handles the application of decorations on shoes and accessories for luxury fashion, it is strictly related to company in the creative activity consulting (so the first step of supply chain: the creation of the model), to company that create accessories and decoration, and to company that cover decoration material. It is evident the intent of being an unique supplier for an entire order traying in this way to leap the cluster organization.

2.4 CHAPTER SUMMARY

Goretti S.r.l. is a textile company which operates in the luxury fashion segment. It is located in *Serra de' Conti* (Ancona, Italy). The company handles the application of decorations on shoes and accessories for luxury fashion. The segment in which *Goretti S.r.l.* operates requires high ability of adaptation to stay competitive with the market maintaining profits and high-quality standard.

In order to have a view of the market size, here revenues will be analysed specifically for the fashion market. Therefore there is the need of a standardized definition of the market which still allows to get hold of valuable data, with homogeneous basis. United Nation (UN) has a classification of economic activities: "*International Standard Industrial Classification"* (*ISIC*). In order to be compliance with this standardisation, *European Union* (*EU*) updated the "*Nomenclature statistique des activités économiques dans la Communauté européenne*" (*NACE*) of 1970. The Italian standard based on these classification is codified into: "*Attività economiche*" (*ATECO*) standard. The code selected to statistically evaluate the market, from an economic point of view, include three different division of the same section, section *C manufacturing activities*:

- *C13: Textile industry;*
- *C14: Confection of wearing articles; confection of leather and fur articles;*
- *C15: Manufacture of leather articles or similar.*

What emerge from the analysis is that the fashion market is a very important market in Italy. In 2018 with about fifty billion turnover it influenced for 1.2% the Italian gross domestic product (GDP). It is useful to investigate deeper the market in which *Goretti S.r.l.* operates, that is to say the small and medium enterprises (SME). In Italy SMEs operating in fashion market are 55,491; and only considering SME, employees amount to 311,697 workers[34] The numbers above reported place Italy as first country in Europe for workers number in these three sectors. In particular, the region in which *Goretti S.r.l.* is located (*Marche*) is second placed in Italy for workers quota: 6% against 7.5% of Tuscany and 1.8% of national average.

It has been then precisely locate Italian market in the European context both to place Italy in an international market and to evaluate the influence of European market on communitarian decision. Italy in the big picture of European market covers an important role: Italy has the highest number of the companies acting in the textile and clothing market in Europe (more than forty thousands), the second highest number of company in the same sector is held by Czech republic with more than ten thousands (and less than fifteen) companies. Furthermore Italy bears also the highest number of employees which, together with Romania Poland and Portugal, it accounts for more than the fifty percent of all European market25[25 above25]. Italy comes out as the biggest producer in Europe (followed by France and Germany)[26]. A very important aspect to understand the validity of Italy inside the European apparel market is import/export analysis. An important dynamic of the market must be highlighted: France is the first European fashion market country for net sales and turnover but this has an interesting motivation. The power of France is determined by the presence of big fashion group (LVMH which is the biggest fashion group in Europe with about forty-seven billion of sales) but low level of production. Italy is exactly the other way around: there are not big fashion groups but high production companies[28]. About export Italy is the leader with twelve billion of export, about 34% of all Europe (followed by Germany with 16% and then Spain with 15%)[27]. The European market total net sales was higher that 160 billion Euro in 2019, France guided the list accounting for 34.6% and then Germany and Spain.

Then it has been tested the capability of domestic market from a global point of view. The world market value for fashion retail is about 1.78 trillion USD. It represents an increase of market size of about 14%[30] with respect to 2018. What came out from statistics is that Italy, until 2012 was the second country in the world for export. From 2012 to 2014 it still held the second place but together with Bangladesh and then in 2015, caused by a fall in exports, Italy drop from second to fourth place after Bangladesh and Viet Nam.

About 2020 and covid-19 pandemic, emerged that all the market will suffer a decrease in turnover:

- *Confindustria moda* forecast for Italy a decrease of 39% on turnover for 2020 second trimester with respect to 2019 second trimester.
- At European level the impact on turnover is forecast in a negative fifty billion euro, as to say a degrowth of 30% of the market turnover with respect to 2019 turnover. This negative effect on market value will surely have an impact on employments level: in the survey *Euratex* submitted to companies for the question about measures to stem losses, 73% of interviewed company replied that they would opt for a reduction of workforce[29].

[34] 2019; "STUDI – Moda, punto di forza del made in Italy grazie a 79 mila MPI che danno lavoro a 372 mila addetti. L'artigianato della moda fattura 21,3 miliardi di euro e genera 6,1 miliardi di valore aggiunto"; *Confartigianato Imprese*

- There are still no data of forecast of world textile and clothing market.

Then it was carried out an analysis on the dynamics which characterize the market. The market is still strictly related to what the brand thinks the final client expect from the product and it is a strongly contractors' market. The procedure to create a new product is started (directly and only exclusively or not exclusively) by brands. Then brands create an order submitted to a cluster of suppliers directly selected by the brand most of the cases. At this level two option are possible: creating a cluster with a senior assistant or with the brand itself as senior assistant. Usually the number of suppliers for what concern machining are four or five while materials suppliers are between ten and fifteen (these data are approximation of average conditions). The cluster structure (with or without senior assistant) influence the communications structure. There is a high communication level between suppliers that try to involve clients as little as possible and only in case of problems and misunderstanding. The communication between companies in a cluster is limited to the communication with the senior assistant. In fact it is possible that a supplier does not know all the companies in the cluster and therefore cannot communicate with them. In case of important communication a supplier must still speak directly with the senior assistant but can communicate with the brand carbon copy (CC).

Because of the checkered demand in the market and because of the strong contractor plant that the market is, it is difficult to have forecast or control over production. This mean that the planification done at cluster level trust more the feeling of management that real data. Because of the high experience of companies in this sector, the feeling are mostly spot-on, but there is still the possibility to have a crisis of the production. This may be guided by an overestimation of the production ability of the company (again because an absence of production control), or an underestimation. An important absence on the monitoring of the production process lead therefor to an increase in cost and to a lack of control over the company. Logically the problem that characterize the market, so the lack of monitoring system, affect the company too. This is represented by the inability to determine the production capacity or the duration in terms of time of an operation. Consequently there are drop-down issues such as the difficulties in scheduling the production or determining the saturation of machinery and operators which may lead to chaotic environment when the production increase abruptly (keep in mind that fashion is a strongly seasonal market).

CHAPTER III DESIGN OF EXPERIMENTS

To understand the work done, before exploring the work accomplished during the thesis period in *Goretti S.r.l.*, it is necessary to explain why the study is needed and how it can influence the company's performances.

3.1 EXTERNAL AND INTERNAL ENVIRONMENT: CHOICES, DISCUSSION AND EVALUATION

3.1.1 EXTERNAL ENVIRONMENT

The knowledge about the company market environment it is necessary to understand the company needs and its procedures. This analysis will be carried out from a supplier in the fashion market point of view because this is the condition of *Goretti. S.r.l.*. The fashion luxury is a strongly customers driven market, this means that brands (*Goretti S.r.l.*'s clients) must spot the willingness of the customers in order to satisfy their demand. The structure the market acquired to answers the checkered demand bring to a very diversified range of product. Brands have difficulties in determine what the customer is willing to have also because demand is not always clear, that is continuously changing and that is strongly seasonal, therefore brands must do a creative job to extrapolate the clients' expected products. In order to define if a product can satisfy final customers' needs, brands designed lots of sample created on trends and feeling basis and brands produce these idea through the work of suppliers cluster which will export the idea design firstly in digital form and then in real form. Indeed, the idea itself is not enough to understand if the final customers will appreciate the product, therefore the brands needs to create the physical product to have the *touch and feel* emotions that the product will transmit to final customers. To achieve the product that final customers will enjoy, there is the need of producing more and more samples but with just few units per product: brands do not need a production of thousands of units to understand the feeling, just few units are enough; a representation of this is the average production of new product *Goretti S.r.l.* has: one new product each two days throughout the whole year. To produce the order brands will collect clusters of suppliers to create one, two or three units of a sample. In Table III.1 a real example from *Goretti S.r.l.* which report all the orders (and just orders) that the company receive in one day (26th October 2020), the thirteen orders were created by twelve different brands. In order to maintain the industrial secret the codification used by the company is changed with a simple chronological order and the name of clients are tinted. The company received thirteen orders in a working day (8 hours) with the delivery time in one, two or at maximum three days. It is important to explain the codification of "Articles" column: the client can order couple if it is about footwear (and therefore even half couple), but at the same time if it is an article or a trial for a working procedure, can order pieces too.

Table III.1 It reports the daily order the company received in 26/10/2020. It reports the dispatch time too. Clients and order code are changed to maintain the industrial secret.

Order code	Client	Articles	Item date	Dispatch date
1	S[redacted]	9 piece	26/10/2020	28/10/2020
2	C[redacted]	1 piece	26/10/2020	28/10/2020
3	B[redacted]	1 piece	26/10/2020	27/10/2020
4	E[redacted]	2 pieces	26/10/2020	27/10/2020
5	D[redacted]	1 piece	26/10/2020	27/10/2020
6	D[redacted]	3 couple	26/10/2020	27/10/2020
7	C[redacted]	18 couple	26/10/2020	29/10/2020
8	D[redacted]	7 piece	26/10/2020	28/10/2020
9	E[redacted]	1 piece	26/10/2020	27/10/2020
10	A[redacted]	1 couple	26/10/2020	26/10/2020
11	M[redacted]	1 piece	26/10/2020	27/10/2020
12	D[redacted]	1 piece	26/10/2020	28/10/2020
13	T[redacted]	½ couple	26/10/2020	27/10/2020

The time to market (TTM) of the sample. It may seem unappropriated speaking about TTM because the production starts from an order and not from the creative idea, anyway the enterprise must develop the initial draft, therefore the term TTM is appropriate. TTM is usually quite short about one or two days but sometimes the brands can leave one week too. This market structure makes hard to predict the production trends as it is hard to forecast the fluctuations of demand and it is even more difficult understand how many samples each brand will need (to spot the awaited final product). It is possible to understand how the source of these issues is a checkered demand. The boundary conditions for *Goretti S.r.l* and therefore the market conditions result in difficulties on scheduling and planning the production for long period for the suppliers. In fact suppliers cannot (or can hardly) predict in advance what requests will brands do few days later. This mean that the planification done at cluster level trust more the feeling of management that real data. Because of the high experience of companies in this sector, the feelings are mostly spot-on, but there is still the possibility to have a crisis of the production. The difficulties came from external environment leads to planning issues from a *macro* point of view, as to say problems in planning the production and the humane resource needed in long term.

3.1.2 INTERNAL ENVIRONMENT

There are difficulties from a *micro* point of view too, these ones prevent suppliers from a daily production planning and they prevent the forecast of cost and time of production for a single product. The difficulties for the single supplier are still due to the external environment but dropping the *macro* aspect inside the company. The market condition which brings brands to create a large number of samples, inside the supplier are converted in the need of being able to highly diversify the production based on what the clients need. The need of diversification (required by brands to suppliers) is in terms of production process, in terms of materials and machining. Therefore a supplier must be able to change rapidly the production process used for sample (or a previous production) changing the physical path of the materials, changing raw material and changing machining too. This approach logically has consequences in terms of managing the company. It is hard to forecast time because of the differences from sample to sample and the possibility (very high) to have a sample with never done path before, it is hard to predict. In Figure III.1 it is reported a real example of *Goretti S.r.l.* production cycle for two products completely different.

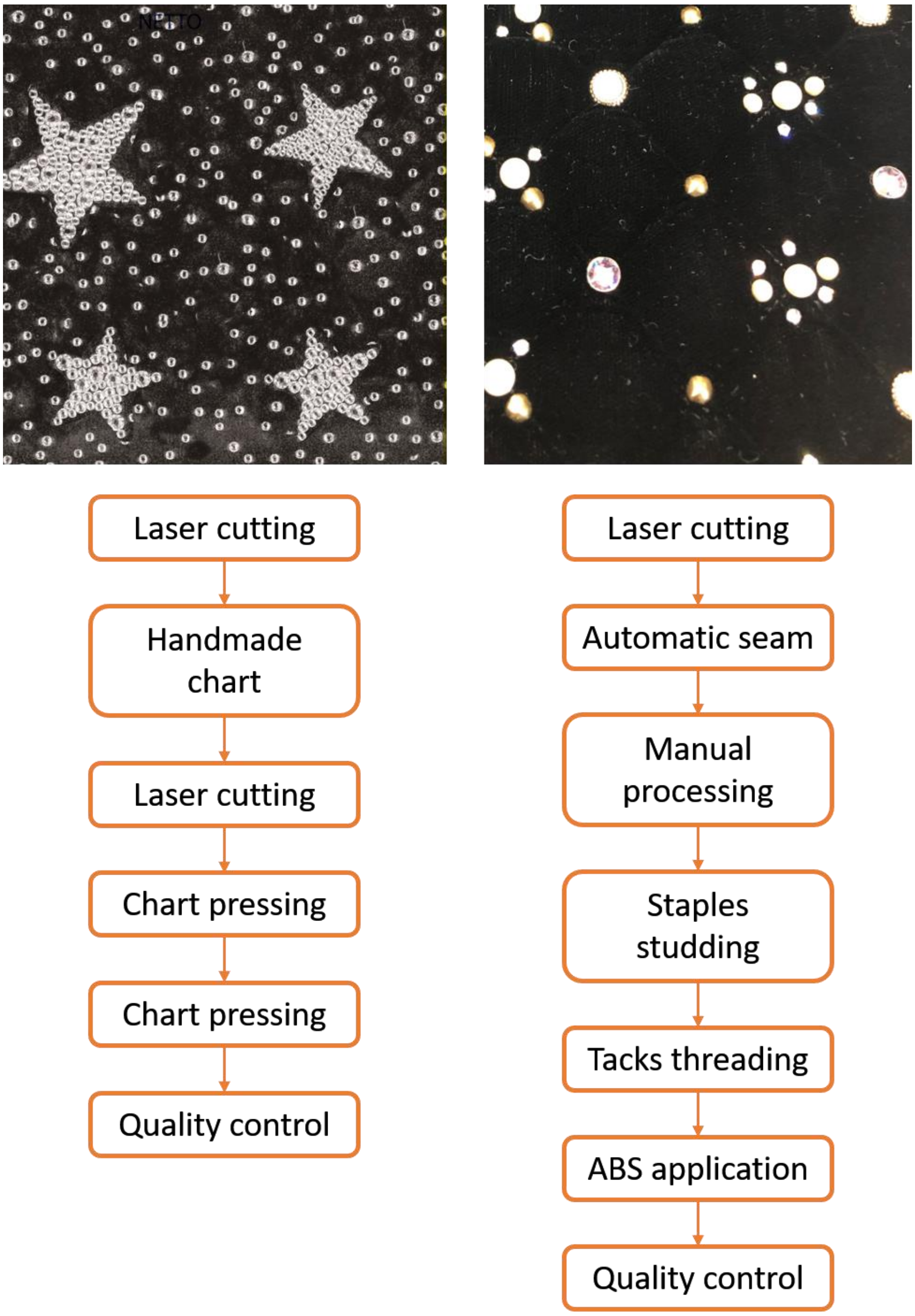


Figure III.1 It represents the production process of the two samples reported above. The production processes are completely different

At the same time, a working station machining process can be very different from sample to sample, neither never done before. Therefore cost forecasting is a very difficult practice to be carried out. There is also another important factor that influence the forecast of cost and the time of production: the craftsmanship of the production. Some machining are completely automated and some other are partially automated, but there are still operations that are fully handmade. Determining the time duration of a handcrafted operation is difficult because there are many variables that influence it. Also small variation such as raw material or millimetric variation in incoming parts can (or cannot) brought to a large operation time shifting.

The high level of craftsmanship and the changes from samples to samples in terms of path and machining involve difficulties in forecasting the time required for each operation. The issues led to difficulties in: scheduling of production and forecasting direct production cost (when it is possible the range of accuracy is very low). The company can hardly predict the direct cost of production then it can hardly create reliable evaluation, which leads to higher than market mark-up and finally this could bring to out-of-market price. Another consequence of the difficulties in forecasting time is in the lack of production control. Wherefore there are drop-down issues such as the difficulties in scheduling the production or determining the saturation of machinery and operators which may lead to chaotic environment when the production increase abruptly (keep in mind that fashion is a strongly seasonal market). In fact historically there is a lack of production monitoring in the fashion market and this is represented by the inability to determine the production capacity or the duration in terms of time of an operation.

Finally in the last years the company gained a rapid growth in terms of turnover and employment level, such improvements in terms of dimension brought the necessity of a deeper and more detailed control over the costs driven toward hidden cost reduction and then improve profitability. To carry out this purpose, *Goretti S.r.l.'s* management first step was the control of direct production cost through time monitoring and predictive model.

These issues coming from external and internal factors may lead to an overestimation of the production ability of the company, or an underestimation. An important absence on the monitoring of the production process lead therefore to an increase in cost and to a lack of control over the company.

3.2 ACTUAL MODEL AND CRITICALITIES

Company is willing to create a system to become aware of production time of orders also because emerged a difficulty in quoting the cost to the client. The lack of this capacity led to not reliable quotes (reliable means that the quotes done by the company suffers of deviation during the production process due to difficult to predict variables).

The company needed a model to relieve time which was easy and fast to implement and at the same time not economically expensive. The solution was identified in relieving time through operators during the machining phase of an order. In this way the company is not able to know or predict the time of machining before the sample, but only after, anyway this solution is perfectly fitting with company needs in fact the estimations are done with the purpose of estimating the cost in which brands will occur if its order will start the production. Once the company relieved the machinery work time of order, it can easily predict the time of production (just by multiplication). The sample units produced for the order are very small number (usually one, two or three units) and therefore the time relieved is an average on a maximum of three data. Because of this the forecast of time production is based on a maximum of three data too. The issue that emerges here is a quality issues. The model developed by the company (operators that relieve time during their work) is a rapid and cheap solution for an important problem, but as Figure III.2 shows, in the *Project management triangle*, this kind of decisions bring to low quality product.

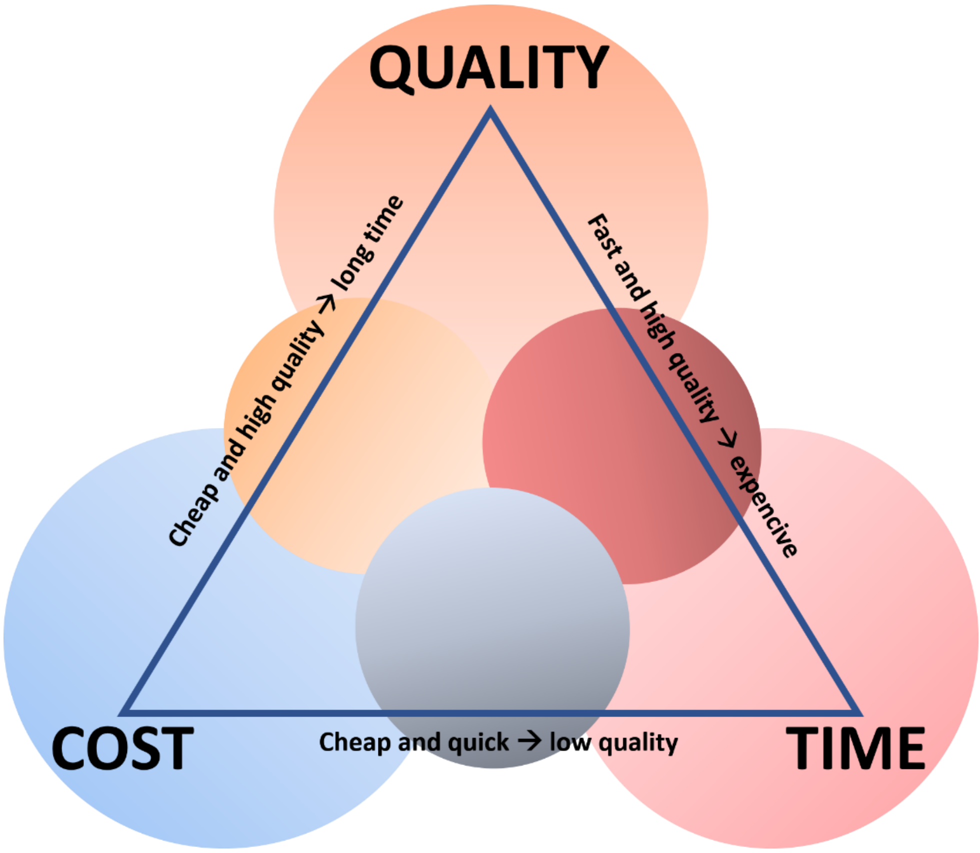


Figure III.2 Project Management triangle. It represents the way in which quality, cost and time interact in a project[35]

The few reliefs (most of the time is one relief per order) done on the machining time result in high data volatility.

Once the time has been acquired and communicated to the Administrative Office of the company, it is converted in cost (by multiplying cost of machine and human resource by the time relieved). Then an evaluation on cost must be carried out: the office employee must analyse the data based on his/her experience and according to this, he/she must give a multiplicator to cost in order to obtain a more reliable data in line with expectations, market and experience. The multiplicator added is a mark-up which must take into consideration the volatility risk of time data but the ratio is not based on objective analysis and then it cannot fully compensate the existing risk. Actually what the company does is to add an high mark-up to cover this risk and grant a return for the company itself but this may bring to have price not in line with the market (or too low or too high).

The difficulties in estimating cost are caused by the relieving time model: this system does not have a strong statistical based and the few data collected are highly variable. The company then cannot rely entirely on data collected, more over the company cannot fully cover the high risk of volatility analysing the data on an experience-based evaluation, finally company because of the low reliability of data, cannot use past reliefs for new orders similar to past ones. The model does not allow having a robust historic data storage: current model is too subject to uncontrolled variables. Therefore there will be always the need of a human resource to monitor data with the aim of creating an estimation comparable with his/her past experience. This kind of approach can work with low

[35] Fernand Pouillon, 2017, M*isfits' architecture*

number of samples and productions but in case of an increase of sample accepted the system used can have a crisis and not be manageable.

Up to now the structure of the model and its influence in administrative management have been described, but there are also other aspects that influence the reliability of the model. To show it, the physical moment (when the operators start to clock) of relieving time is analysed. First important aspect: guidance for operators on when start relieving time, when stop, when and if stopping the relieve. If the guidance are not homogeneous in the whole company or, worst, if there are not guidance, the operators are left free to relieve as he/she thinks it is more appropriate and therefore he/she may relieve differently from order to order. The consequence is that data are not comparable one each other and then it would not make sense to create a history data storage. Another aspect that influence the reliability of data is that it is possible for operators to relieve time gross of time waste (such as breaks, inactivity and others); furthermore it is possible to have errors due random variable which will not be excluded because of the few reliefs done. Finally it is possible to have *User Interface* issues or lagging system which makes the relieve from operators even more difficult, below in Figure III.3 an example of *User Interface* relative to the *Goretti S.r.l.* management system.

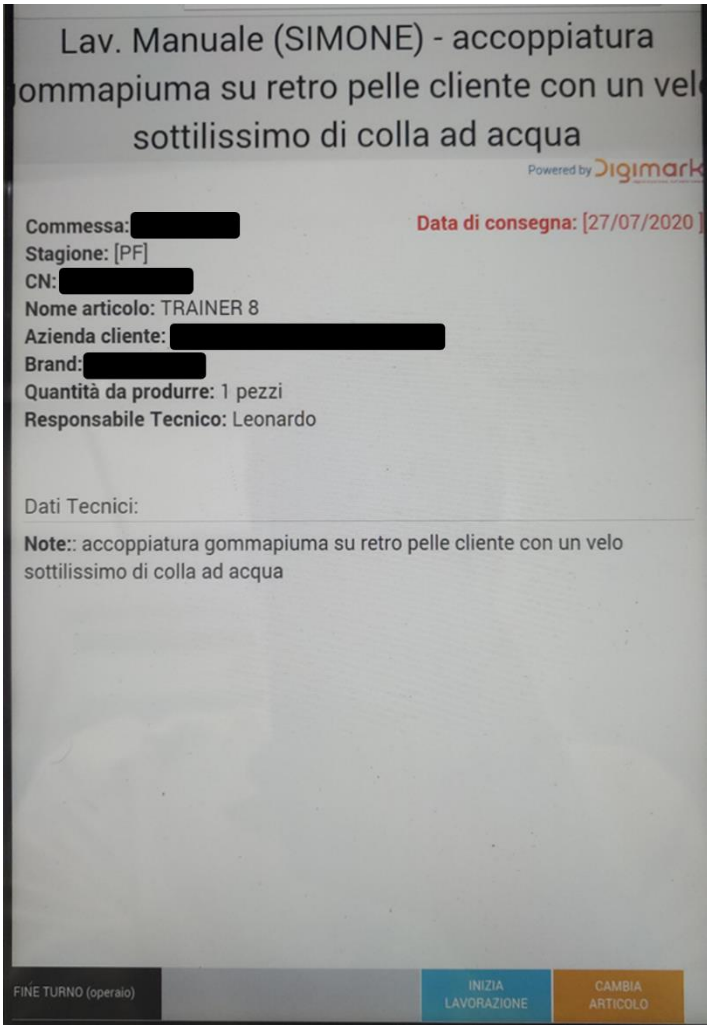


Figure III.3 It represent an executive order communication from technical office to operators. It is an example of the User Interface in the Goretti S.r.l. software.

The company adopted model suffers of the lack of information relieved. The time is collected during the sampling, it means when the operators produce the order for the first time: the operators' awareness of the product is very low and therefore the time spent in following the machining, in finding materials and in quality control is much higher than the one spent in production phase. An example explains how the model used does not consider learning economies, so it does not consider unitary cost of product decreasing due to the knowledge acquired in production. The example:

"During the machining phase for example it is possible (selecting specific parameters) for the machine to not cut the wire at the end of a part (cutting is called "threat trimmer"*), in this case the operator has to do it (it is done because in some case "*threat trimmer" *gives problem with next starting point). During the sample the operator will look constantly at the machine to understand when cut the wire and where. But during the production phase the operators can carry out other task while machining phase and then monitor the machine only when and where there is the need to cut the wire. In this way the saturation of operators change and also the cost of resources change (therefore the saturation too)".*

Conclusion: the company adopted model cannot guarantee the forecasting cost and time of production

3.3 BENCHMARK MACHINE AND DIFFICULTIES

From the Analysis of the external environment in which the company operates, the internal environment and the model currently used, it is possible to understand the needs to improve the monitoring and increase the robustness of their forecasting production model.

The production analysis evidences that is not possible for the analyst to create a model that forecast the production time of the entire line because the path of each order is different one another. It is only possible to create a forecasting model for each working station.

3.3.1 MACHINE BENCHMARK

The process model developing process is time and cost consuming. These limits induce procedural choice as the selection of a benchmark instead of the full line. Therefore the management of the company selected a technological benchmark (working station) to study a first model.

For the selection of the technological benchmark there are three possibilities: completely automated working station, semi-automated working station or completely handcrafted work. The management of the company opted for a completely automated working station, therefore the thesis is focused on a specific machinery called *Rodella Automatic Machines* (*RAM*) which is an automatic seam machine. The machine has three fixed head which are used not to work in parallel more part but can change wire colour for each product seam. The machine accept input file of extension *.xdd* (these kind of file interact with line profile fitting program), which is created by the modelling office of the company; this file is sent to the machine computer and it gives instruction to the machine on which path follow for the seam. It is possible to divide the process in three step:

1. Machine tooling
2. Production
3. Discharge the product.

3.3.1.1 4.3.1.1 – *Machine tooling*

At first it is analysed the machine tooling. The material is uploaded into the machine through a stainless steel frame represented in Figure III.4 on which is uploaded what is called a “table”.

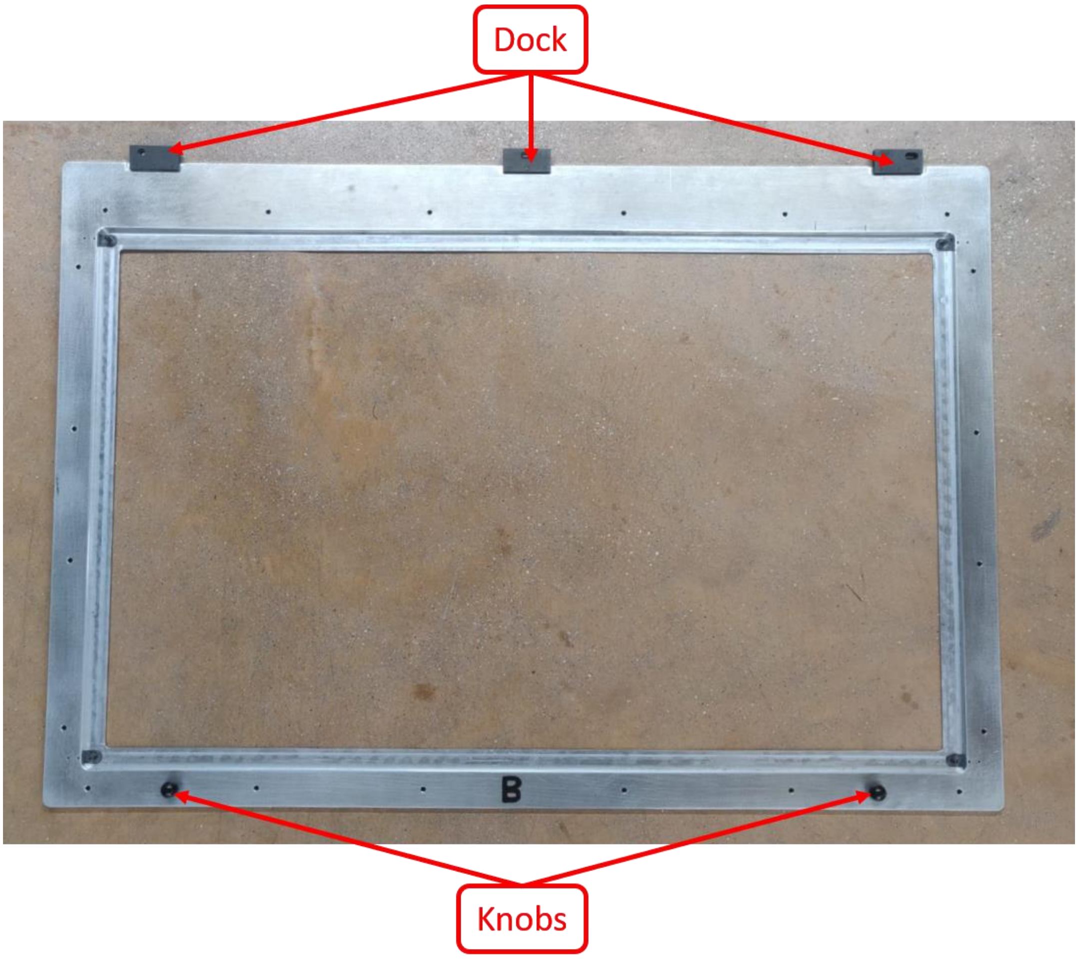


Figure III.4 This is the stainless steel frame used to upload the material in the machine.

The table is a double plastic layer, the lower layer is made of light transparent plastic on which has been cut the area of the product (to be seamed) and punched a series of small holes. The aim of these light plastic film is to fix the material on which will be carried out the machining: the holes cut are used to insert and fix tacks (as reported in Figure III.5) with the purpose of holding the material to be machined.

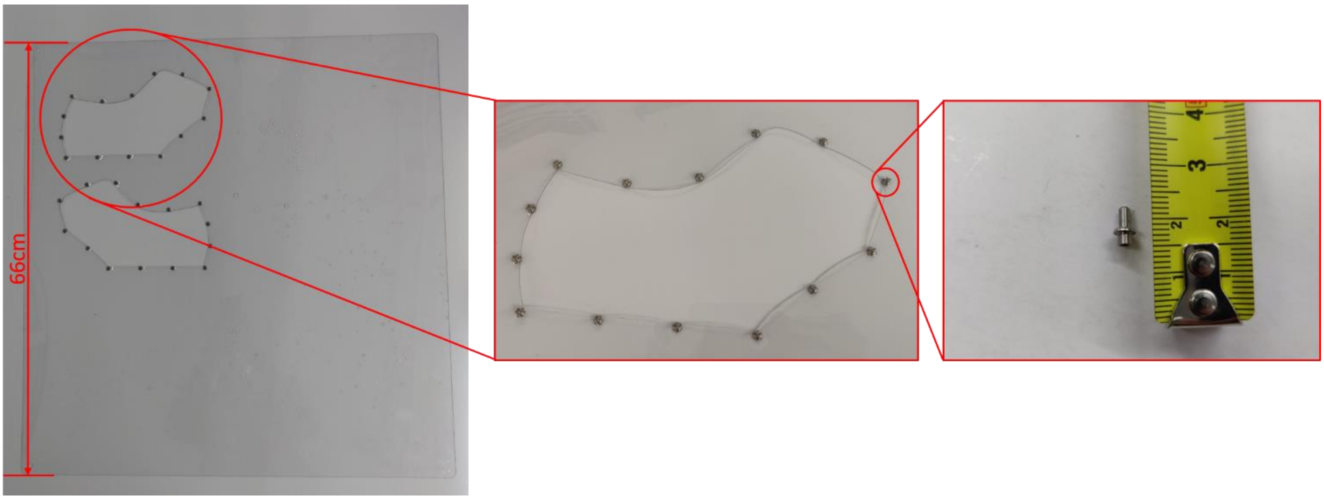


Figure III.5 The left photo reports the lighter plastic film (table) aimed to fix the material. The right photo reports the tacks used to fix the material to the tables.

The upper thick plastic film gives robustness and solidity to the table to sustain the material. In the upper plastic film it is cut an area that includes: the area of the material to be machined end the holes done for the tacks on the light plastic film (Figure III.6 is a photo of the upper plastic film, Figure III.7 is a detail of the cut area). Figure III.5, Figure III.6, Figure III.7and Figure III.8 were taken on the component of the same order.

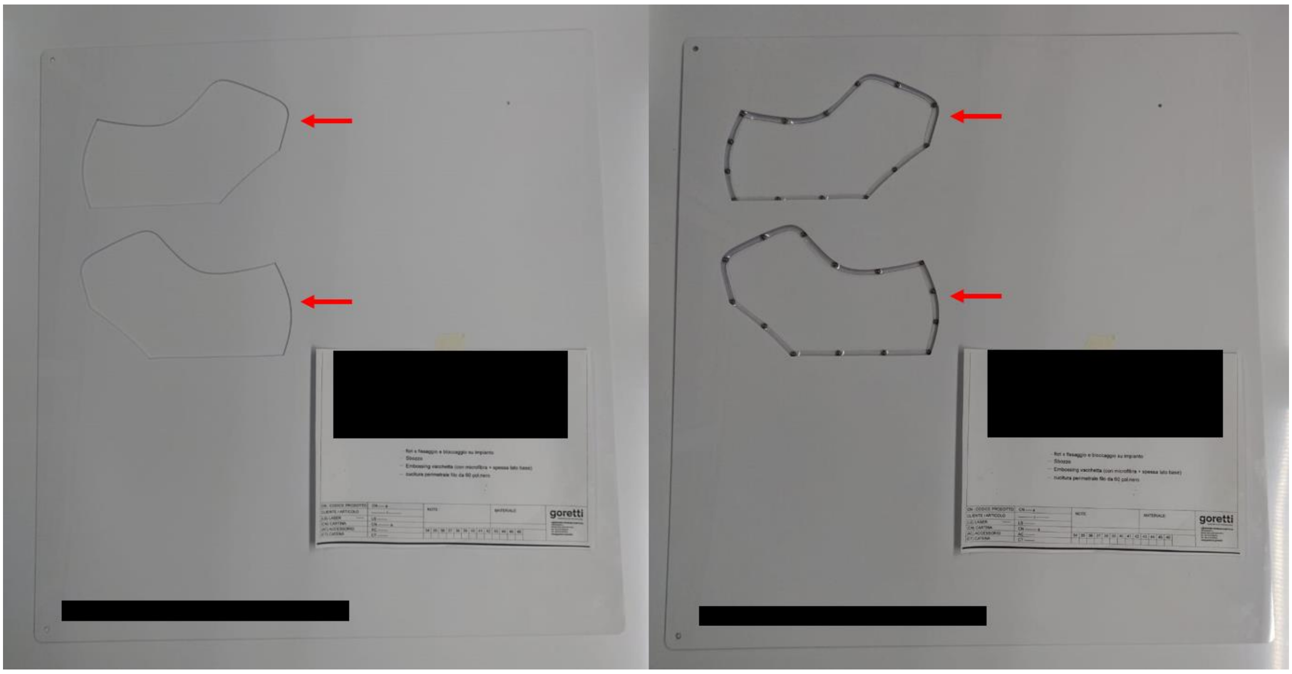


Figure III.6 This photo represent the upper table used for the same machining of previous photo on the left. On the right is reported a photo of overlapped white and transparent table.

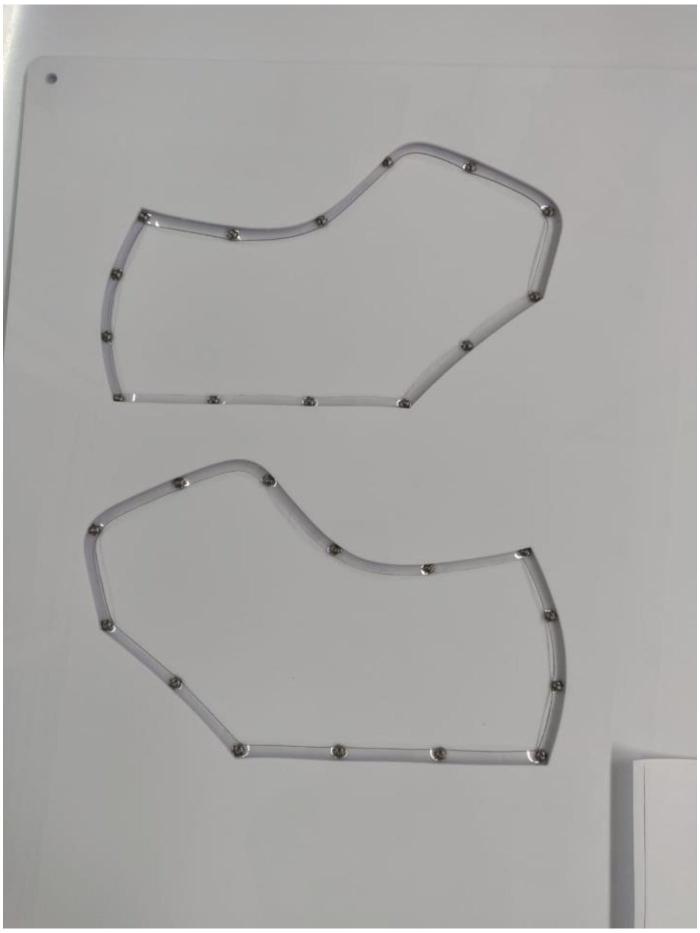


Figure III.7 It is a white and transparent table overlap detail. Here it is possible to notice how the hole in the white table circumscribes the tacks in the transparent table.

Finally a second film of the same upper film material is cut to create masks. They are used to cover tacks and fix the material. The procedure to start the machining is:

1. glue together the lower and the upper plastic films;
2. position the table obtained in the stainless steel frame;
3. put the material on the tacks, put masks on the tacks and finally approach the stainless steel frame to the machine bracket.

Figure III.8 shows the moment in which material are fixed to the table.

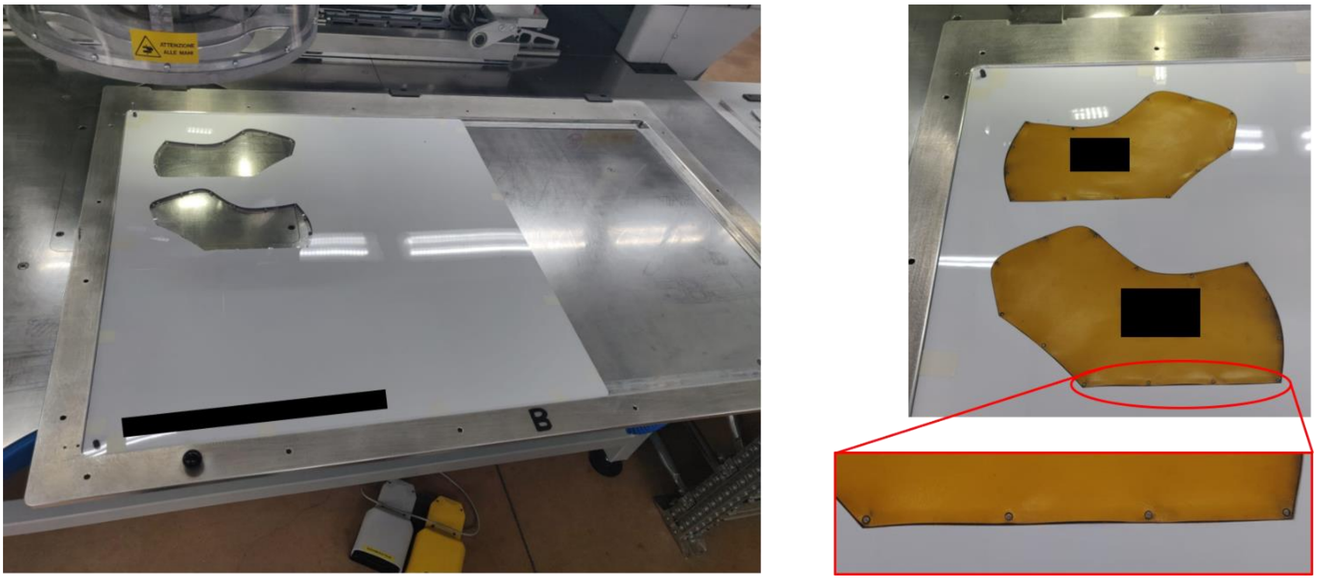


Figure III.8 The photos represent the chronological order of the procedure through which the material is fixed to the table. On the left, the first step, when table is positioned in the stainless steel frame. Then on right material is fixed on tacks. In this case the material is not fixed on the tacks using the mask.

3.3.1.2 4.3.1.2 – PRODUCTION AND DISCHARGE

Now it is analysed the production and product discharge. Once the machine hooked the stainless steel frame, it is moved in order to complete the steam following the path of the file selected on the machine PC. To insert the file (therefore the path) there are two different procedures: the first one consist in the operator that directly interact with the machine computer and select the machining code; the second procedure is principally used in the productions, in this procedure a barcode is created for each product and when the machine locks the frame docking points, it automatically scan the barcode and recognise the product. Once the machining phase is ended the machine unlock automatically the docking points of the frame and then the operator can extract the frame from the machine, remove the masks and then remove machined material.

3.3.2 DIFFICULTIES

It has been already analysed how different and a heterogeneous are the machining phase for each order and other difficulties are faced also in the single machining phase (such as in the one of *Rodella*). The heterogenous characteristics of same machining phase for different orders bring a difficulty in creating a predictive model for each machine. To deeply understand why these heterogeneous characteristics has as consequences a difficulties in determining a forecasting model it is important to understand the differences between orders. These differences in the specific machining phase of *Rodella* can be spot out in: the number of stitches that the machine has to sew, in the path that the machine as to follow and in other differences from a technical draw point of view (such as radii of curvature and angles). Because of these difficulties the machine head does not reach the cruising speed. Therefore qualitative and quantitative aspects it is difficult to define the discriminatory drivers for the machining time. Next it will be reported real products which differs one each other for different parameters; but also inside the same ordered some characteristic change creating more difficulties forecasting parameters (such as average seed). Figure III.9 shows a product with variable radii of curvature change for a curve. Figure III.10 shows how much angles and fillets can change inside a single machining or in different machining.

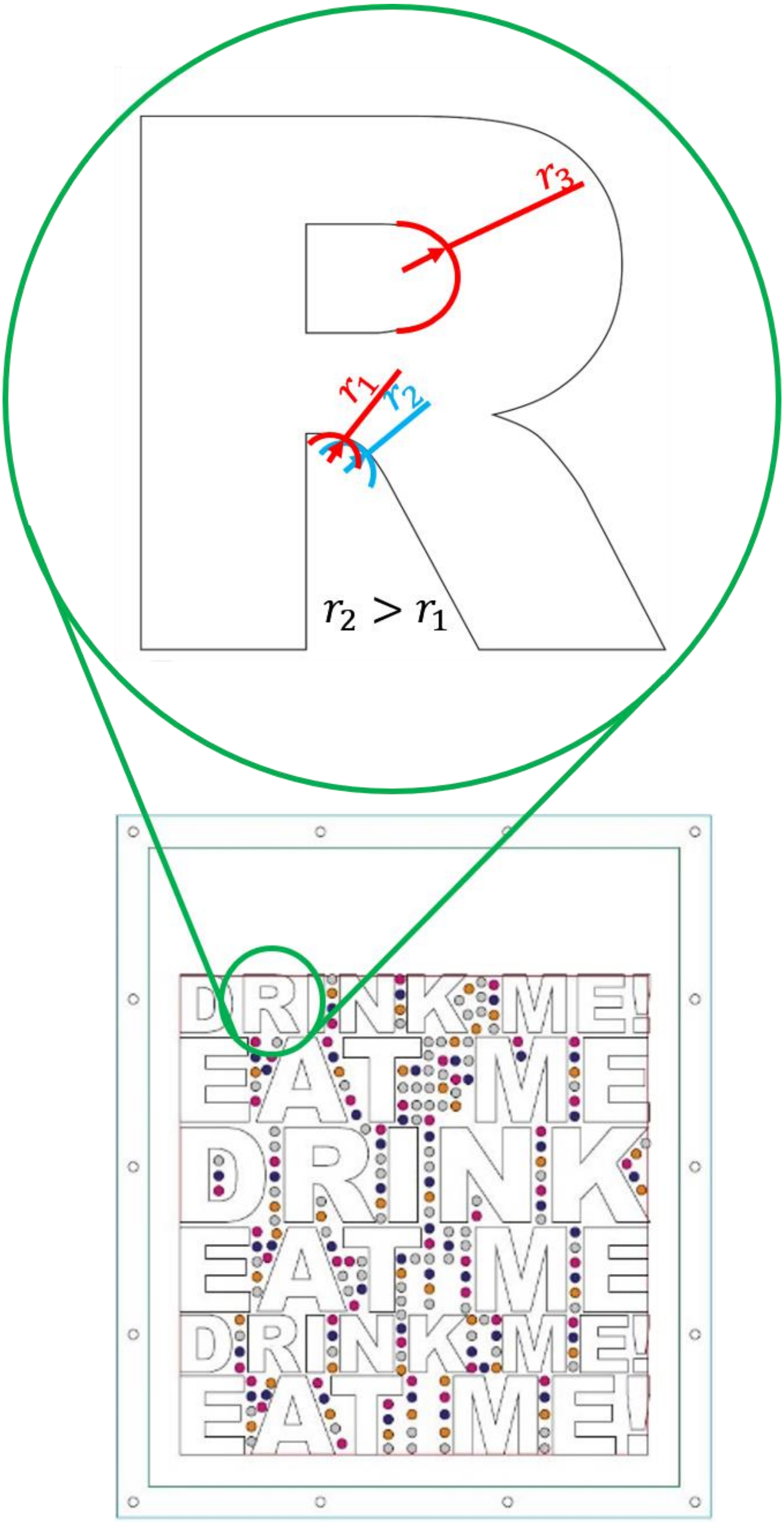


Figure III.9 It shows how radii can change inside a machining and how radii can change inside a curve too. In this way predicting the time needed for the machining it is highly difficult.

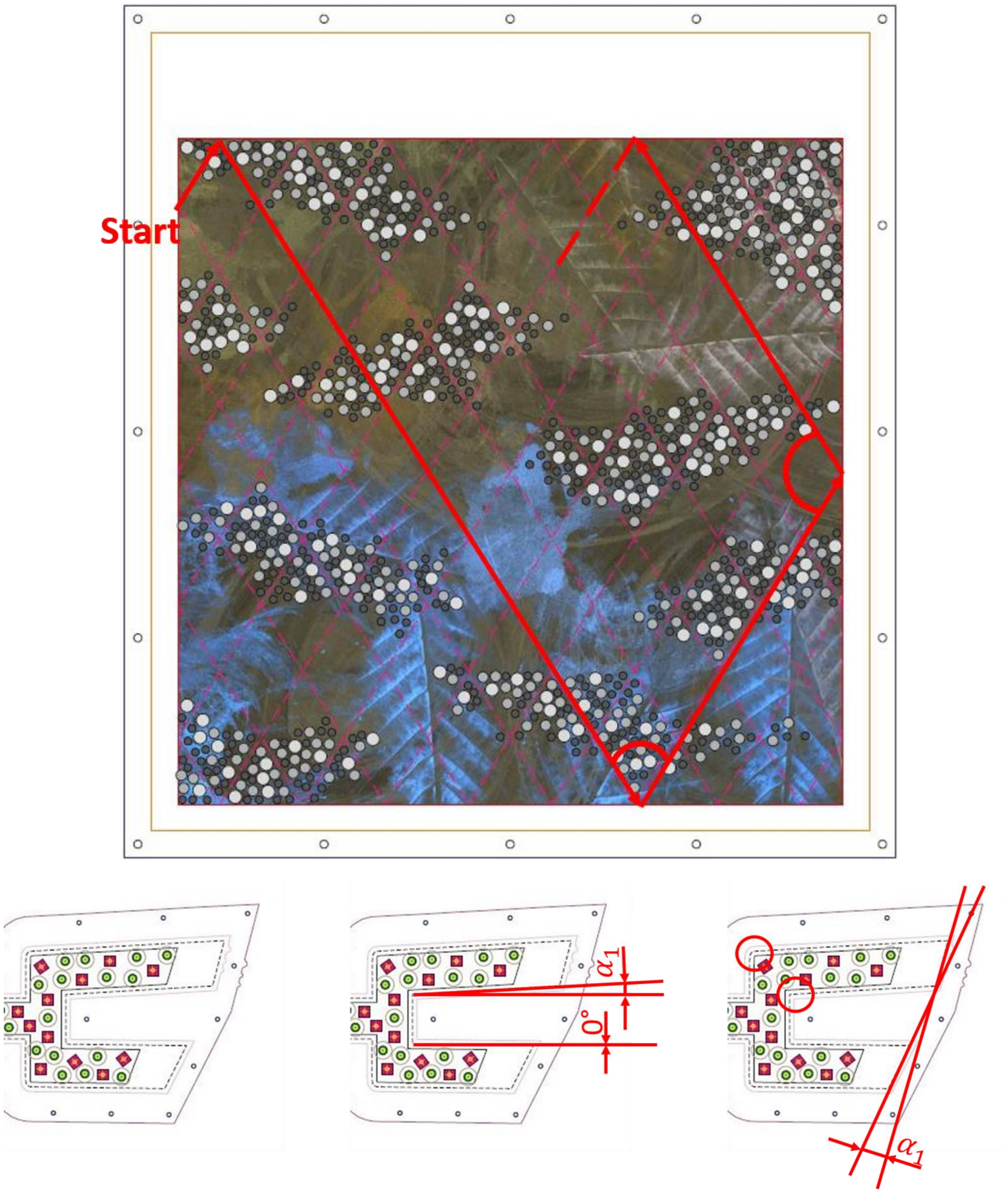


Figure III.10 It shows how angles change in a single machining and between different machining. In this way the forecast of time is impossible with average velocity.

3.4 MODELS

Different approaches can be used to satisfy the company needs:

1. A group of methods that use an equivalent measure to commute the real path covered by the machine into a linear equivalent path; therefore they are called generative models.
2. Empirical models use historic data storage to determine the driver of machining time and based on the drivers forecast the future machining time; therefore they are called variational model.

The validity of these two classes of models is confirmed by the long-time use inside the manufacturing industry, but it is necessary to contextualize these models inside this specific company.

3.4.1 GENERATIVE MODEL: EQUIVALENT LENGTH MODEL

Equivalent length models is a method taken from hydraulic. In the fluid dynamics environment, the pressure drops depending on the kind of variation the pipes have. Because the analysis of each of these pressure drop would implicate too long time, during years tables have been constructed reporting equivalent length of pipe which would be characterized by a distributed pressure drop equal do the localized pressure drop (Table III.2).

Table III.2 This is an example of hydraulics conversion table for concentrated pressure drop[36].

Valces, etc.		Equivalent pipe lenghts in m						
		Internal diameter in mm						
		25	40	50	80	100	125	150
Seating Valve		3-6	5-10	7-15	10-25	15-30	20-50	25-60
Membrane valve		1.2	2.0	3.0	4.5	6.0	8.0	10.0
Sluice gate		0.3	0.5	0.7	1.0	1.5	2.0	2.5
Knee bend		1.5	2.5	3.5	5.0	7.0	10.0	15.0
Elbow R=d		0.3	0.5	0.6	1.0	1.5	2.0	2.5
Elbow R=2d		0.2	0.3	0.3	0.5	0.8	1.0	1.5
T-piece		2.0	3.0	4.0	7.0	10.0	15.0	20.0
Reduction		0.5	0.7	1.0	2.0	2.5	3.5	4.0

In this way to evaluate the total pressure drop it's enough to evaluate the distributed pressure drop along a linear pipeline.

The approach reported in an automated seam machine is hypothetically similar: it would work with number of stitches sew and equivalent number for any variation from a linear sequence of stitches. In this way the model will create an equivalent number of stitches to the one of the real path covered by the the machine. The equivalent number will be distributed along a linear path and

[36] *KIESS, equipment for blast – cleaning, conveying, dedusting and coating*

therefore the time will be given dividing the number of stitches over the stitches per minute (PPM) obtained the minutes of the machining time. In fact with the equivalent path the machine would reach the cruising speed; the speed is given as stitches per minute (PPM) and the standard cruising speed is 600 PPM. This model create time forecasting more accurate than empirical model because based on *ad hoc* table database, but the implementation of this model requires the existence of the conversion tables (to convert number of stitches) and a software that is autonomously able to carry out the converting procedure.

At the state of the art there is no evidence of publicly available conversion tables. These tables sometimes are produced by the enterprise that produce the machine, for example one machine must control the machining speed as function of curvature radii, therefore the equivalent length is known. It means that the analyst will have to create this table from the beginning during the thesis period and this would be possible in two different way:

1. Studying specific geometry created *ad hoc* to analyse the decrease in the machine speed for different and specific variation from linearity stitches distribution;
2. Using past products as a reference and converting new path in equivalent reference path.

The creation of this conversion tables is a long process that require specific studies.

In the market it does not exist a software which convert the path of a seaming machine into an equivalent linear path then it must be developed. There are issues related to the development:

1. The software cannot be based only on geometric characteristics taken from drawing software;
2. Developing process is expensive and difficult for an out-of-the-market company;
3. An economic feasibility analysis and a strategic analysis should be run to understand if the development would be a good choice.

To facilitate the understanding the first issue, it is possible to analyse a *Goretti S.r.l.* real order. The Figure III.11 is a schematic representation of the seam. The red line represents the seam and so the path that the machine has to cover.

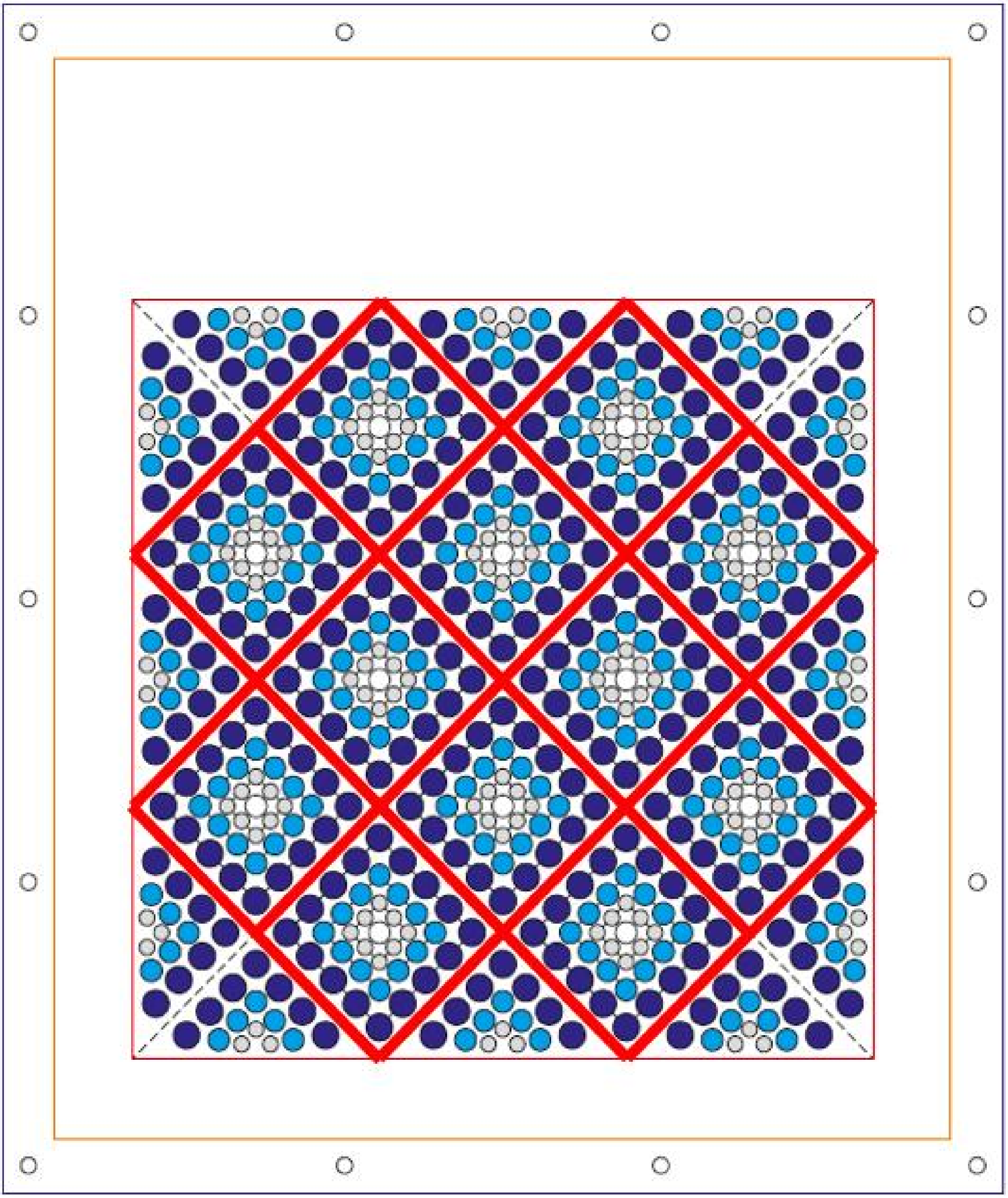


Figure III.11 This is a real draw example of a machining part for Rodella. The red lines represent the path the machine has to cover to complete the seam.

Only analysing the draw coming from the technical software it can be erroneously evaluated that the order characterized by twenty-one angles of the same degree (90°). Instead if we evaluate the same order considering the machine software as in the Figure III.12 it is possible to see that the machine will carry out three different paths of which two will be closed path and one open. The two closed paths will both include a total of three angles each, it means that the real number of angle covered by the machine are six and not twenty-one.

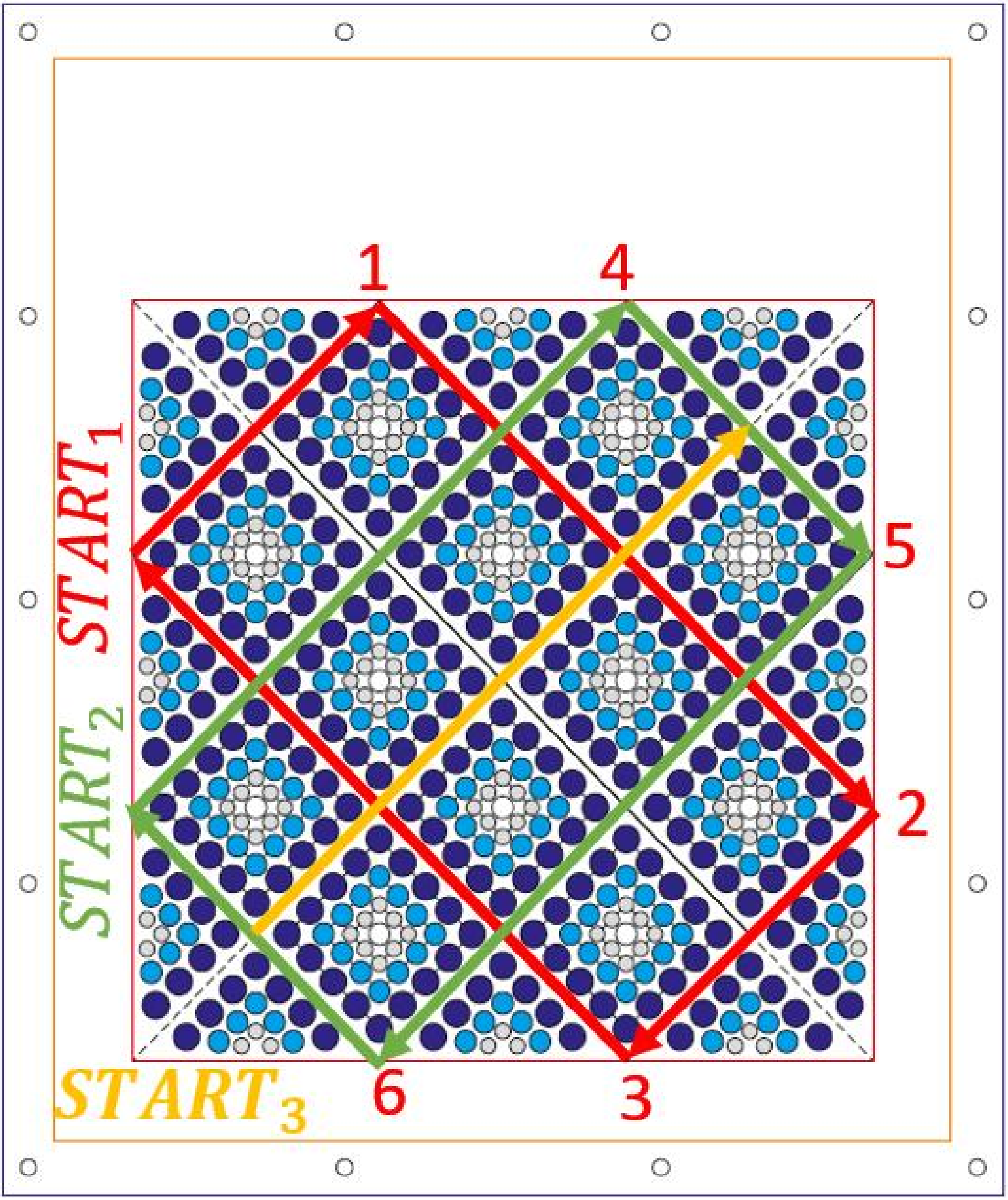


Figure III.12 This is a real draw example of a machining part for Rodella. In this case the coloured lines represent the ordered path Rodella will cover to accomplish the work. This path is shown by the machine software.

At the same time the software to be developed cannot only be based on the evaluation of the machine software because it doesn't include enough information to determine a technical evaluation (as the length or angle degree). This mean that the only geometric information or the only path information are not enough to determine the equivalent number of stitches but there is the need for an interpretation software which would communicate with the technical drawing software and the machine software.

The second important aspect listed to be analysed concerning the software is the cost: because of the absence in the market of such kind of software, it will be necessary an house developing and development is a cost which will be sustained by the company. Then before creating the software will be necessary to catty out a feasibility study to discover in how much time the cost of the development will be covered by the gain given in terms of more precise cost evaluation.

The creation of such a model require high machine availability which cannot be guaranteed and furthermore the absence of conversion table makes it hard to actuate. Because of this the model is discharged and it will not be analysed more.

3.4.2 VARIATIONAL MODELS: EMPIRICAL MODELS

The second class of models are empirical ones. They forecast the machining time by the evaluation of historic data storage. Based on these data it is possible to define indexes which will act as drivers to forecast machining time (such as technical characteristics of products). Thus the approach is called variational approach too: any new product machining time is obtained through the combination of already present machining data. Indexes depend on historic data storage, then database must be reliable and full of measurements to determine the real characteristic parameters that define the machining time. Two different condition bring to two different empirical model: with existing data storage and without.

3.4.2.1 EMPIRICAL MODEL WITH EXISTING HISTORIC DATA STORAGE

In this case there is already a data storage. It means that the company already as its internal knowledge has a historical machining time database. It has already been deeply discussed how the existing database cannot be used as a reliable source of information. A brief summary of unreliability reasons is because the methodologies used until now in the company do not bring relieved time homogeneous with respect to the determination methodology and therefore they cannot be used neither compared one each other. The consequence is that this kind of empirical model cannot be used and therefore it is discharged and it will not be analysed deeper.

3.4.2.2 EMPIRICAL MODEL WITH LACK OF HISTORIC DATA STORAGE

In the case in which the historic data storage is absent in the company database, to apply an empirical model there is the need of creating it. Once the storage will be completed, the procedure will be the same of the *empirical model with the existing historic data storage*. Therefore there will be a parameterization of specific characteristic of a work in order to determine the driver and the indexes which would help in forecast machining time.

Based on the analysis carried out on the two different classes of models that could be applied in order to create a forecasting method for machining time it is possible to deduce how the only possible model is the *empirical model with lack of historic data storage*. The need of creating a reliable data storage (on which run qualitative analysis) implies a deeper evaluation of the procedure to be followed in order to create the storage.

3.5 HISTORIC DATA STORAGE CREATION

The model selected imposes the creation of a new data storage of machining time. It is needed because the data storage will be analysed to find the parameters or indexes that mostly influence the machining time. After their discovery a model based on this parameters or indexes will be created. Then first of all there would be the need of collecting data in a standard and well known way to maintain the statistical validity of data. Analysing the *time and method* bibliography emerged that exists different technics to collect time data, the most famous are chronotechnical technique and table technique.

Cronothecnical technique is based on the relieve of times by analyst with a chronometer. Time relived are then weighted (*Normal time)* with an operator efficiency value called *pitch* (this value can be determined through two methods: *Bedaux* or *levelling).* The weighted time obtained is then increased by some specific add-ons. Then the time assigned to the operators can be evaluated as well as the time to be considered at administrative level for economic reasons.

Table technique is also called Methods-Time Measurement (MTM). The analyst obtains directly a weighted time (*Normal time*) based on tabled value without defining the *pitch* neither relieving time.

Independently from the methodology selected, the data must be monitored and updated any time the machining procedure change from first time relieve.

3.5.1 CRONOTHECNICAL TECHNIQUE

The first operation to carry out adopting the cronothecnical technique is to deeply analyse the benchmark machining operation. Analyst must divide each operation in sub-operation to simplify the relieving time operations therefore he/she observes repeatedly the operations and control their repeatability. Once the analysts have a clear idea on how to subdivide the method (operations) he/she can practically divide the operation in sub-operation dividing human and machining phases which duration must be a measurable amount of time. After the division is done the analyst can carry out a first trial of relief, but to control if the feasibility of relief using the division of the method created. If issues rise the analysts must control again the division and adapt it to the criticality discovered. After the division of the method is done and verified, the analyst can create the document used to record the reliefs: *relief sheet*. This document contains information that depend on the kind of cronothecnical technique selcected (which differs for the way in which the *pitch* is evaluated). Principally they are: *Bedaux* and *levelling method.* Anyway one information is common to every technique: add-ons. Add-ons are percentage based on common shared table which help improving the weighted time (*Normal Time)* because of three categories: unexpected, fatigue and physiological needs. Literature presents this tables in a quite uniform model which is therefore globally accepted.

Physiological needs tables (Table III.3) are divided in three parts based on the gender present inside the working station: male, female and mixed. For woman and mixed working station, the add-on is bigger than that of man-working station.

Table III.3 Add-ons based on gender composition of the working station[37].

Physiological needs	Add-on	Time over a day working time (480 min) [min]
Male	4.16%	20
Female	5.00%	24
Mixed gender	5.00%	24

Unexpected add-ons (Table III.4) are divided based on the kind of operation and on the kind of accidents. Easy operations are considered shop floor operations, while hard operations are for example assembly.

Table III.4 Unexpected add-ons based on kind of unexpected[37].

Unexpected	Easy operation add-on range	Hard operation add-on range
Unexpected due to materials	[0.00%; 2.00%]	[0.00%; 3.00%]
Unexpected due to production process	[0.00%; 2.00%]	[0.00%; 4.00%]
Unexpected due to means of production	[0.00%; 2.00%]	[0.00%; 4.00%]

Finally fatigue add-ons (Table III.5). These kinds of add-ons are divided in classes based on the kind of parameter that can bring tiredness which are: physical effort (divided in man and woman), nervous tension, monotony, noise, lighting, temperature, danger and last smells and dusts. It is possible to find in literature tables for each one of the parameters reporting a range of value for each add-on and a description of the causes for the specific range. This help the new analyst in defining the appropriate value. Reporting all the tables for every parameter would be unnecessarily long, therefore only two of them are reported with figurative purposes.

[37] Marco Minati; 2012; “Tempi e Metodi”; *IPSOA*

Table III.5 Example of fatigue add-ons, specifically add-ons on monotony and on danger. Each add-on is next to a brief description to determine which value the analyst should give[37].

Monotony		**Danger**	
Add-on	Description	Add-on	Description
0.00%	Lack of monotony. Variable cycle with higher than 60 second frequency.	0.00%	No danger. Small object without corners manufacturing.
1.00%	Low monotony. Repetitive cycle with frequency between 15 and 60 seconds.	1.00%	Low danger. Use of small tools and machine with protections. Danger of scratches
2.00%	Monotony. Repetitive cycle with frequency between 6 and 15 seconds.	2.00%	Accidents danger. High attention level.
3.00%	Monotony. Repetitive cycle with frequency lower than 6 seconds.	4.00%	Serious danger. Full attention. Blast-furnace, foundries, work at height without protection…

3.5.1.1 Bedaux cronothecnical technique

In this specific method of cronothecnical technique the efficiency of the operators, so the *pitch*, is evaluated with the *Bedaux method*. With this method an efficiency scale is created with a minimum value a *normal* value and a maximum value. It is important to define this values because based on them the weighted time will be evaluated. The maximum value of the efficiency is defined as the level for which a worker exhaust all his/her psycho-physical energy exploiting his work. The normal value is indicated as the maximum value decreased of 75%. Literature reports that in normal working condition 96% of operators is able to overcome the normal value[37]. Logically the value of the scale depends on the scale selected, principally there are three scale:

- Bedaux scale (or 60/80 scale):
  - *Normal* value: 60;
  - Maximum value: 80;
- BTE-Pirelli scale (or 75/100 scale):
  - *Normal* value: 75;
  - Maximum value: 100
- Centesimal scale (or 100/133 scale):
  - *Normal* value: 100;
  - Maximum value: 133[38].

The information that must be reported in the *relief sheet* are all the data relieved, and for each measure analyst will report time and *pitch* of the measure for each sub-phases. The *relief sheet* will report then general information as: who is the analyst, when the relief is carried out and who is the operator; then other information that describe the phase that is analysed. It is important also to insert information that help identifying the product machined. The central part of the document are

[38] Marco Raimondi; “Studi di Fattibilità – Manufacturing & Plants; cronometraggio”; *Università Carlo Cattaneo*

columns for each sub-phases and this columns must be divided in two parts one for the relief of time and one for the relief of *pitch*. Under this central part, there will be an area to evaluate the average of time and *pitch* and some specific indicator (Figure III.13 represents a standard *relief sheet* template).

RELIEF SHEET

Analyst	
Date and time	
Relief n° _ Sheet n°	

Machining center		Articles	
		Pieces/cycle	

Operator	M	F
	standing	sitting
Claudio		

	Machine cycle		Sub-phase 1		Sub-phase 2	
	Time [s]	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**
NOTES						
Measure 1						
2						
3						
4						
Average						
Normal pitch						
Normal time						
Unexpected add-ons						
Fatigue add-ons						
Tot. Add-ons						
Nominal time						
Cyclicity						
Assigned time						
Physiological needs add-ons						
STANDARD time						

Figure III.13 It represents a standard relief sheet template with essential information.

There are three fundamentals evaluation of time that must be insert in the *relief sheet* for each sub-phases*: Normal Time, Assigned Time and Standard Time.* The notation used exclude any recall to sub-phases for clarity of writing, but it is important to highlight how each formula is used in any sub-phases.

- *Normal time*: it is a weighted time only aimed to evaluate *assigned time.* If $\overline{T}$ is the average time (calculated as the average of all the reliefs) and $\overline{P}$ is the average *pitch* and P_N is the *normal* value of the pitch, then *Normal Time (NT)* is*:*

$$NT = \frac{\overline{T} \cdot \overline{P}}{P_N} \tag{3.1}$$

- *Assigned time:* is the time the management will assign to an operator to carry out the work. Calling add-on for unexpected M_1 and add-on for fatigue M_2, then *assigned time* (*AT*) will be:

$$AT = NT \cdot (1 + M_1 + M_2) \tag{3.2}$$

- *Standard time*: it is the time used at administrative level to evaluate the cost of a human resource as it consider the *assigned time* increased of the time for physiological needs and therefore in is a part of the 8 working hour a day. Calling M_3 the add-on for physiological needs, *Standard time* (*ST*) is:

$$ST = AT \cdot (1 + M_3) \tag{3.3}$$

This technique requires the analyst calibration for the *pitch*. In fact it is difficult to define the efficiency of an operator. In order to simplify the calibration process a new kind of technique has been introduced: *levelling cronothecnical technique.*

3.5.1.2 Levelling cronothecnical technique

As already analysed the *Bedaux pitch* is difficult to determine because of the need of a calibration otherwise the evaluation given by the analyst may be not precise and report wrong *assigned* and *standard time*. A different method was created with the aim of reduce as much as possible the subjective evaluation of the analysts. This technique is called *levelling*.

The procedure of the reliefs is different from the *Bedaux* one: in this technique the analyst will relieve only the time for each sub-phases of each measurements, but not the *pitch*. It will be evaluated at the end of the relief using some specific tables, which report for a specific level of efficiency a value of an add-on. There are four tables about four levelling factor: *ability, application, condition, regularity*. Each of these factors have six evaluation classes from A (which represent the maximum efficiency in the specific factor) to F (which represent the minimum efficiency in the specific factor). A sum up of evaluation of every table is reported in Table III.6. Usually each evaluation of each factor is supported by a description which can help the analyst defining the level of efficiency; Table III.7 is used as representative example.

Table III.6 This is a sum up of the coefficient divided per evaluation. Each table represent a levelling factor[37].

ABILITY		
Ability level	*Code*	*Rate*
Very skilled	A1	+0.15
	A2	+0.13
Skilled	B1	+0.11
	B2	+0.08
Good	C1	+0.06
	C2	+0.03
Medium	D	0.00
Moderate	E1	-0.05
	E2	-0.10
Low	F1	-0.16
	F2	-0.22

APPLICATION		
Application level	*Code*	*Rate*
Highest	A1	+0.13
	A2	+0.12
Very high	B1	+0.10
	B2	+0.08
High	C1	+0.05
	C2	+0.02
Medium	D	0.00
Moderate	E1	-0.04
	E2	-0.08
Low	F1	-0.12
	F2	0.17

CONDITION		
Working conditions	*Code*	*Rate*
Ideal	A	+0.06
Excellent	B	+004
Good	C	+0.02
Medium	D	0.00
Moderate	E	-0.03
Poor	F	-0.07

REGULARITY		
Regularity	*Code*	*Rate*
Perfect	A	+ 0,04
Excellent	B	+ 0,03
Good	C	+ 0,01
Medium	D	0,00
Moderate	E	- 0,02
Poor	F	- 0,04

Table III.7 This table is a representative example of the descriptive table that can help new analyst defining the efficiency of an operator. In detail this table describes the level of ability of the operator so the analyst can assign him a proper rate[37].

ABILITY		
Ability level	Code	Description
Very skilled	A	Very fast and very precise, operator fit for his task
Skilled	B	Fast and self-confident operator
Good	C	Above average operator. Good work in less time
Medium	D	Yardstick operator
Moderate	E	Experienced operator but unfit
Low	F	Characteristic of a new operator

The *relief sheet* in this case will not report the pitch for each measure but will report the four value of the factors per each sub-phase. Then the *levelling factor* for each sub-phases (*LF*) will be reported, which is evaluated as, considering the four factors as F_i:

$$LF = 1 + \sum_{i=1}^{4} F_i \qquad \{3.4\}$$

It is important to highlight how the value of the summation can be negative too, and therefore the *levelling factor* can assume value lower than one. Then in the *relief sheet* will be reported the same information of a *Bedaux technique relief sheet*: *Normal Time, Assigned Time and Standard Time*. The *normal time*, being $\bar{T}$ the average time of sub-phases, is:

$$NT = \bar{T} \cdot LF \tag{3.5}$$

Then *assigned time* and *standard time* are evaluated in the same way of *Bedaux technique*:

$$AT = NT \cdot (1 + M_1 + M_2) \;\; ; \;\; ST = AT \; \cdot (1 + M_3) \tag{3.6}$$

Also here the notation used exclude any recall to subphases for clarity of writing, but it is important to highlight how each formula is used in any sub-phases.

3.5.2 METHODS-TIME MEASUREMENT (MTM)

This method is based on numerous scientific papers. The *International MTM Directorate* agreed in identifying the work of Gilbreth (1911) as that illustrated the basis of this model then industrially applied from 1948 by Maynard *et al*. The idea on which it is based is that each movement done (in an industrial environment, done by operators) can be divided in micro-movements. To each of this movements can then be assigned a time which characterized the duration of the movement. This time is independent from operator to operator and from industry to industry.

Studies focalized in individuating the most important and simple movements in which each other complex movement can be divided. Then the simple movements have been studied and divided in the micro-movements. Finally each micro-movement has been measured in terms of time from lots of scholars and MTM’s users. The tables that nowadays are used for MTM underwent a process of validation so long in time and so diversified (as to say from so many different person) that their validity is globally accepted.

An important aspect to take into consideration is the measurement unit of time: micro-movements are so short time spending that second is not a usable unit of measurement. Sometimes as measurement units are used second, millisecond and microsecond but due to the difficulties to manage with them, a new measurement unit was created: *Time Measurements Units (TMUs)*. TMU is defined as $\frac{1}{100{,}000}$ hours, so that:

$$\begin{aligned} 1\,TMU &= 0.036\,sec \\ 1\,sec &= 27.8\,TMU \end{aligned} \tag{3.7}$$

In industry it has been introduced an high number of method based on MTM but changed to better adopt to the specific industrial field. In general some tables have been manteined in all MTM derivated system because of the fundamental movement they describe. To each movement is assigned a code to identify a specific kind, once identified the willing code. The sum of all TMUs that characterize an operation’s micro-movements, result in the *normal* time of the operation. It is possible to convert the TMU duration given by tables into seconds in this way:

$$NT\;[sec] = TMUs \cdot 0.036 \tag{3.8}$$

Here an example of one MTM table (Table III.8).

Table III.8 It is a table of MTM-1 method. It is about a motion element: reach (symbol R). On the right there is a description of cases[39].

Time in TMU				
Distance [cm]	A	B	C or D	E
<2.0	2.0	2.0	2.0	2.0
2.5	2.5	2.5	3.6	2.4
5.1	4.0	4.0	5.9	3.8
7.6	5.3	5.3	7.3	5.3
10.1	6.1	6.4	8.4	6.8
12.5	6.5	7.8	9.4	7.4
15.2	7.0	8.6	10.1	8.0
17.8	7.4	9.3	10.8	8.7
20.3	7.9	10.1	11.5	9.3
22.9	8.3	10.8	12.2	9.9
25.4	8.7	11.5	12.9	10.5
30.5	9.6	12.9	14.2	11.8
35.6	10.5	14.4	15.6	13
40.6	11.4	15.8	17	14.2
45.7	12.3	17.2	18.4	15.5

LEGENDA	
A	Reach to object in fixed location, or to object in other hand or on which other hand rests.
B	Reach to single object in location that may vary slightly from cycle to cycle.
C	Reach to object jumbled with other objects in a group so that search and select occur.
D	Reach to a very small object or where accurate grasp is required
E	Reach to indefinite location to get hand in position for body balance or nect motion or out the way

3.6 BEDAUX CHRONOTECHNICAL TECHNIQUE APPLIED

The MTM methods need very long time to be understand and applied, furthermore when the operator fulfils more complex movements simultaneously (e.g. lower on machine table, insert wire with pliers in one side of the needle and try to get out the wire from the other side of the needle with the other hand) the technique is very difficult to adopt for a new analyst. Therefore due to its difficulties in the use, this technique has been exonerated and has been selected the Bedaux cronothecnical technique.

The Bedaux technique has been preferred to the levelling technique because the initial process of studying the machine process in order to detect sub-operations in which divide the operation took about one month. This month has been spent side by side with the same machine all the day, and with the same operators every day. This helped evaluating a wide range of different production type: samples, orders, trials and production, so the analyst learned a heterogeneous spectrum of operator's speeds and efficiencies that allowed a calibration of *Bedaux pitch* but only for the specific machining and the specific operator. On the other hand the use of levelling tables would be a loss of time in terms of processing data after a reliefs which could be easily skipped using *Bedaux pitch*.

Now an analysis on the application of Bedaux chronotechnical technique at the benchmark machine is carried out. The benchmark technology selected is the three heads authomatic seam machine: Rodella. The analysis will follow the different phases of study carried out during the thesis period, so first a look at the sub-phases definitions and their cyclicity, then at the add-ons, after the first

[39] Stephan Konz, Steven Johnson; 2008; "Work design"; *CRC Press*

relief, an analysis of the *pitch* and finally a look at the database created. In each phase will be analysed the criticalities found.

3.6.1 SUB-PHASES DEFINITION AND CRITICALITY

The identification procedure of sub-phases brought easily to the identification of fourteen phases to divide the macro-phase. These sub-phases are reported and described below:

1. Transparent table positioning: the first step of each machining phase is positioning the transparent table (on which the material will be fixed through the pins) on the stainless steel through other, bigger, pins;
2. Tables adhesion: then, after the transparent table is fixed, the heavier white table is fixed on it with adhesive ribbon to give more robustness to material support;
3. Pins coverage: once tables are fixed together on the frame, this is overturned because the pins used to fix the material on the table are directly touching the machining plan (with scratching risk) and therefore wire could get stuck with pins. Therefore pins are covered with adhesive ribbon;
4. External wire change: this sub-phase and next three sub-phases do not have an exact position in the machine setting procedure: operator actually perform them at the moment he wants before starting the machining phase. In this subphase the external (upper) wire is substituted with the one indicated by technician office;
5. Needle change: as the previous sub-phase this one has not a precise position in the setting-up procedure. During this sub-phase the operator can change the needle of the machine to substitute it with a bigger or smaller one, ore because the one presents is worn out;
6. Internal wile coil change: as the two previous sub-phases, this one neither has an exact position. During this phase the operator interact with the machine PC in order to unlock the housing hatch of internal wire coil, to change it;
7. Machining file selection: then the operator can select the file created by the technician office with the machining information for the machine;
8. Material positioning: now the operator place the material in the transparent table pins;
9. Adhesive ribbon application: because the material can move, after previous sub-phase, the operator fix material with adhesive ribbon;
10. Machine commissioning: then the operator approach the stainless steel frame to the machine which will hook it;
11. Machine cycle: the machine start and finish its automated procedure;
12. Monitoring: during the machining phase the operator can monitor the work to evaluate if the work is proceeding as standard;
13. Material removal: after the machining phase is ended, the operators can remove the material from the machine;
14. Quality control: finally the operator can control if the worked material is acceptable or not for quality standards.

The division and identification of sub-phases has criticalities, in fact the operator does not follow a written strict procedure which can help creating a routine, instead operator performs the activities in the order he wants. Even if this does not compromise the work, the relieving procedure is strongly made difficult. In fact the analyst can hardly predict what operation will occur after the previous one (the operator often change the order in which sub-phases are fulfilled). Here it comes a criticality during the application of the system: understand the starting and the finish of each sub-phases. In a first moment it was created a draft which can make understandable when each sub-phases start and end occur, this draft was then perfected resulting in the Table III.9:

Table III.9 This table reports the initial and ending movement for each sub-phases individualized.

SUB-PHASE	START AND FINISH DEFINITION	
1. Transparent table positioning	START	Table positioned on machining plan
	FINISH	Hands removed from table
2. Tables adhesion	START	Finished sub-phase 1
	FINISH	Start stainless steel frame overturning
3. Pins coverage	START	Stainless steel frame overturned
	FINISH	Stainless steel frame overturning after adhesive ribbon application
4. External wire change	START	Finish previous operation
	FINISH	Wire cutting after sticking the wire in the needle
5. Needle change	START	Finish previous operation
	FINISH	Wire cutting after sticking the wire in the needle
6. Internal wile coil change	START	Finish previous operation
	FINISH	Repositioning of hatch
7. Machining file selection	START	Finish previous operation
	FINISH	Press [X END] button on machine PC
8. Material positioning	START	Finish previous operation
	FINISH	Handling adhesive ribbon for material fixing
9. Adhesive ribbon application	START	Handling adhesive ribbon for material fixing
	FINISH	Adhesive ribbon removed from machine plan
10. Machine commissioning	START	Hand positioned on knobs
	FINISH	“Clack” sound of machine hooking the frame
11. Machine cycle	START	“Clack” sound of machine hooking the frame
	FINISH	Sound of head at limit switch after machining
12. Monitoring	START	This would be defined as a percentage of time
	FINISH	This would be defined as a percentage of time
13. Material removal	START	Sound of head at limit switch after machining
	FINISH	Last produced part removed from table
14. Quality control	START	Last produced part removed from table
	FINISH	Last part positioned in the buffet

It is possible to notice that the sub-phases can be divided by three classis:

1. Starting with a specific movement;
2. Starting with a movement which is the same finishing movement of the previous sub-phase;
3. Starting when the previous sub-phases finish.

The first group (starting with a specific movement) are operation that usually occur in order but not always, therefore the starting movement of the next sub-phase is temporally identical to the end of the first one but it is not the same movement, doing so there is the freedom of having a change in the order but maintaining the possibility of following the order. An example: after sub-phase 2 usually come sub-phase 3 but not always. If the start of sub-phase 3 was "Finish previous operation " and if the order is not followed and for example before the sub-phase 2 occur sub-phase 7, it means that the time required to go from the machine PC to the machine plan would be included in the relieved time for sub-phases 3. The time added then would make the specific data of the relief an outlayer and therefore eliminated. The sub-phases that usually comes in a specific order belong to the second group (one starting with a movement which is the same finishing movement of the previous sub-phase) and this because it is always like this. Finally the three sub-phases that has a start classified as "Finish previous operation" are operation that require more time and therefore the influence of few second is negligible, furthermore for these operation it was impossible to detect a movement clear and repeated every time that could constitute the start of the operation.

An important aspect to analyse in the sub-phases "Monitoring". This duration strongly depends on what kind of product is machining: an order is monitored during all the machining time, instead a trial is monitored only in the specific phase which can give criticalities finally during a production the monitoring time is reduced to the absolute minimum.

When this division was applied for the trial timekeeping, it fit. But after different reliefs the division was renowned ineffective. Therefore the analyst decided to join together some phases, remove and change others in order to make easier relieving time. The changes made were:

1. "Adhesive ribbon application" sub-phase was converted into "Mask application". This because during the relieving procedure, the operator changed the kind of pin used and therefore the application of adhesive ribbon was substituted by or nothing (pins alone were enough to fix the material) or applying the masks.
2. "Monitoring" sub-phase was removed because even if it can be considered a sub-phase it is strongly influenced by all other operation and it is still an inactivity time. Considering it as an activity brought to wrong evaluation of operator saturation level.
3. "Quality control" was removed for the same reasons of "Monitoring" removal.
4. "Frame shift" and "Frame load" sub-phases waere added. "Frame shift" sub-phase emerged only during production of lots: the frame used in these case are two and therefore after one frame finished the machining, it is removed from the machine plan to allow "Machine commissioning" to the other frame. Start: Sound of head at limit switch after machining. Finish: knobs left. In exact opposite way it works for the "Frame load" which is the operation through which the operator loads the stainless steel framework on the machine. Because the movements of the operator are the same, these two subphases are treated as *twins* sub-phases
5. "Template marking" sub-phases added. This phase occurs when a table is used for the first time and the machining ended. The table and mask are marked in order to easly discover the orientation in the case the table will be used again. Start: Last part positioned in the buffet. Finish: Table positioned in the table buffet.

This innovation to the relieving method were adopting for the majority of the reliefs duration. When the collected data has been analysed to create the model, other changes was suggested by the data control:

1. “Material positioning” and “Mask application” can be unified in a single sub-phases called “Material fixing”. In fact during the reliefs sometimes the distinction between the two phases was not clear and the operator could position a material and immediately apply the mask, making the relieve of time impossible.
2. “Pins application” was added. The operation was previously done by other working station, but with the introduction of the new kind of pins and the long process for application, this was yielded to the *Rodella* working station and therefore was added as sub-phases.

After the introduction of the last change, then the analysis was carried out in the best condition. Before controlling the result is important to evaluate other aspect of the method.

The cyclicity of all the sub-phases described is one, it means that their repetition inside an entire machining cycle is only one.

3.6.2 ADD-ONS

During the first period in which the analyst monitored the machining phase to understand how many sub-phases were possible, there was the possibility to control the environment and how the machine used to work in order to assign the add-ons.

About the physiological needs, add-ons are standard, so there is no possibility of modifying them. Their value change if the working station is composed by men, women or mixed gender. In case the working station is composed only by man, then the add-on is of 4.16%. In the remaining case, the add-on is o f 5%. The *Rodella* working station is composed only by one machinery which need only an operator to be operative, in fact *Rodella* is controlled by only one male operator which set the physiological need add-on at 5%. Based on a daily work, so eight hours, 4.16% represents twenty minutes. *Goretty S.r.l.* grants its employees a break in the morning for fifteen minutes to carry out physiological needs, it means that on the remaining throughout of the day a break of five minutes must be granted. Five minutes over a day work represent 1.01% of the time. It means that the add-on for physiological needs will be 1.01%.

The unexpected add-ons has three voices. During the analysis of the machine cycle it was possible to determine the value of each of them. In this case the add-on is divided into two class: easy operation and hard operation; *Rodella* working station accomplish only easy operation. Even if already listed here are reported with the value chosen for the machinery.

- Unexpected due to materials, finished products or semi-machined products. It can happen sometimes that incoming parts present some imperfection (principally due to wrong gluing of parts) which makes the machining impossible or, in other case, require more time to the operator to prepare machine set-up. The frequency is very low but it still have an impact, therefore the add-on related to materials will be 0.50%.
- Unexpected due to production process. It has never happened that the working station suffered of unexpected attributable to the production process. Then the add-on related to this will be 0.00%.
- Unexpected due to means of production. It has been frequently reported issues related to machinery. In fact it has a weel-known issues by operators and technicians which can compromise an entire order of one or two pieces. Furthermore the machine in some case shift the seam work of millimetres from the given one and then the technical office has to

replace the machine work by moving little by little the work with a trial and error approach. This happen quite frequently and it has a strong impact on production, so this add-on is evaluated of 2% (its maximum acceptable value).

Finally add-ons due to fatigue. The attribution of this add-on is quite long procedure because of all the variable to consider. It has been already listed and explained all the sub-session, therefore now it will be analysed only the one which has an attributed value.

- Physical effort: the tabled physical effort for a stand-up work is 3% for male. But in this case, there are some *bonus* which decrease the value. The work is not carried out all day but only when necessary (when clients require orders). Only in case of production the operator works on the station all day long. Furthermore the weight to be raised are less than kilos and the movement is minimum, a torsion of less than 180°. Because of these reason the add-on is reduced to 2.00%.
- Nervous tension: in a first moment it has been evaluated as 0%. Then, after the following of a production, the analyst noticed tension between operators specifically with operators dealing with the previous and sequent working phase. Because of this the value attributed is 1%: slight tension.
- Noise: the area in which *Rodella* operates is far from other machines. This mean that the noise is low or only the one produced by the machine. The add -on given is 0.50% because the noise is contained in a range between fifty-five and sixty decibels.
- Temperature: the ambient follow the seasonal change of temperature without exceed in term of hot or cold. Because the changing of temperature does not influence production capacity and working operation, then the value of the add-on is 0.50%.
- Danger: the working station is not danger, the operator does not interact directly with moving parts of machine neither needs to approach them. But the machine set-up require to manage needles, screwdrivers and pliers which increase the add-on to 1.00%.

To sum up all the add-ons, here a summative table (Table III.10).

Table III.10 It summarizes all the add-ons chosen for each area each aspect of each area.

Add-ons	description	Value
physiological needs	Male	1.01%
unexpected	Unexpected due to materials	0.50%
	Unexpected due to production process	0.00%
	Unexpected due to means of production	2.00%
	TOTAL	2.50%
1.00%fatigue	Physical effort	2.00%
	Nervous tension	1.00%
	Monotony	0.00%
	Noise	0.50%
	Lighting	0.00%
	Temperature	0.50%
	Danger	1.00%
	Smells and dusts	0.00%
	TOTAL	5.00%

3.6.3 RELIEF SHEET

The organization of the last updated *relief sheet* is reported in Figure III.14.

GORETTI RELIEF SHEET

Analyst	
Date and Time	
Relief n°_Sheet n°	

Machining center
Rodella 3 heads

Operatore	M	F
	Standing	Sitting
Claudio		

	Machine cycle		Pins application		Transparent table positioning		...	
	Time [s]	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**
Notes								
Measures 1								
2								
3								

Order	
Pieces/Cycle	
Stiches n°	
Stitches lenght	
PPM	
Thickness	
pins	

Figure III.14 It is part of the relief sheet used to relieve time. All the information on the right will be used to create the forecasting model.

The phases reported in columns are, in order

1. Machine cycle;
2. Pins application;
3. Transparent table positioning;
4. Tables adhesion;
5. Pins coverage;
6. External wire change;
7. Needle change:
8. Internal wile coil change;
9. Machining file selection;
10. Material fixing;
11. Machine commissioning;
12. Frame shift;
13. Frame load;
14. Material removal;
15. Template marking.

Each phase column is then divided in two columns reporting *Time* and *Pitch*. Below there is a space for note and then all measures. The general information introduced in the sheet are: analyst's generalities, date and time, number of reliefs, operators and condition. This general information will be used in future in case the relieving activity will proceed inside the company. Then some other general information are reported in order to collect enough information to create the forecasting model. The information are: order code, pieces/cicle (and these are standard info), then number of point put by the machine, the standard speed of the head, thickness of material; number of pins. All these data will be used to create the model.

3.7 CHAPTER SUMMARY

The market in which *Goretti S.r.l* operates is characterize of a highly checkered demand which brings to a diversified range of product. Brands (company's clients) have difficulties in determine what really the customer is willing to have, therefore brands must do a creative job to extrapolate the clients' expected product. In order to do so brands produce lots of sample ordered to cluster of suppliers. Suppliers cannot (or can hardly) predict in advance what requests brands will do within few days. This mean managing difficulties in planning the production or the humane resource needed in long term.

The market condition which brings brands to create a large number of samples, inside the supplier turns in the need of being able to highly diversify the production both in terms of production process and in terms of materials and machining. A supplier must be able to change rapidly the production process used for sample changing the physical path of the materials, changing raw material and changing machining too. Therefore in terms of forecasting process of cost it is a very difficult practice to be carried out. There is also another important factor that influence the forecast of cost and the time of production, it must be taken into consideration when analysing fashion supplier companies: the craftsmanship of the production. Therefore in terms of forecasting process of time and cost it is a very difficult practice to be carried out.

Company then is willing to create a system to become aware of production time of orders also because it noticed a difficulty in estimating the cost to the client. The solution was identified in the relief of the time done by operators during the machining phase of an order. This method led to not reliable estimates and reliable means that the estimation done by the company suffers of deviation during the production process due to variables difficult to predict.

With the management it has been chosen as technological benchmark the automatic seam machine: *Rodella.* A series of models on the creation of forecasting model have been studied. The class of model selected is the empirical models. In this kind of model the forecasting of time is obtained true an evaluation of historic data storage, based on these storage it is possible to define index which would be used as a parameter forecast time of machining. In the case in which the historic data storage is absence in the company database in order to apply an empirical model there is the need of creating the historic data storage. To collect data the method chosen is the Bedaux cronothecnical technique. Therefore the analyst proceeded in: defining the sub-phases of machining process and their cyclicity, then defining the add-ons and finally data relief (time and *pitch*) and an analysis of the database created.

CHAPTER IV RESULTS AND DISCUSSION

The *Bedaux chronotechnical technique* method was chosen as relieving process method, it is implemented through a physical relief of time taken from the analyst on site, together with time the analyst will assign also a measure of efficient to the operator (i.e. *Bedaux pitch*). Applying this method the analyst was able to gain numerous data which will be covered below.

A brief description of the craftsmen is carried out to better understand the environment in which the analysis was carried out and to lower the reader down within the context of the company (which will be helpful to understand the allocation of the *Bedaux pitch*). *Rodella* machine (the technological benchmark chosen for the reliefs) is monitored and used only by an employee called Claudio. *Rodella* was chosen as technological benchmark because it is the most affected machine by production time shift from estimation. The situation is exacerbated because the machine has strong potentiality: some clients commission products to a supplier only if it has a *Rodella* which will machine the product. The employee has been working for the company since 2014, while the three heads machine *Rodella* with has been bought in 2019, previously the company bought (in 2016) another machine similar to *Rodella* but with one head. Since 2019 the only operator dealing with *Rodella* was Claudio, supported sometimes with another operator (Emir). The operator is therefore expert and then his efficiency can be considered medium-high and surely higher than all other employees in the company. It is always a delicate relationship between an operator and a time relieving analyst, in fact if not well defined the analyst work, craftsmen could become hostile considering the relieving an evaluation of the operator's work (or the person evaluation). It is very important to communicate to the workforce the exact work of the analyst, explaining the relieving procedure and the scope of the work. It is upon the analyst to maintain a cooperation environment. In the specific case, Claudio has always shown great availability in explaining the production process of *Rodella* and clarifying every doubt or question the analyst has on the machine. Claudio showed also flexibility reaching out some analyst request. Overall the collaboration atmosphere can be positively evaluated with good operator openness.

Last brief evaluation before data analysis must be dedicated to the way in which physically data has been collected and scanned. Figure IV.1 shows the sheet used for time relief. Data format used in this sheet was in a first moment *hh:mm:ss* so that the first task accomplished has lower value. Because the operator does not have an ordered procedure to follow but can accomplish tasks in the order he prefers (exception done for some specific task), it was not possible to list the activity in a chronological order. Therefore in first position of relief sheet it is always positioned the machine cycle. Then there is a hypnotized logical order for tasks. In Figure IV.1 it is possible to notice how the first task is “Pins application”, then “Transparent table positioning”, then “Tables adhesion” and last “Machine cycle”. The list of task are not ordered progressively but the time is incremental, talking about Figure IV.1 if the first task “Pins application” lasts for about thirty-five minutes, the second task “Transparent table positioning” will last the time noted under the sub-phase, about thirty-eight minutes, less the time of previous sub-phases.

GORETTI RELIEF SHEET

Analyst	Francesco Gatto
Date and Time	12/10/2020 16:30
Relief n°_Sheet n°	3_6

Machining center
Rodella 3 heads

Operatore	M	F
	Standing	Sitting
Claudio		

	Machine cycle		Pins application		Transparent table positioning		Tables adhesion		...	
	Time [s]	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**
Notes										
Measures 1	00:59:48	100	00:34:52	95	00:38:17	100	00:46:15	95		
2	01:01:20	100	00:34:00	100	00:39:50	110	00:46:03	95		
3	01:00:06	100	00:35:05	95	00:39:02	105	00:45:58	100		

Order	---
Pieces/Cycle	2
Stiches n°	382
Stitches lenght	2.5
PPM	600
Thickness	leather
pins	30

Figure IV.1 This is an example of a portion of relief sheet filled out with representational value.

The method of time relieving previously described clearly needs an additional processing of data: the time relieved per each task is not the duration of the task itself (the time is collected in incremental way) but it is the duration of the process until the end of the sub-phases. The relieving of incremental time was adopted because during the relieving procedure it allows to fill out the *relief sheet* just inserting only the time read on the chronometer. It means that exception for the first task, each *i-th* task duration (*t*) will be evaluated as:

$$t_i = t_i - t_{i-1} \quad , i > 1 \qquad \{4.1\}$$

The result of this procedure applied at the relieving sheet of Figure IV.1 *i*t is reported in Figure IV.2. Then the time of each measures under each sub-phases represents the real duration of the specific sub-phases.

GORETTI TIME RELIEFS ANALYSIS

Analyst	Francesco Gatto
Date and Time	12/10/2020 16:30
Relief n°_Sheet n°	3_6
Machining center	Rodella 3 heads
Operatore	M / Standing · F / Sitting
Claudio	

Order	---
Pieces/Cycle	2
Stiches n°	382
Stitches lenght	2.5
PPM	600
Thickness	leather
pins	30

	Machine cycle		Pins application		Transparent table positioning		Tables adhesion		...	
	Time [s]	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**	**Time [s]**	**Pitch**
Measures 1	00:13:33	100	00:34:52	95	00:03:25	100	00:07:58	95		
2	00:15:17	100	00:34:00	100	00:05:50	110	00:06:13	95		
3	00:14:08	100	00:35:05	95	00:03:57	105	00:06:56	100		
Average	14:19	100	34:39	96.6667	04:24	105	07:02	96.6667	---	---
Normal pitch		100		100		100		100		100
Normal time	14:19		33:30		04:37		06:48		---	
Unexp. add-on	2.50%		2.50%		2.50%		2.50%		---	
Fatigue add-on			5.00%		5.00%		5.00%		---	
Tot. add-on	2.50%		7.50%		7.50%		7.50%		---	
Nominal time	14:41		36:00		04:58		07:19		---	
cyclicity	1		1		1		1		---	
Assigned time	14:41		36:00		04:58		07:19		---	
Physiol. needs add-on			1.01%		1.01%		1.01%		1.01%	
Standard time	14:41		36:21		05:01		07:23		---	

Figure IV.2 It represents the analysis sheet which was used to convert the progressive duration of tasks into the duration of each task.

The sequence of task accomplished by the operator is not always the same and he can change the procedure as he wants (because procedure are not strictly given by company management), in this case the first task is "*Pins application*" then "*Transparent table positioning*", followed by "*Tables adhesion*" and finally "*Machine Cycle*". Consequently data processing must be carried out for each relief without the possibility of using an automatic software (as Excel function) but manually: processing each task of each relief.

All the sub-phases can be classified in three classes with model creation purpose:

1. Data deficit sub-phases;
2. Independent data sub-phases;
3. Model needed sub-phases.

The relation that links these three classes is reported in Figure IV.3. The condition in which the market brings the company to operate and therefore the employees to work (*Chapter 3*) imply that the workers not always need to carry out the same tasks on the same products but it can happen that the sub-phases is carried out for the minority of cannot generate a relevant amount of reliefs (and so data). Sub-phases with this deficit cannot be analysed neither a model can be created because the lack of data do not allow to recognize a pattern in data and finally these sub-phases model cannot neither be verified once created. In this case the sub-phases are "*Data deficit sub-*

phases". All sub-phases for which data relieved were enough to be analysed can then be divided in the two other classes listed above. Some sub-phases require a time which is not depending on the characteristic of the product, it means that the time of this tasks can be compared with the same data relieved for other reliefs. This sub-phases will be called the "*Indipendent data sub-phases*". The forecasting model of these sub-phases is easily obtained evaluating the *assigned time* and *standard time* applying their formulas on the totality of data collected. Finally, the last class of sub-phases are the one in which the time required to accomplish the sub-phases strongly depend on the characteristics of the product and therefore a specific study is needed phase-by-phase.

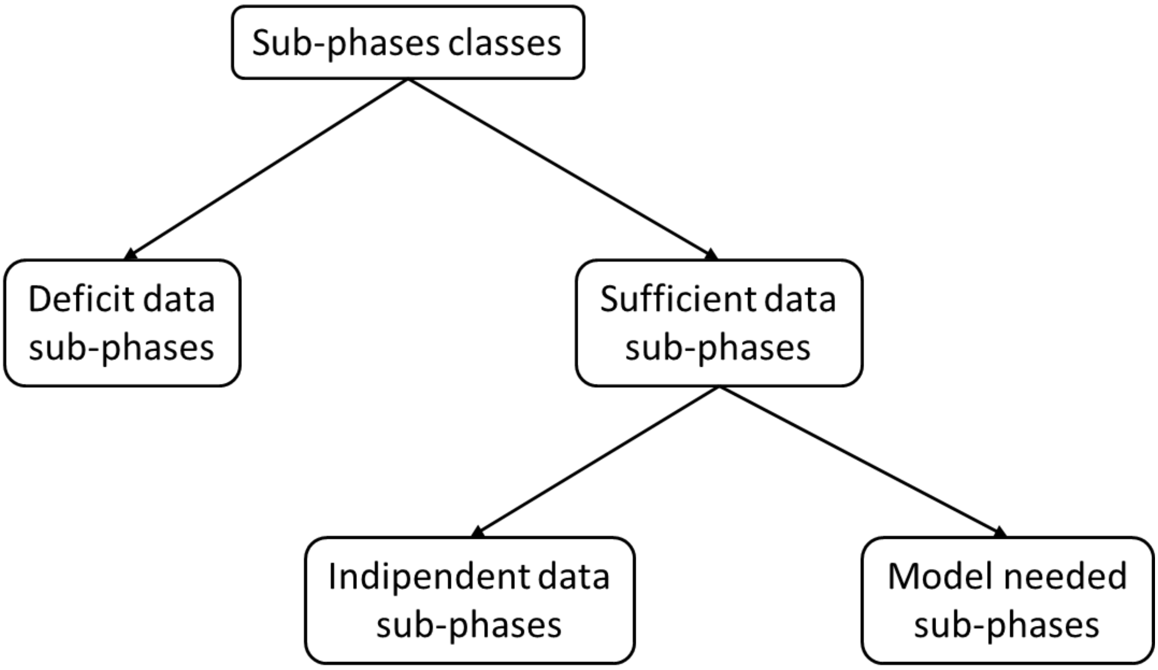


Figure IV.3 It reports the relationship between the three classes of sub-phases.

For simplicity the latest updated list of the tasks are listed and a table is reported (Table IV.1) dividing the sub-phases in the tree classes just described:

15. Pins application;
16. Transparent table positioning;
17. Tables adhesion;
18. Pins coverage;
19. External wire change;
20. Needle change;
21. Internal wire coil change;
22. Machining file selection;
23. Material fixing;
24. Machine commissioning;
25. Machine cycle;
26. Frame load;
27. Frame unload;
28. Material removal;
29. Template marking.

Table IV.1 It represent the classification of identified sub-phases in the three classes listed above. In brackets the cronological position of the sub-phases.

	SUFFICIENT DATA SUB-PHASES	
DEFICIT DATA SUB-PHASES	**INDIPENDENT DATA SUB-PHASES**	**MODEL NEEDED SUB-PHASES**
Transparent table positioning (2)	External wire change (5)	Pins application (1)
Tables adhesion (3)	Needle change (6)	Material fixing (9)
Pins coverage (4)	Machining file selection (8)	Machine cycle (11)
Internal wire coil change (7)	Machine commissioning (10)	Material removal (14)
Template marking (15)	Frame load (12)	
	Frame unload (13)	

The data collecting and the analysis carried out to obtain the forecasting model are discussed step by step.

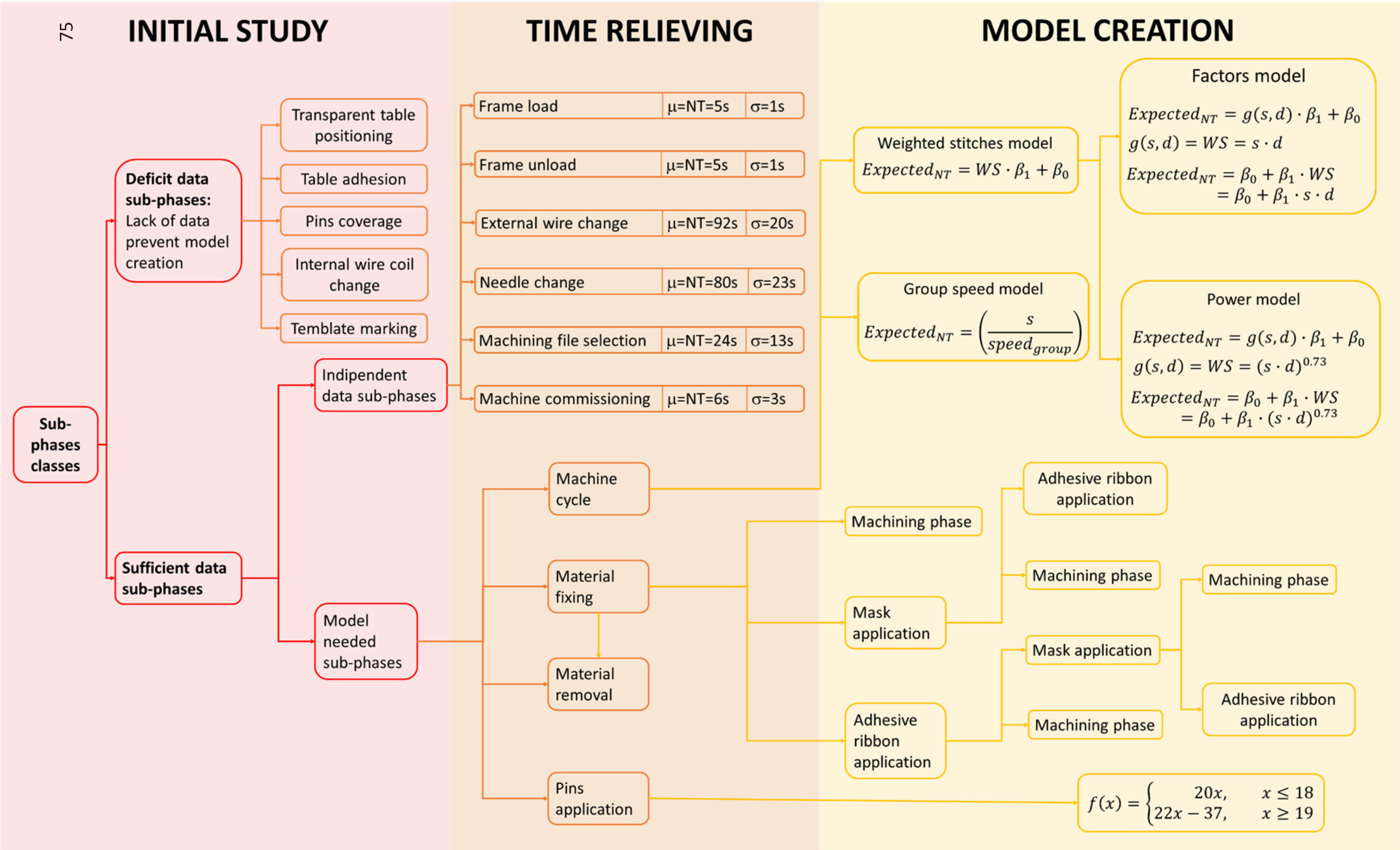
To facilitate the understanding of the sub-phases classification and the model created, a schematic sum-up is reported in the next page. Here the legend:

- Red line indicates sub-phases classes;
- Orange line indicates sub-phases;
- Yellow line indicate models.

About *independent data sub-phases*, aside each one is reported the average value (μ) and the standard deviation (σ).

All the subphases, reliefs and models will be explained singularly but to have an easy read of the models' sum-up here a brief legend of symbols:

- $Expected_{NT}$ is the expected normal time, output of the model;
- WS is the *weighted stitches* used as auxiliary variable;
- β_i are regressors;
- s is the number of stitches;
- d is the *difficulty index* which is used as weight for the number of stitches;
- $speed_{group}$ is the average speed of a products group;
- x is the number of pins


INITIAL STUDY
TIME RELIEVING
MODEL CREATION
Sub-phases classes
Deficit data sub-phases: Lack of data prevent model creation
Sufficient data sub-phases
Transparent table positioning
Table adhesion
Pins coverage
Internal wire coil change
Temblate marking
Indipendent data sub-phases
Model needed sub-phases
Frame load μ=NT=5s σ=1s
Frame unload μ=NT=5s σ=1s
External wire change μ=NT=92s σ=20s
Needle change μ=NT=80s σ=23s
Machining file selection μ=NT=24s σ=13s
Machine commissioning μ=NT=6s σ=3s
Machine cycle
Material fixing
Material removal
Pins application
Weighted stitches model
$Expected_{NT} = WS \cdot \beta_1 + \beta_0$
Group speed model
$Expected_{NT} = \left(\frac{s}{speed_{group}}\right)$
Factors model
$Expected_{NT} = g(s,d) \cdot \beta_1 + \beta_0$
$g(s,d) = WS = s \cdot d$
$Expected_{NT} = \beta_0 + \beta_1 \cdot WS = \beta_0 + \beta_1 \cdot s \cdot d$
Power model
$Expected_{NT} = g(s,d) \cdot \beta_1 + \beta_0$
$g(s,d) = WS = (s \cdot d)^{0.73}$
$Expected_{NT} = \beta_0 + \beta_1 \cdot WS = \beta_0 + \beta_1 \cdot (s \cdot d)^{0.73}$
Machining phase
Mask application
Adhesive ribbon application
Adhesive ribbon application
Machining phase
Mask application
Machining phase
Machining phase
Adhesive ribbon application
$f(x) = \begin{cases} 20x, & x \leq 18 \\ 22x - 37, & x \geq 19 \end{cases}$

4.1 DATA DEFICIT SUB-PHASES

This class includes:

- Transparent table positioning;
- Tables adhesion;
- Pins coverage;
- Internal wile coil change;
- Template marking.

These sub-phases do not have enough data to be studied and therefore cannot be created a model based on data collected. The manned activities of these sub-phases are punctually described to understand the time acquisition difficulties.

4.1.1 TRANSPARENT TABLE POSITIONING SUB-PHASES

This task is the first step of each machining phase and it includes the positioning of the transparent table (on which the material will be fixed through the pins) on the stainless steel frame. It starts when the table is positioned on machining plan and it finishes when operator's hands are removed from the machining table. *Rodella* is not a full time used machine because of not all production portfolio requires its use. This can obstacle the analyst work that must also interviews the employees, therefore there are difficulties in data transmission and time. Furthermore the management does not often know in which phases each order is and only the operator can communicate it. The only data collected are the one reported in Table IV.2.

Table IV.2 The table reorts data collected during the thesis period.

Reliefs (relief_sheet)	3_1	5_3	8_1
Code	[redacted]		
Add. Info	Man		
Parts number	10	2	4
Pins	86	10	42
Normal time [s]	199	64	79

This step has two alternative configurations: the table employs all the four stainless steel frame pins (it means the "bigger table") or just two pins (or both left-side, or both right-side; this is the "smaller table"). The frame has 4 pins (one in each angle, as Figure IV.4 shows).

Figure IV.4 It represents the number of pins in the stainless steel.

The parameter influencing the sub-phase required time is the dimension of the table (stick four pins requires for the “bigger table” requires more time than stick two pins for the “smaller table”) which is chosen by technician office and therefore it is known before the production start and the it can be forecasted.

4.1.2 TABLE ADESION SUB-PHASE

Transparent table is locked on the stainless steel, and then the heavier white table is fixed on it with adhesive ribbon adhesive ribbon to give more robustness to material support. The task relieved time starts when *transparent table positioning* ends and stops when the stainless steel frame is overturned. The amount of adhesive ribbon that the employee applies to the table depends on:

- The dimension of table;
- The shape of the products.

Normally the adhesive ribbon positioned are along the sides of table in correspondence of the frame, but if the table cover all the frame, two adhesive ribbon strips are positioned parallel the long side. Then the bonding agent is placed in order to cover the sides of the product. Because of the high diversity of production and shapes of products and because of the high variability of adhesive ribbon positioning, it is hard to forecast which parameter may be the driver for time duration of task. It is reasonable to think that the amount of adhesive ribbon may be dependent on the length of the seam. Figure IV.5 *and* Figure IV.6 reports a case where the number of point is not proportional to the time required to application of adhesive ribbon. It can easily be understood that when the product has numerous coves then the number of fixing material applied are not proportional because they will not be applied in each side of the product but above the coves. *Figure 5* represent schematically a real product with a total amount of 870 stitches. *Figure 6* represent a real product with 2359 stitches.

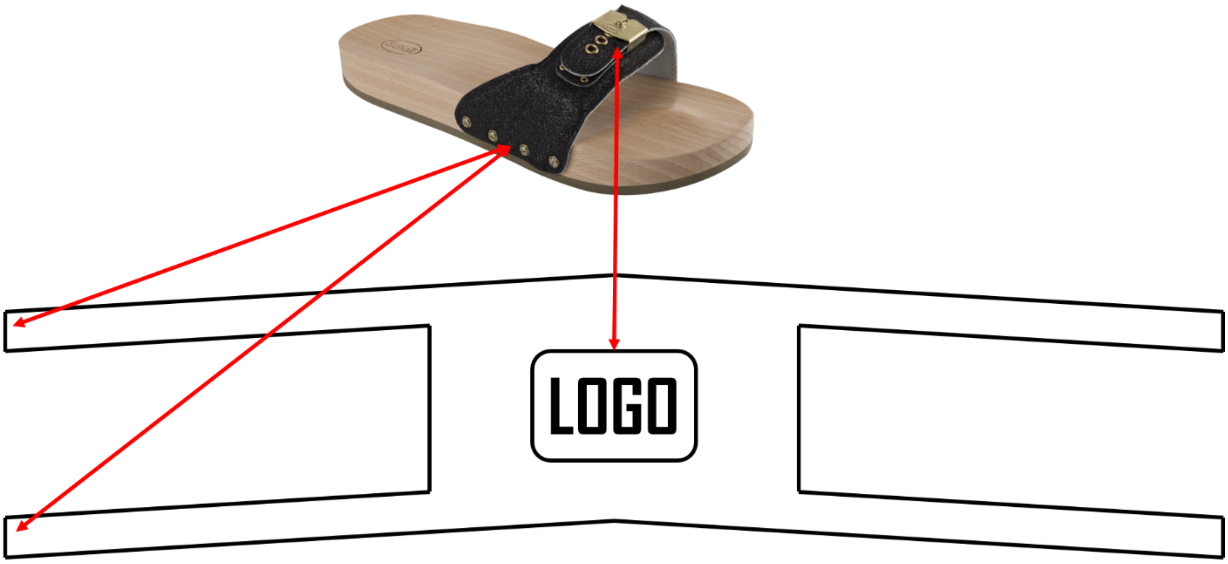


Figure IV.5 it is the representation of an upper slipper part omitted for contractual confidentiality obligation.[40]

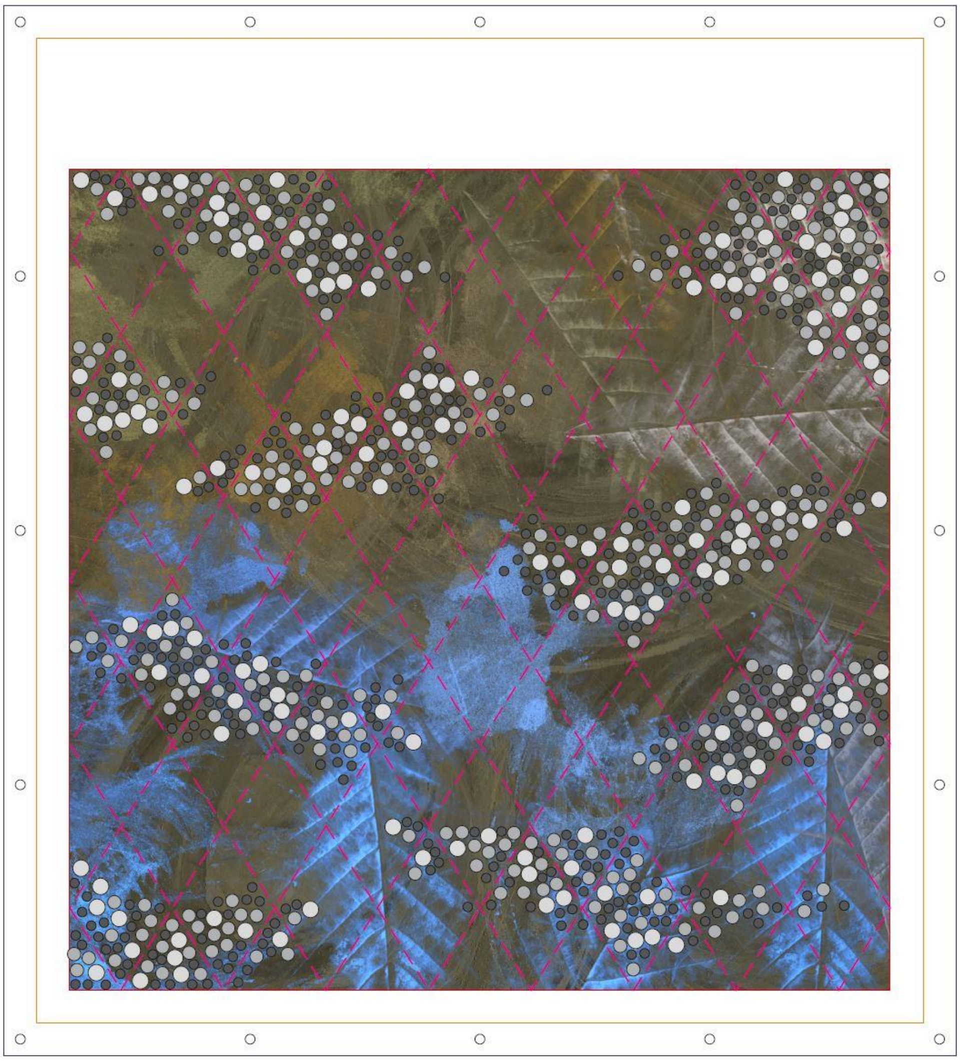


Figure IV.6 It represents a quilted seam machined by Rodella

[40] *Dr. School* website

The total amount of adhesive ribbon strips used is equal for both the cases and consequently the time required is almost the same. In fact the real driver that influence the number of strips used to fix tables (and therefore time) is given by the geometric polygon in which the product can be inscribed, which is a rectangle in both cases (as Figure IV.7 reports).

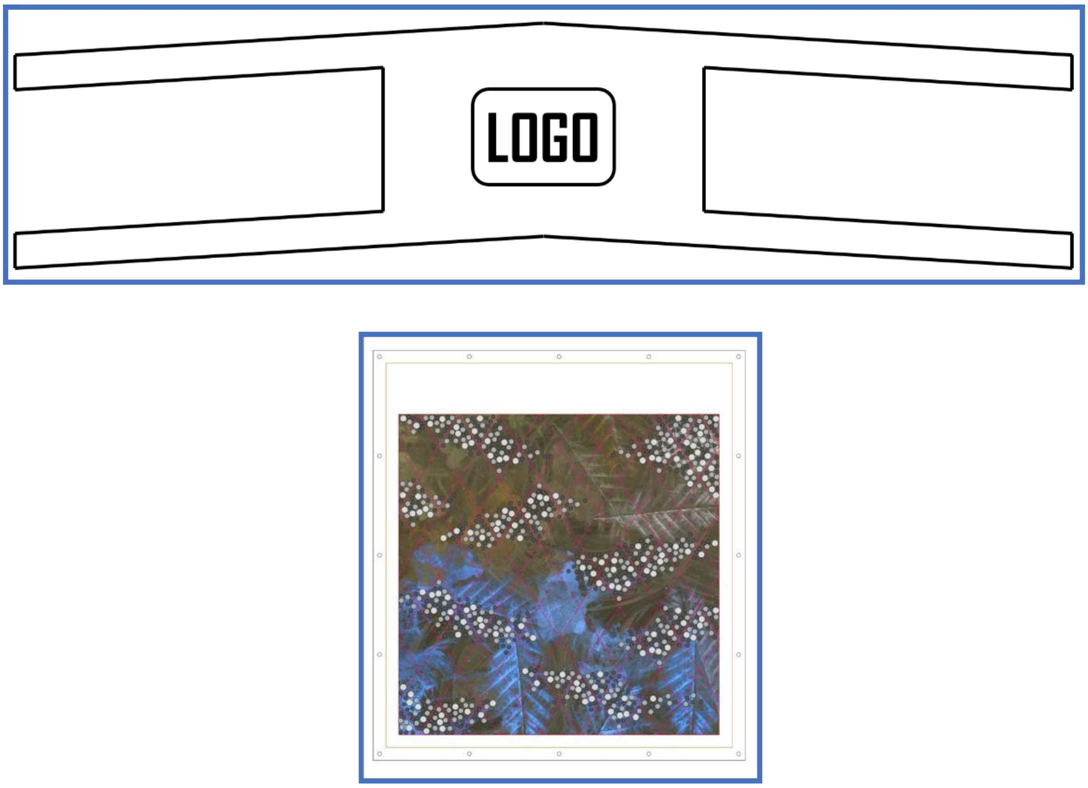


Figure IV.7 The blue rectangles around the product represents the polygon in which the two products can be inscribed.

The definition of the polygon that circumscribes the product can be defined through a software or just by technical office based on common sense and evaluation, but also this procedure is not always easy one. In Figure IV.8 circumscribing polygons for the same product are reported. In fact it is important to highlight how the real target is not to minimize the sides of the polygon that circumscribes the product but to forecast the real amount of strips the operator is going to fix.

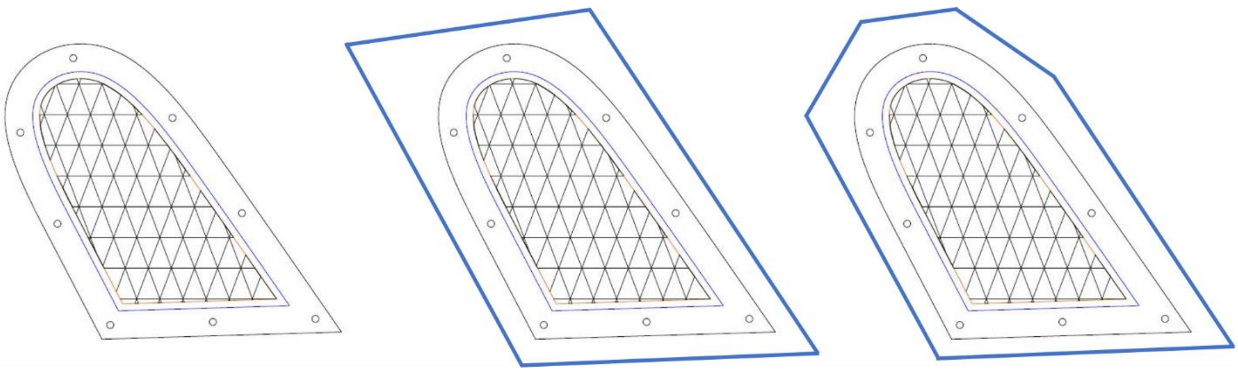


Figure IV.8 Two different circumscribing polygon solution are showed.

For the same product showed in Figure IV.8 the different solution range goes from twenty strips to thirty strips. Therefore the total amount of stitches it is not enough to forecast the time required and at the same time a personal evaluation may be misleading. An alternative method evaluates two parameters (drivers) simultaneously: number of point and number of pins (for example, product shows in Figure IV.5 has eighteen pins while the product in Figure IV.6 has sixteen pins. The way in which pins and stitches combine to produce a parameter that can be used as time forecasting driver requires a deeper study of the sub-phase and more data are needed to accomplish and verify the hypothesis explained. Some data collected during the analysis are reported in Table IV.1:

Table IV.3 Data collected for Table adhesion sub-phase.

Reliefs (relief_sheet)	3_1	5_3	8_1
Code	[redacted]	[redacted]	[redacted]
Add. Info	Man		
Parts number	10	2	4
Stitches	8302	517	1078
Pins	86	10	42
Adhesive ribbon strips	12	12	18
Normal time [s]	296	231	361

4.1.3 PINS COVERAGE SUB-PHASES

During this phase the operator overturnes the stainless steel and the tables fixed together because the pins used to fix the material on the tables are directly touching the machining plan (with scratching risk); therefore wire could get stuck with pins, then pins are covered with adhesive adhesive ribbon. The phase starts when the stainless steel frame is overturned the first time and it ends when the frame is overturned again after adhesive adhesive ribbon application. This phase is not always carried out because it depends on different factors: kind of pins used, kind of machining and amount of parts to produce. The most important factor is the number of pins used.

The application of pins method used by the operator changed during the time reliving period. In a first period the pins are fixed to tables with white glue (Figure IV.9). Then in a second period the this method was replaced with riveting pins (Figure IV.10). The reasons of the change are exposed below.

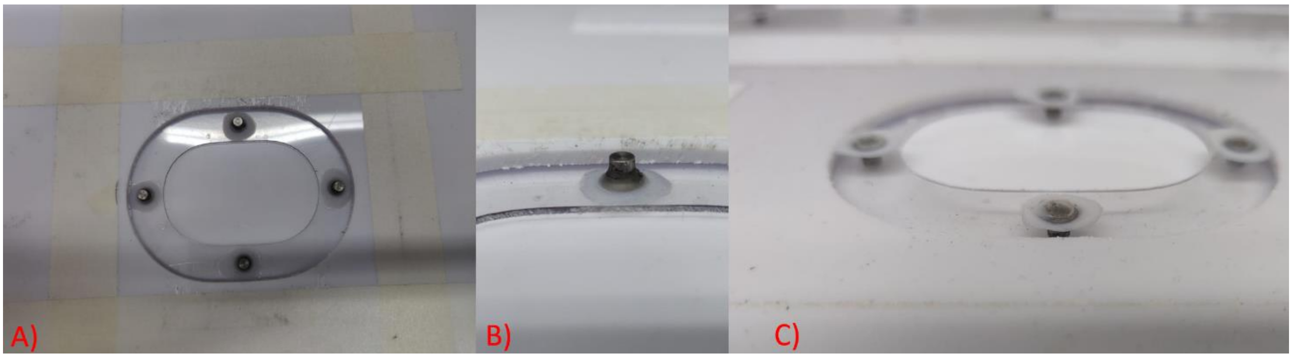


Figure IV.9 An example of pins fixed with glue. A) upper view of the tables. B) detail of a pin fixed with white glue. C) detail of a pin taken below the table and therefore in the side touching the machining table, using this fixing method there is no possibility of wire stucking.

This method had two negative consequences:

1. The time required to fix the pins and wait the glue to dry was long;
2. The pins during machining tended to break away.

The described method was not the best one, the worst consequence were the pins breaking away from the table, in fact without pins the material would be fixed by adhesive adhesive ribbon. The application of adhesive adhesive ribbon is highly time consuming. Therefore operator decided to adopt an alternative fixing method of pins on tables: riveting pins. This operation requires more time than gluing but at the same time guarantee more stable and durable joint. Riveting procedure is carried out by hammering the pins against a pen aimed to expand the head of the pins fixing them to the table as shown in Figure IV.10.

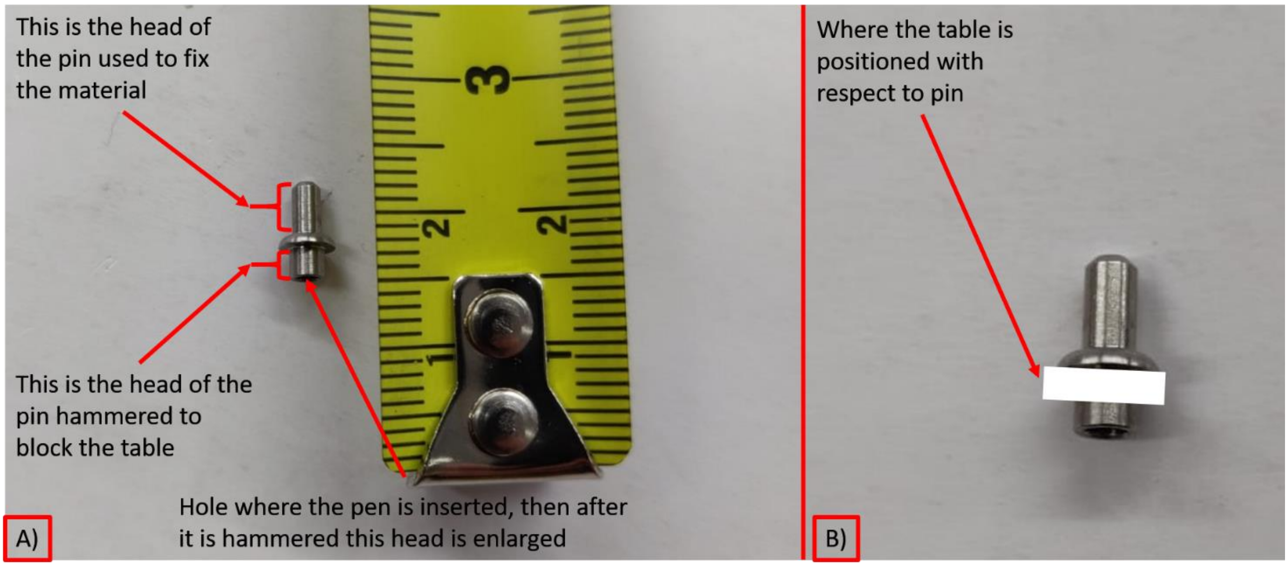


Figure IV.10 A) it is shown the description of each pin parts. B) it is reported how the pin is inserted inside a table hole.

Because each pin must be rivetted then the procedure is quite long and at the same time the back of the pins (the head crushed by the hammer) presents burrs which can intercept wire during the machining phase and block it. This is way pins are covered with textile adhesive ribbon, even if in a first moment the operation was not carried out (Figure IV.11 represents the pin covered with textile adhesive ribbon and without).

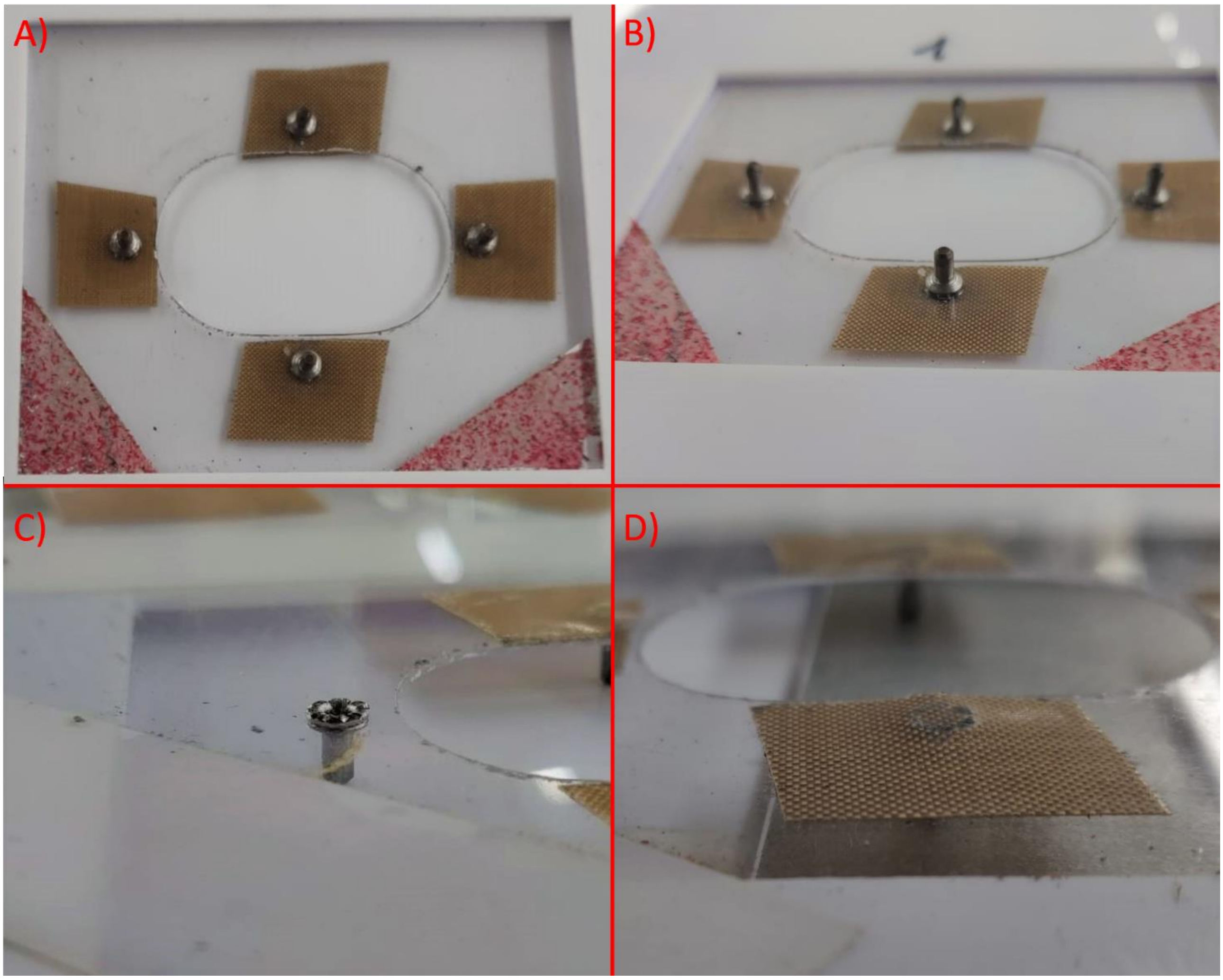


Figure IV.11 Method adopted later by operator alternative to Figure IV.9: A) here rivetted pins are used. B) represents a side view of rivetted pins above the tables, so where the material will be fixed. In the last two figure it is represented a side view below the table and then this side is in contact with the machining plane. C) represents the head of a pin not covered with textile adhesive ribbon, it is evident that the few millimetres (about 1mm) can scratch the machining plan or stuck the wire. D) Textile adhesive ribbon is fixed upon the head.

Furthermore if the number of parts to be machined are just one, operator may opt not to cover pins because the time consumed by this procedure impact too much on a single product Table IV.4shows the data collected up to now.

Table IV.4 Data collected for Pins coverage sub-phases.

Reliefs (relief_sheet)	8_1
Code	[redacted]
Add. Info	
Pins	42
Normal time [s]	510

The high variability of conditions make difficult to forecast when the operation may be carried out. The operator does not have a list of strict procedure to follow (also with chronological order) and therefore he can choose what and when accomplished sub-phases. This phase strongly depends on the number of pins, which is a technical data decided by the technician office choice and so it is known before the starting of machining, then the task forecasting time should be easy to determine.

4.1.4 INTERNAL WIRE COIL CHANGE SUB-PHASE

This sub-phase is used to change the lower wire of the machine. The seam process need the use of two different wire: a top wire and a bottom wire, these two wire intertwine in the middle of the material in a procedure represented in Figure IV.12.

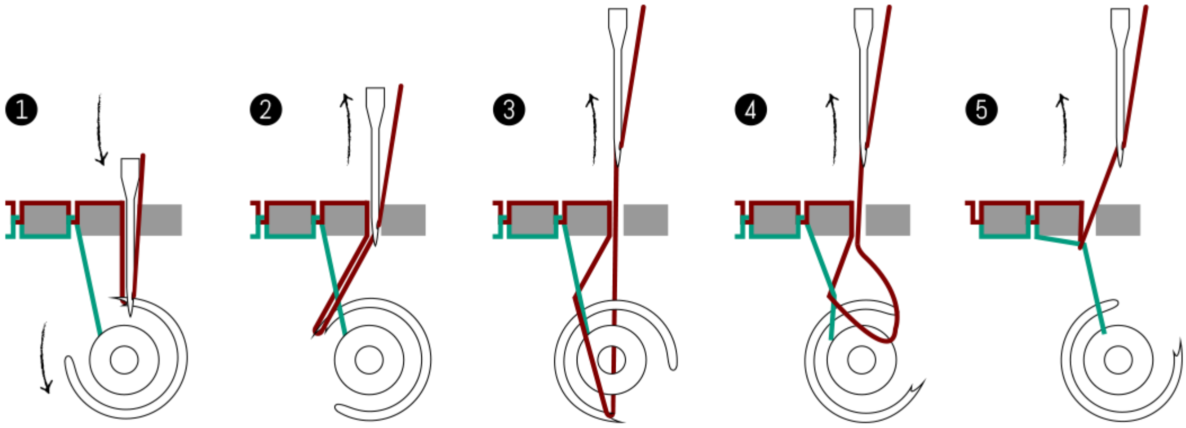


Figure IV.12 This is the seam process represented with a counterclockwise rotation of bottom needle.[41]

In this phase the bottom wire, blue one, is the internal wire coil. The position of this coil is reported in Figure IV.13.

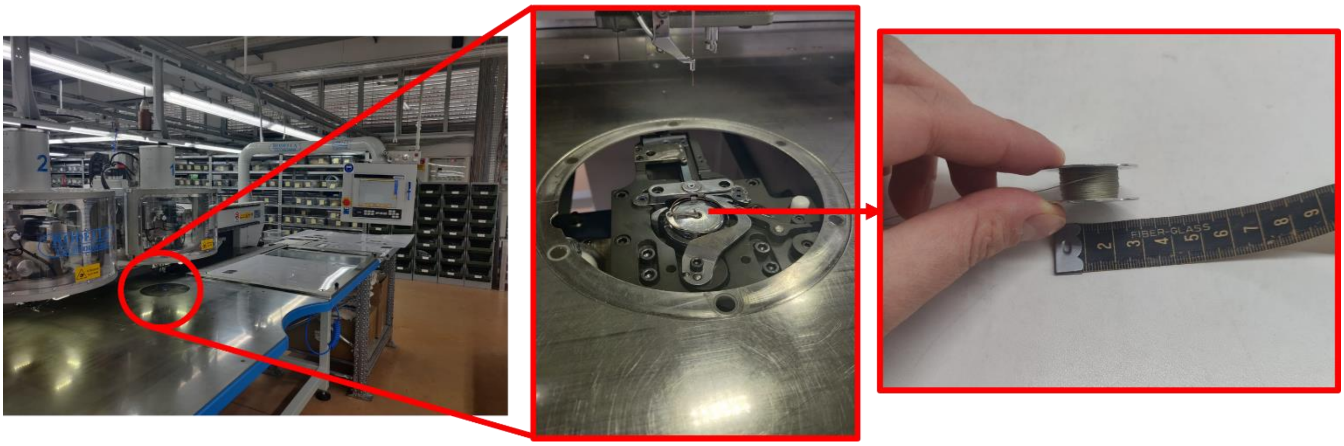


Figure IV.13 The internal coil is positioning and a detail of the internal coil.

This sub-phase does not need a model to forecast the time duration: it does not depend on technical characteristics of the products, it means that changing the product, the duration of this sub-phase does not change. Therefore it is sufficient to relieve a significant amount of data and evaluate their average to forecast the duration of this task. Instead it is difficult to understand when this task will be needed. A reason for the change is the end of a coil but the company does not have enough managerial resources to monitor and forecast when it will end, therefore the forecast of the need for this operation is very difficult. The most important reason is that the internal wire is rarely visible

[41] *Makermauz sewing* website

in a product and therefore it is not always needed to change it. It is upon the client to require a specific bottom wire. Also because of this it is quite rare a change of internal wire and so the relief relieved is just one. Because of its absolute shabbiness it will not be reported in the analysis.

4.1.5 TEMPLATE MARKING SUB-PHASES

This phase occurs when a table is used for the first time and the machining is ended. The table and mask are marked (Figure IV.14).

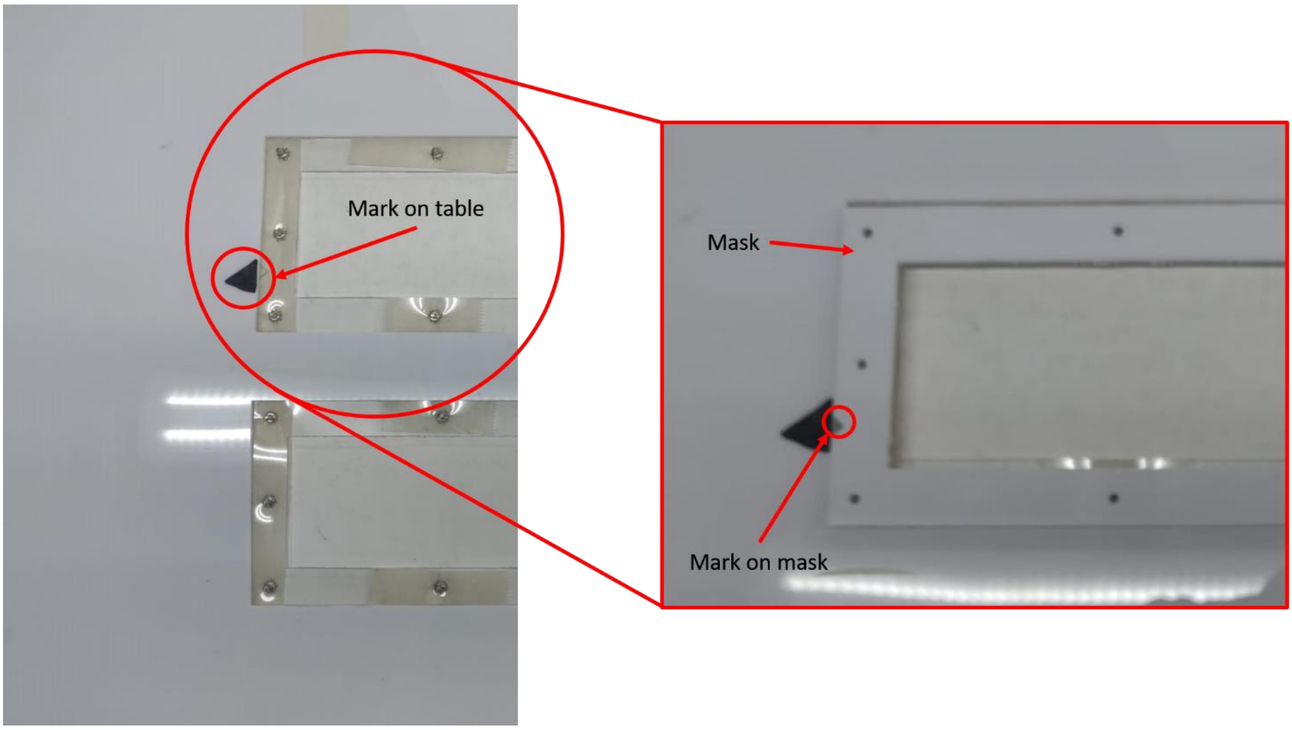


Figure IV.14 The figure shows how the marking system works to help operator recognition the mask orientation.

It starts when the last part produced is positioned in the buffet and it ends when the tables are positioned in the table buffet. When the machining phase is finished, parts are removed and a new product or table must be machined, the old tables are not discarded but are put aside in a buffet. This because it can happen that an order will transform into a production and then the table can be reused. At the same time it can pass long before this happens and then the operator finds useful to put a mark on table and masks which help him to recognize the orientation of the mask on the table.

The sub-phase is not always carried out: if the masks orientation is easy to understand or if the order will never transform into an order, then the operator does not mark it. Furthermore the operation is not carried out at the same chronological order:

- during the pre-relieving phase of analyst, the marking of tables was carried out at the end of the machining phase;
- during the relieving phase it was rarely carried out, but in this case the analyst was not present or the marking was done before the start of a new (different) machining then when a new table was loaded.

Due to these conditions no relief was carried out, but it should be asked if the relieving of this sub-phases is really useful in terms of forecasting the total phase time duration: the impact of tables marking in total time is very low. Anyway if the management of the company will require further studies on this phase too it is logical to expect a strong relation between the number of pins present in the tables and the time duration of the phase.

4.2 INDIPENDENT DATA SUB-PHASES

All the sub-phases inside this class are:

- External wire change;
- Needle change;
- Machining file selection;
- Machine commissioning;
- Frame load.

This class enough data have been collected and therefore it was possible to construct a forecasting model on them. At the same time the duration of these sub-phases do not depend on parameters but they are independent to the product that has to be machined, then the forecasting model will estimate the weighted average of time (weighted on efficiency). Specifically for each sub-phases the times and *pitches* relieved were put together independently from the relief. Then the "*normal time"* (it is the time at which work would be done if not delay incur[42]) was evaluated on these data and the standard deviation too in order to control the statistical validity of data.

4.2.1 EXTERNAL WIRE CHANGE SUB-PHASE

The seam process need the use of two different wire: a top wire and a bottom wire, these two wire intertwine in the middle of the material in a procedure represented in Figure IV.12. The red wire is the top one, here called "external wire". The time of this sub-phases is considered independent because wire can be changed independently from the technical characteristic of the products for example because the wire breakdown. It is still possible to have a change of wire (most of the time) because the client requires a specific wire colour and this one is not the same of the last machining. Then it is possible to consider the presence or absence of this operation and therefore longer or shorter phase time duration. Currently the company has no method implemented to evaluate if the next machining has the same or different wire colour, neither when the wire will end. Therefore it is impossible to forecast if add or not the time. The external wire is maintained in spools and it is positioned in a dedicated location (Figure IV.15).

[42] Piyush Yadav, "Difference Between Standard Time and Normal Time"

Figure IV.15 It is possible to notice on the left the specific location for the spoon on top of which a metallic weight is positioned. On the right a detail of two spoons.

Anyway it is quite usual to have an external wire change and therefor it could be helpful to consider this sub-phase always present when forecasting the total time duration of the phases.

The times relieved are shown in Table IV.5.

Table IV.5 Here all the reliefs about the change of external wire are shown.

Data n°	Reliefs (relief_sheet)	Time	Seconds	Pitch
1	1_1	00:01:11	71.00	110
2	1_2	00:01:26	86.00	100
3		00:01:34	94.00	95
4	2_1	00:02:39	159.00	85
5	5_1	00:01:15	75.00	100
6	6_1	00:01:25	85.00	95
7	6_2	00:01:41	101.00	90
	Average		95.86	96.4286
	Normal pitch			100
	Normal time		92.43	
	Unexp. add-on		2.50%	
	Fatigue add-on		5.00%	
	Tot. add-on		7.50%	
	Nominal time		99.37	
	cyclicity		1	
	Assigned time	00:01:39	99.37	
	Physiol. needs add-on		1.01%	
	Standard time	00:01:43	100.30	

It is necessary to evaluate the standard deviation of changing wire time after a further data processing. In fact the use of time as it is relieved does not give a proper evaluation of standard deviation for *normal time* because this one is normalized with respect to the *Bedaux pitch*. Then it is needed to evaluate the weighted value of each time (*WT*):

$$WT = \frac{T \cdot P}{P_N} \tag{4.2}$$

- T is the time relieved;
- P is the *Bedaux pitch* for the specific relief;
- P_N is the *normal pitch.*

The value of the weighted time for each relief is reported in Table IV.6:

Table IV.6 Calculated weighted time of each relief.

Data n°	Reliefs (relief_sheet)	Seconds	Pitch	Normal pitch	WT
1	1_1	71.00	110	100	78.1
2	1_2	86.00	100	100	86
3		94.00	95	100	89.3
4	2_1	159.00	85	100	135.15
5	5_1	75.00	100	100	75
6	6_1	85.00	95	100	80.75
7	6_2	101.00	90	100	90.9

The value of the standard deviation based on the weighted time is: 20.43 seconds and the average is 90.74 seconds. Data collected are not enough to represent graphically a normal distribution. It is important to highlight the thrift of data because it has also an impact on the high value of standard deviation.

In conclusion the average time spent in changing the external wire is 92.43 seconds, the time that should be assigned to the operator increased with the add-ons for fatigue and unexpected for this sub-phase is 99.37 seconds. For accounting reasons the company must consider 100.30 seconds because this is effectively the time for which the employee is paid, then considering the assigned time increased by the physiological needs add-on.

4.2.2 NEEDLE CHANGE SUB-PHASE

In this subphases the operator can change the needle of the machine to substitute it with a bigger or smaller one, ore because it is worn out (Figure IV.16).

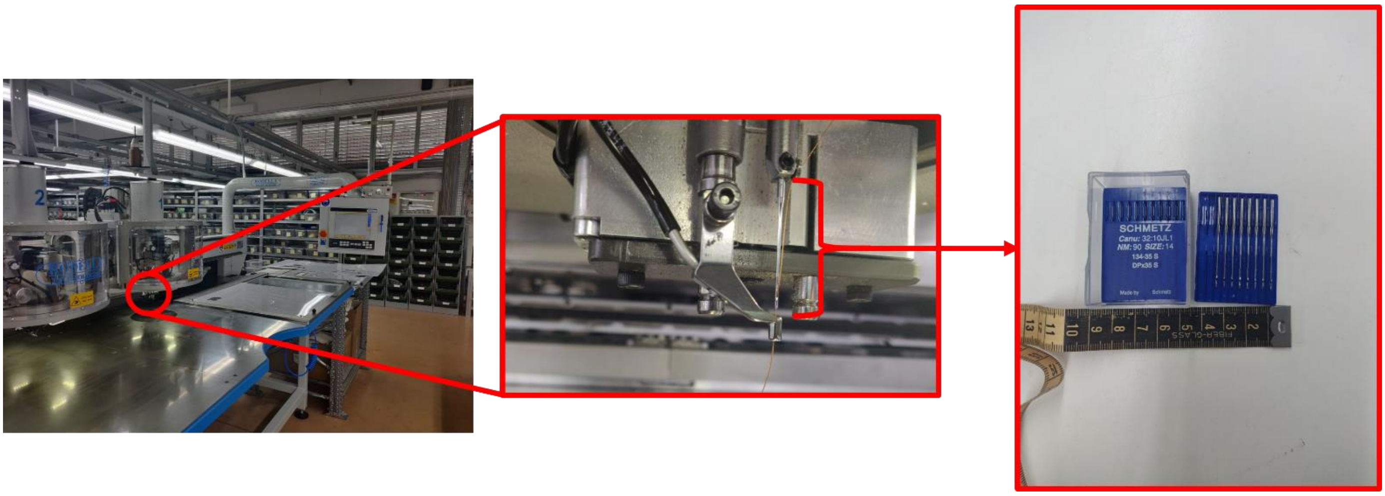


Figure IV.16 A) needle positioning, B) detail, C) needle replacement (in this case size 14).

Also in this case, as the previous sub-phases, the change of wire is independent from the technical characteristics of the product but can depend on client request: wire and therefore needle dimension required or because the needle is worn out or broken. The company does not have system to forecast the brake or the wear of the needle neither it has software that control if the last machining carry out on *Rodella* has the same (or not) needle of next machining.

For this sub-phases time relieved are reported and analysed in Table IV.7.

Table IV.7 "Needle change" time relieved.

Data n°	Reliefs (relief_sheet)	Time	Seconds	Pitch
1	4_3	00:01:56	116.00	90
2	4_3	00:01:56	116.00	90
3	6_1	00:01:06	66.00	90
4	6_2	00:01:21	81.00	90
5	7_2	00:00:50	50.00	100
6	9_2	00:01:28	88.00	95
	Average		86.17	92.5
	Normal pitch			100
	Normal time		79.70	
	Unexp. add-on		2.50%	
	Fatigue add-on		5.00%	
	Tot. add-on		7.50%	
	Nominal time		85.68	
	cyclicity		1	
	Assigned time	00:01:39	85.68	
	Physiol. needs add-on		1.01%	
	Standard time	00:01:43	86.49	

Also for this sub-phases is carried out the evaluation of the standard deviation and average too: it is important to notice two factors:

1. For this sub-phase the low amount of data influence the high standard deviation;
2. Standard deviation must be evaluated with the same formula {4.2}

$$WT = \frac{T \cdot P}{P_N}$$

Standard deviation is therefore evaluated on this data reported in Table IV.8*:*

Table IV.8 Weighted time and standard deviation of needle change sub-phases.

Data n°	Reliefs (relief_sheet)	Seconds	Pitch	Normal pitch	WT
1	4_3	116.00	90	100	104.4
2	4_3	116.00	90	100	104.4
3	6_1	66.00	90	100	59.4
4	6_2	81.00	90	100	72.9
5	7_2	50.00	100	100	50
6	9_2	88.00	95	100	83.6

The average time is 79.11 seconds and the standard deviation value is then: 22.69 seconds.
To conclude the time that shold be assigned to the operator is 85.68 seconds, instead the time that the management should take into consideration is 86.49 seconds.

4.2.3 MACHINING FILE SELECTION SUB-PHASE

This sub-phases is used to select the file created by the technician office with the process parameters. The procedure is done once for each machining group: if the order is for three products, the selection of the file is done only for the first machining, then every next time the machine is started, it will start automatically with the last machining carried out. Physically, the operator interacts with the machine PC and select the file from a list (Figure IV.17).

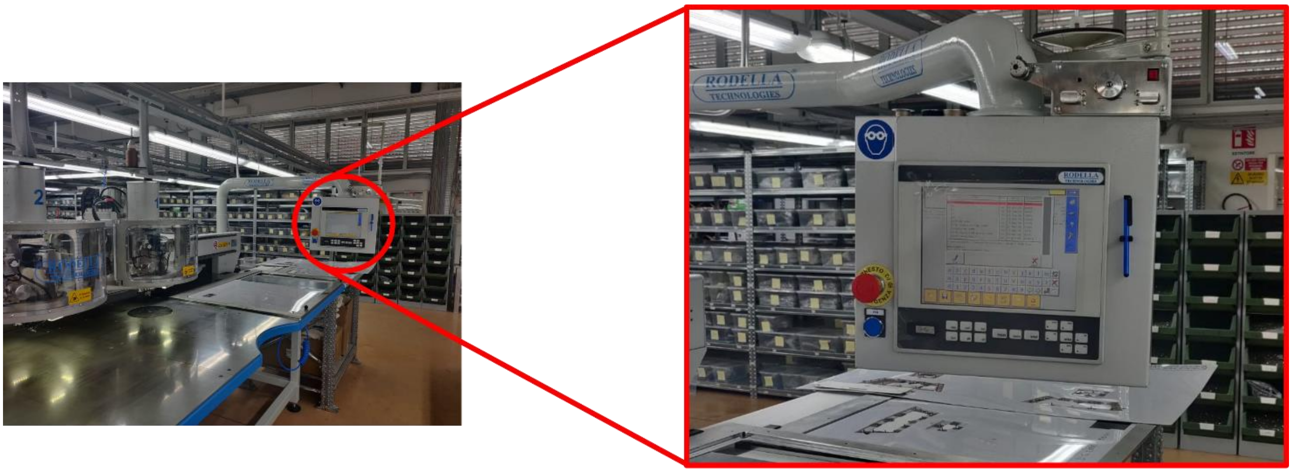


Figure IV.17 It shows the location and the machine PC with which the operator must interact to acomplish al the machine operations. In thi specific case the selection of the machining file.

What happen for production is different from orders. In fact the machine has the possibility of automatically recognize the file through a bar-code. This one is created by the technician office, then it is printed and glued to the table. This process is used only for production where the number of products is high and then the selection of the file could have a significant impact in the total time (Figure IV.18).

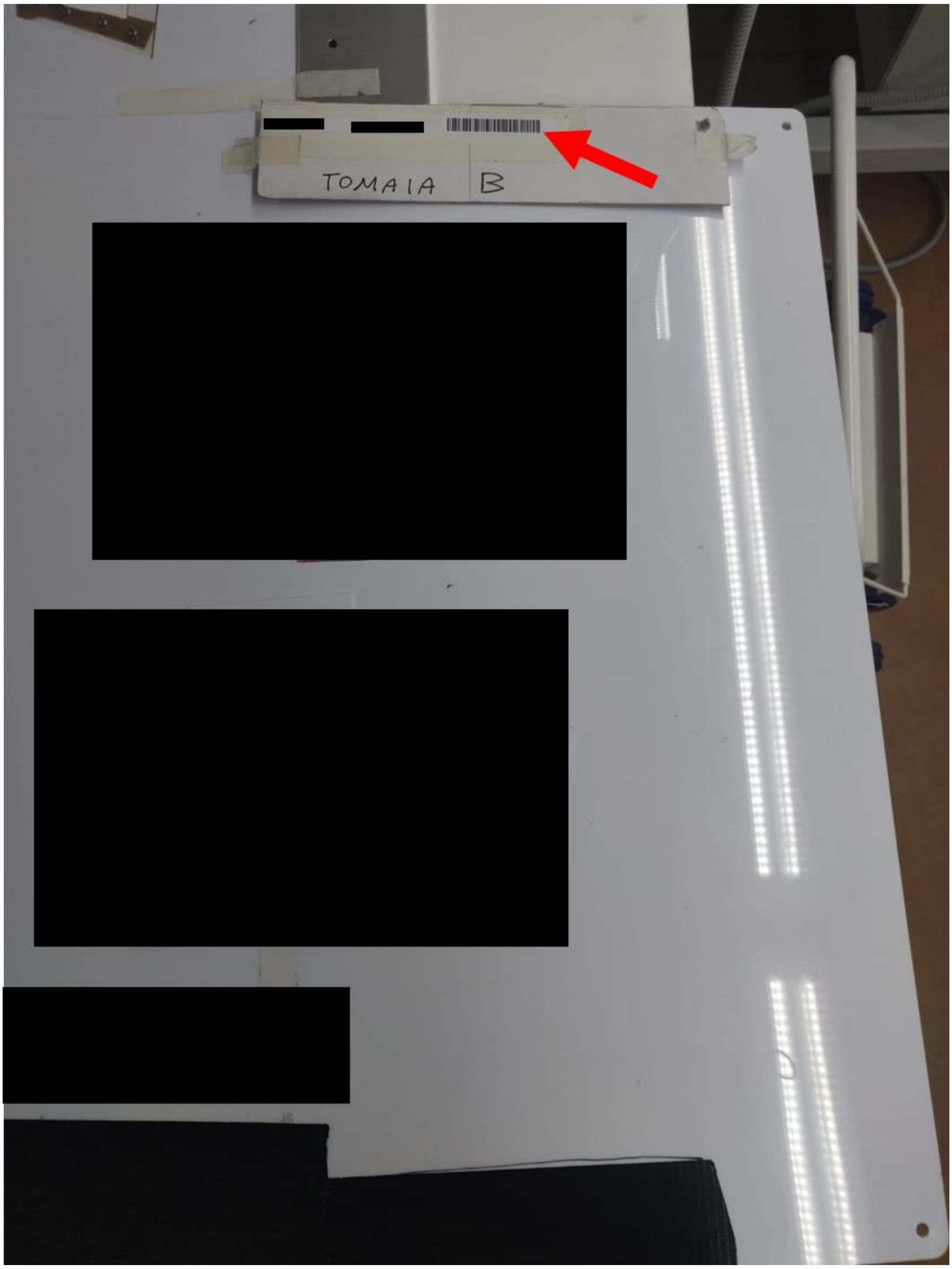


Figure IV.18 This is the bar code applied on a table through a paper adhesive ribbon. All other sensitive information have been obscured.

The relief of this task can occur only in orders and not production where the sub-phases does not appear. It is important to highlight how the model for machining cycle is developed on orders and not on production phase, therefore data are consistent.

Data relieved for this sub-phase are reported in Table IV.9.

Table IV.9 File selection sub-phases time relieved.

Data n°	Reliefs (relief_sheet)	Time	Seconds	Pitch
1	1_2	00:00:24	24.00	100
2	1_2	00:00:17	17.00	100
3	1_2	00:00:20	20.00	100
4	1_2	00:00:30	30.00	90
5	1_2	00:00:21	21.00	85
6	2_1	00:01:09	69.00	95
7	3_1	00:01:03	63.00	85
8	4_1	00:00:15	15.00	100
9	4_1	00:00:20	20.00	100
10	4_1	00:00:20	20.00	100
11	4_2	00:00:15	15.00	100
12	4_3	00:00:30	30.00	100
13	4_4	00:00:21	21.00	100
14	5_1	00:00:31	31.00	90
15	5_1	00:00:31	31.00	95
16	5_2	00:00:22	22.00	100
17	5_3	00:00:22	22.00	100
18	6_1	00:00:19	19.00	100
19	7_2	00:00:12	12.00	100
20	7_2	00:00:12	12.00	100
21	8_1	00:00:17	17.00	100
22	8_1	00:00:16	16.00	100
	Average		24.86	97.2727
	Normal pitch			100
	Normal time		24.19	
	Unexp. add-on		2.50%	
	Fatigue add-on		5.00%	
	Tot. add-on		7.50%	
	Nominal time		26.00	
	cyclicity		1	
	Assigned time	00:00:26	26.00	
	Physiol. needs add-on		1.01%	
	Standard time	00:00:26	26.24	

An analysis on the standard deviation is carried out using {4.2}.

All weighted time are reported in Table IV.10

Table IV.10 Weighted time and standard deviation measurements.

Data n°	Reliefs (relief_sheet)	Seconds	Pitch	Normal pitch	WT
1	1_2	24.00	100	100	24
2		17.00	100	100	17
3		20.00	100	100	20
4		30.00	90	100	27
5		21.00	85	100	17.85
6	2_1	69.00	95	100	65.55
7	3_1	63.00	85	100	53.55
8	4_1	15.00	100	100	15
9		20.00	100	100	20
10		20.00	100	100	20
11	4_2	15.00	100	100	15
12	4_3	30.00	100	100	30
13	4_4	21.00	100	100	21
14	5_1	31.00	90	100	27.9
15		31.00	95	100	29.45
16	5_2	22.00	100	100	22
17	5_3	22.00	100	100	22
18	6_1	19.00	100	100	19
19	7_2	12.00	100	100	12
20		12.00	100	100	12
21	8_1	17.00	100	100	17
22		16.00	100	100	16

On these data then the standard deviation and average are evaluated which respectively are: 12.78 seconds and 23.79 seconds. Based on this data it is possible to check graphically the statistical distribution of data (Figure IV.19).

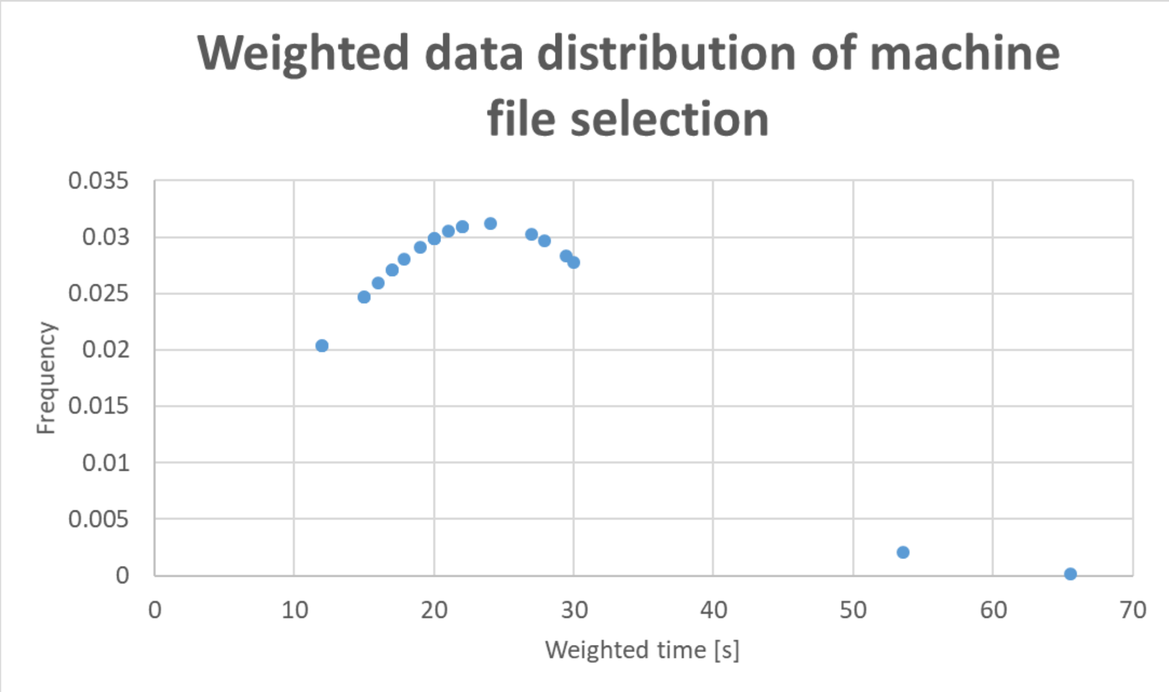


Figure IV.19 Graphical distribution of data collected.

The distribution appears to be close to a Gaussian distribution.

In brief the time that should be assigned to operator is 26 seconds and the time that should be considered for accounting reasons it is 26 seconds.

4.2.4 MACHINE COMMISSIONING SUB-PHASE

After the operator selected the file for the machining process, the machine is automatically ready to lock the frame and start the machining. The operator approaches the stainless steel frame to the machine catching it through the knobs and the machine, after locking the frame, starts the machining (Figure IV.20).

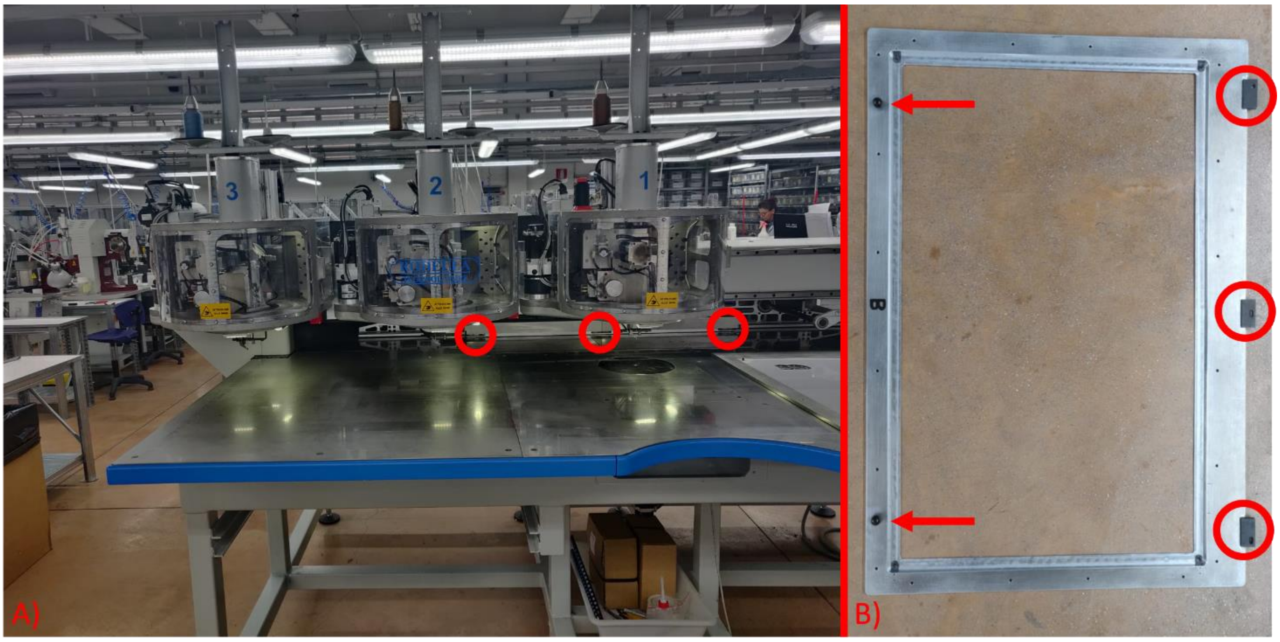


Figure IV.20 A) locking holes position in the machine. B) the circles represent the parts that will be locked into the machine and the arrows indicate the knobs.

This sub-phase is carried out every time there is a machining and therefore the amount of data collected is high. All data reported in **Errore. L'origine riferimento non è stata trovata.** where The central red line divides two progressive groups which would be too space consuming to locate one below the other. Data n° column has a progressive numeration of data.

Data n°	Reliefs	Time	Seconds	Pitch	Data n°	Reliefs	Time	Seconds	Pitch
1	1_1	00:00:11	11.00	105	38	5_3	00:00:05	5.00	100
2		00:00:06	6.00	105	39		00:00:04	4.00	100
3	1_2	00:00:04	4.00	100	40		00:00:05	5.00	100
4		00:00:05	5.00	100	41	6_1	00:00:04	4.00	110
5		00:00:05	5.00	100	42		00:00:06	6.00	100
6		00:00:08	8.00	90	43	7_1	00:00:05	5.00	100
7		00:00:06	6.00	100	44	7_2	00:00:04	4.00	100
8		00:00:06	6.00	105	45		00:00:04	4.00	100
9		00:00:11	11.00	100	46		00:00:03	3.00	100
10		00:00:02	2.00	110	47		00:00:06	6.00	100
11		00:00:05	5.00	100	48	8_1	00:00:04	4.00	100
12		00:00:03	3.00	100	49		00:00:03	3.00	105
13	2_1	00:00:20	20.00	90	50	8_2	00:00:06	6.00	100
14		00:00:17	17.00	85	51	9_1	00:00:08	8.00	100
15	3_1	00:00:08	8.00	90	52	9_2	00:00:04	4.00	100
16	4_1	00:00:07	7.00	95	53		00:00:04	4.00	100
17		00:00:08	8.00	95	54		00:00:08	8.00	100
18		00:00:06	6.00	100	55		00:00:08	8.00	100
19		00:00:05	5.00	100	56		00:00:06	6.00	100
20		00:00:05	5.00	100	57		00:00:05	5.00	100
21		00:00:09	9.00	95	58	9_3	00:00:07	7.00	100
22		00:00:07	7.00	100	59		00:00:07	7.00	100
23		00:00:04	4.00	100	60		00:00:07	7.00	100
24	4_2	00:00:14	14.00	90	61		00:00:08	8.00	100
25		00:00:05	5.00	100	62	11_1	00:00:05	5.00	100
26	4_3	00:00:17	17.00	85	63		00:00:06	6.00	100
27	4_4	00:00:04	4.00	100	Average			6.32	100
28	5_1	00:00:03	3.00	110	Normal pitch				100
29		00:00:04	4.00	110	*Normal time*			6.30	
30		00:00:04	4.00	105	Unexp. add-on			2.50%	
31		00:00:06	6.00	100	Fatigue add-on			5.00%	
32		00:00:03	3.00	105	**Tot. add-on**			7.50%	
33		00:00:04	4.00	100	Nominal time			6.77	
34		00:00:05	5.00	100	cyclicity			1	
35	5_2	00:00:06	6.00	95	**Assigned time**		00:01:39	6.77	
36	5_3	00:00:05	5.00	100	Physiol. needs add-on			1.01%	
37		00:00:08	8.00	100					
					Standard time		00:01:43	6.83	

Also in this case it is possible to evaluate statistical relevant variable as standard deviation (Figure IV.21). And the weighted time for each relief is reported in Table IV.11 using formula {4.2}.

Table IV.11 Machine commissioning time. The central red line divides two progressive groups which would be too space consuming to locate one below the other. Data n° column has a progressive numeration of data.

Data n°	Reliefs	Seconds	Pitch	Normal pitch	WT	Data n°	Reliefs	Seconds	Pitch	Normal pitch	WT
1	1_1	11.00	105	100	11.55	33	5_1	4.00	100	100	4
2		6.00	105	100	6.3	34		5.00	100	100	5
3	1_2	4.00	100	100	4	35	5_2	6.00	95	100	5.7
4		5.00	100	100	5	36	5_3	5.00	100	100	5
5		5.00	100	100	5	37		8.00	100	100	8
6		8.00	90	100	7.2	38		5.00	100	100	5
7		6.00	100	100	6	39		4.00	100	100	4
8		6.00	105	100	6.3	40		5.00	100	100	5
9		11.00	100	100	11	41	6_1	4.00	110	100	4.4
10		2.00	110	100	2.2	42		6.00	100	100	6
11		5.00	100	100	5	43	7_1	5.00	100	100	5
12		3.00	100	100	3	44	7_2	4.00	100	100	4
13	2_1	20.00	90	100	18	45		4.00	100	100	4
14		17.00	85	100	14.45	46		3.00	100	100	3
15	3_1	8.00	90	100	7.2	47		6.00	100	100	6
16	4_1	7.00	95	100	6.65	48	8_1	4.00	100	100	4
17		8.00	95	100	7.6	49		3.00	105	100	3.15
18		6.00	100	100	6	50	8_2	6.00	100	100	6
19		5.00	100	100	5	51	9_1	8.00	100	100	8
20		5.00	100	100	5	52	9_2	4.00	100	100	4
21		9.00	95	100	8.55	53		4.00	100	100	4
22		7.00	100	100	7	54		8.00	100	100	8
23		4.00	100	100	4	55		8.00	100	100	8
24	4_2	14.00	90	100	12.6	56		6.00	100	100	6
25		5.00	100	100	5	57		5.00	100	100	5
26	4_3	17.00	85	100	14.45	58	9_3	7.00	100	100	7
27	4_4	4.00	100	100	4	59		7.00	100	100	7
28	5_1	3.00	110	100	3.3	60		7.00	100	100	7
29		4.00	110	100	4.4	61		8.00	100	100	8
30		4.00	105	100	4.2	62	11_1	5.00	100	100	5
31		6.00	100	100	6	63		6.00	100	100	6
32		3.00	105	100	3.15						

By processing the data as in the previous sub-phases, the following values are obtained, average: 6.18 seconds; standard deviation is: 2.9 seconds. Because the implementation of *unexpected, fatigue* and *physiological needs* add-ons, the time that should be used for accounting scope is 6.83 seconds. The values are plotted in Figure IV.21.

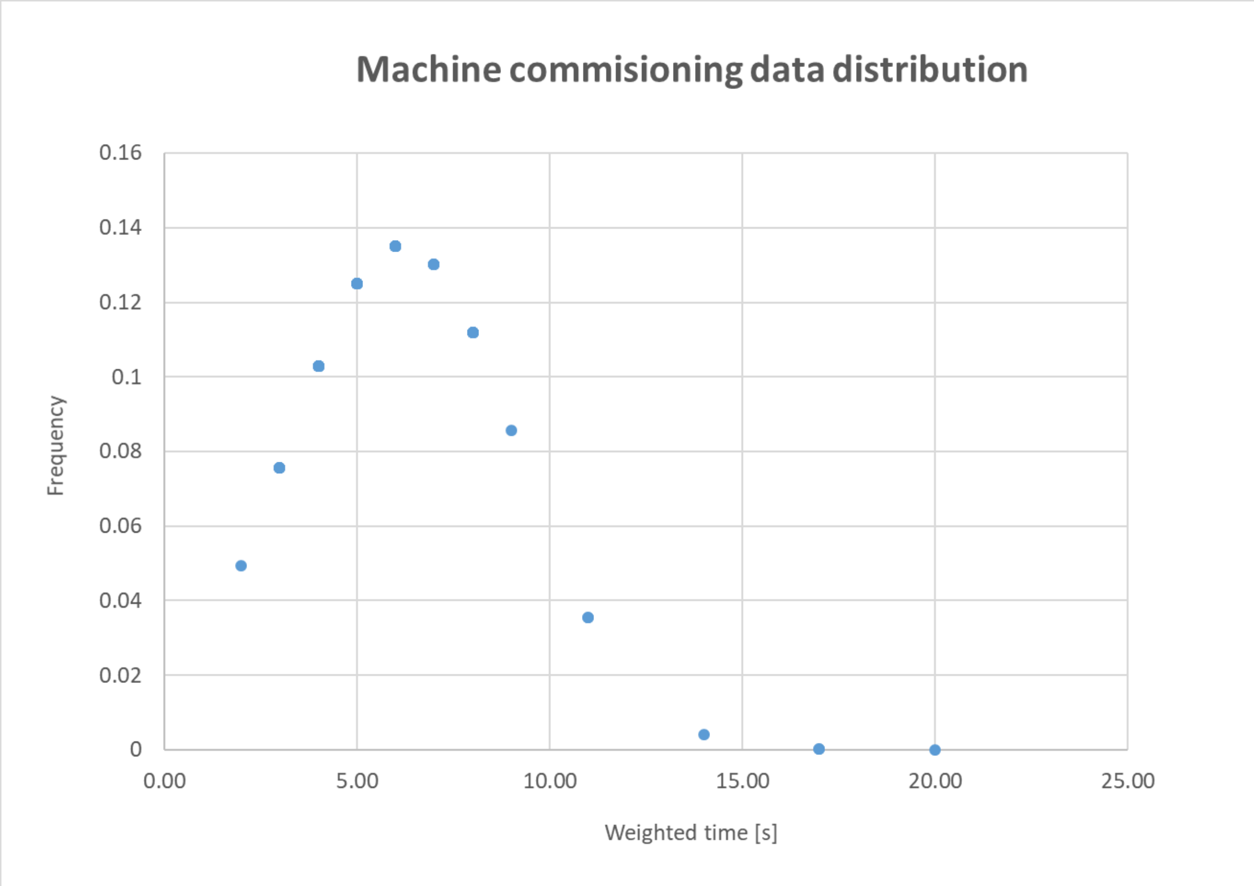


Figure IV.21 "Machine commissioning" time distribution.

4.2.5 FRAME LOAD AND UNLOAD SUB-PHASE

During the descried process there are two frames and therefore after one frame finishes the machining, it is removed from the machine plan to allow "Machine commissioning" to the other frame. It starts when the sound of head at limit switch. Data collected are reported in Table IV.12.

Table IV.12 Load sub-phase data collection.

Data n°	Reliefs (relief_sheet)	Time	Seconds	Pitch
1	9_2	00:00:04	4.00	100
2	9_2	00:00:06	6.00	100
3	9_2	00:00:05	5.00	100
4	9_2	00:00:06	6.00	100
5	9_2	00:00:04	4.00	100
6	9_2	00:00:06	6.00	100
7	9_2	00:00:04	4.00	100
8	9_2	00:00:06	6.00	100
9	9_2	00:00:05	5.00	100
10	9_2	00:00:06	6.00	100
13	9_2	00:00:06	6.00	100
16	9_2	00:00:04	4.00	100
19	9_3	00:00:05	5.00	100
20	9_3	00:00:05	5.00	100
21	9_3	00:00:07	7.00	100
26	11_1	00:00:06	6.00	100
27	11_1	00:00:08	8.00	100
	Average		5.47	100
	Normal pitch			100
	Normal time		5.47	
	Unexp. add-on		2.50%	
	Fatigue add-on		5.00%	
	Tot. add-on		7.50%	
	Nominal time		5.88	
	cyclicity		1	
	Assigned time	00:01:39	5.88	
	Physiol. needs add-on		1.01%	
	Standard time	00:01:43	5.94	

It is from the analysis of the above table is that the *Bedaux pitch* assigned is always the *normal pitch* and it is due to the fact that:

1. The duration of the phase is quite short and therefore it is difficult to spot higher than normal efficiency or inefficiency in the operator's work. It is easy to spot efficiency variations only when they are blatant;
2. The times relieved, were taken during a production when the operator was in a "stress" condition and therefore he paid more attention in carring out efficiently his work.

The fact that the *pitch* is one hundred for every relief helps in the evaluation of the standard deviation for *normal time* in fact there is not the need of evaluate the weighted time for every relief.

The standard deviation is: 1.12 seconds and the average time is: 5.57 seconds. In this case it is possible to trace the statistical distribution of data. Here the total amount of reliefs is lower than *"Machine commissioning"* sub-phase, Figure IV.22 shows the distribution.

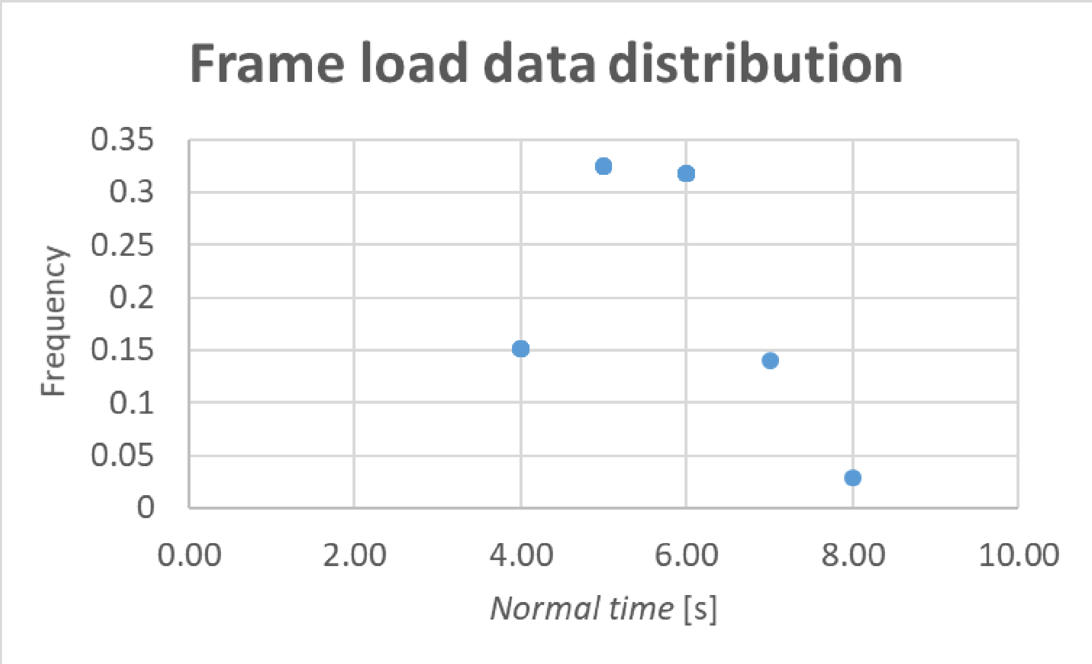


Figure IV.22 "Frame load" distribution.

Concluding the time assigned to the operator to accomplish this sub-phases should be 5.88 seconds, instead the time to take into consideration when the company carries out accounting tasks is 5.94 seconds.

Another important sub-phase is the frame unload: this phase is exactly the opposite of frame load. In this sub-phase the stainless steel is positioned on the machine plane with the same exact movement of the frame load sub-phases. Therefore the analyst considered reliable to use the same time relieved for frame shit into frame unload.

4.3 MODEL NEEDED SUB-PHASES

In this case the time depends on the characteristics of the product (Figure IV.23), therefore it is impossible to use an average time.

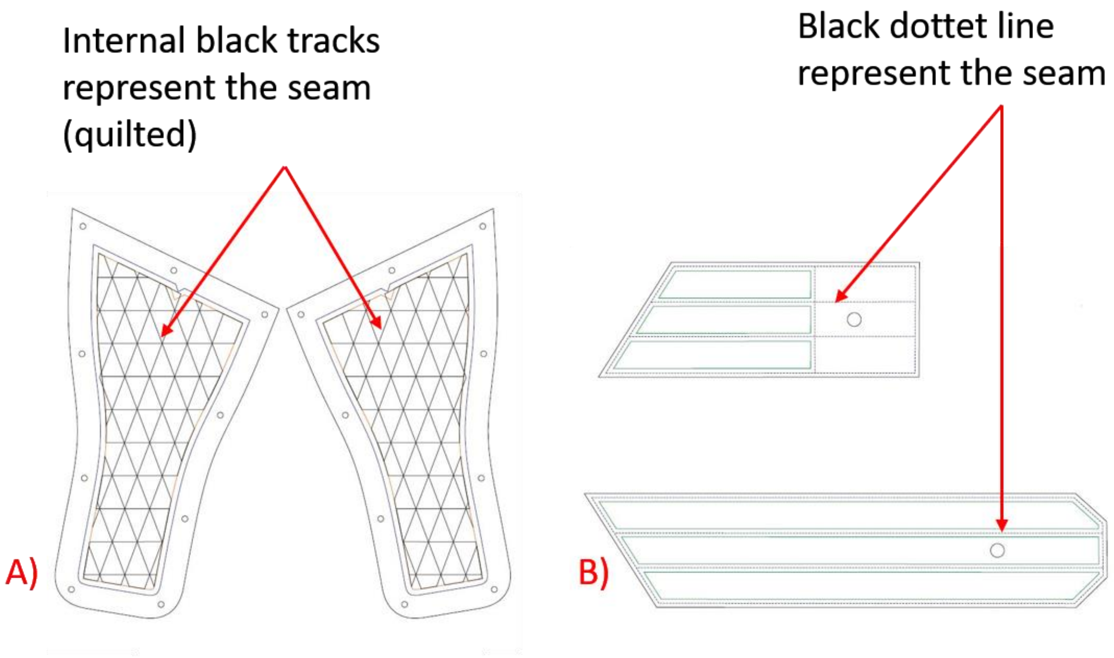


Figure IV.23 A) figure there is a quilted seam with an high number of stitches, B) it is reported a normal linear seam. Logically the two machining do not have nothing in common and it makes no sense to use the raw time relieved to evaluate future machining time

To forecast the time duration of the machining phase of a third product totally different from the previous two (Figure IV.23) it cannot be used the average of the time of the two reliefs. Therefore for these sub-phases it must be created a mathematical model which links the time duration drivers of a sub-phases with the time required.

The class includes the following sub-phases: pins application, material fixing, machine cycle and material removal. The most complex sub-phases for which the model was created is the "*machining sub-phases*" that has the strongest impact in the total time.

4.3.1 PINS APPLICATION SUB-PHASES

The pins are applied to the table through riveting. This operation requires more time than gluing but at the same time guarantees more stable and durable pins. Riveting procedure is carried out by hammering the pins against a pen aimed to expand the head of the pins fixing them to the table (Figure IV.10).

The riveting procedure is carried out on a metallic surface where a small and metallic support is positioned. The head of the pins is pressed on the support. Then the metallic pen is positioned in the hole and with the hammer the pin is rivetted.

Data collected are reported in Table IV.13.

Table IV.13 It reports data collected for pins application.

Reliefs (relief_sheet)	8_1	12_1	12_2
Code	[redacted]		
Add. Info			
Pins	42	13	14
Relieved time	00:14:46	00:04:42	00:04:13
Pitch	100	90	105

The higher impact on the duration time of this sub-phase is expected to be the number of pins. In fact, theoretically, the operator should carry out pins application with an average constant speed. The analyst decided to evaluate the average speed as $\frac{sec}{pin}$ and check for an linear trend. In fact based on analyst's intuitions, in a *relief VS speed* plane the trend curve should be a straight line as much as possible parallel to x axis, as to say constant average speed. Instead in a *pins VS time* plane the expected curve should be as near as possible to the straight line: $y = ax$ therefor passing through zero.

Table IV.14 reports *normal time* and average speed for each relief. Here the *normal time* formula:

$$NT = \frac{\bar{T} \cdot \bar{P}}{P_N}\,^{43} \qquad \{4.3\}$$

- $\bar{T}$ is the average time;
- $\bar{P}$ is the *pitch* relieved;
- P_N is the *normal pitch* which is recall to be one hundred because of the selection of the *centesimal scale* inside the *Bedaux chronotechnical technique.*

Table IV.14 Average speed for each relief.

Reliefs (relief_sheet)	8_1	12_1	12_2
Code	[redacted]		
Add. Info			
Pins	42	13	14
Relieved time	00:14:46	00:04:42	00:04:13
Relieved time [s]	886	282	253
Pitch	100	90	105
Normal time	886	254	266
Average speed [sec/pins]	21	20	19

Figure IV.24 shows *pins VS speed* and Figure IV.25 *pins VS time*.

[43] "Industrializzazione prodotto"; *Istituto ITS maker*

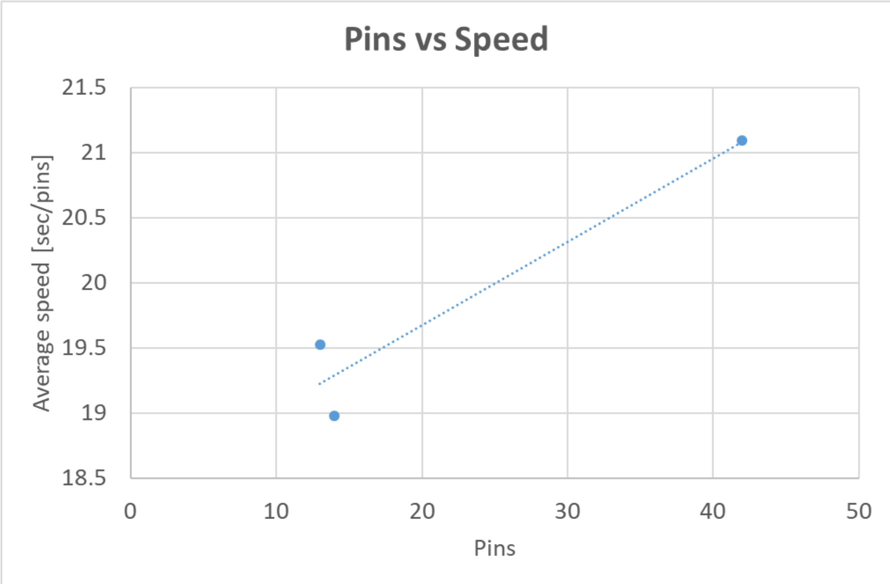


Figure IV.24 Represent Pins vs Speed plan and trend curve.

The expectation for the trend curve of this model was an equation similar to:

$$y = x + average\ speed, \qquad average\ speed = 20\frac{sec}{pin} \tag{4.4}$$

The model is close to the expectation and it has high R^2 value, therefore no assumption can be done surely. For what concern *Pins vs Time* it is reported in Figure IV.25.

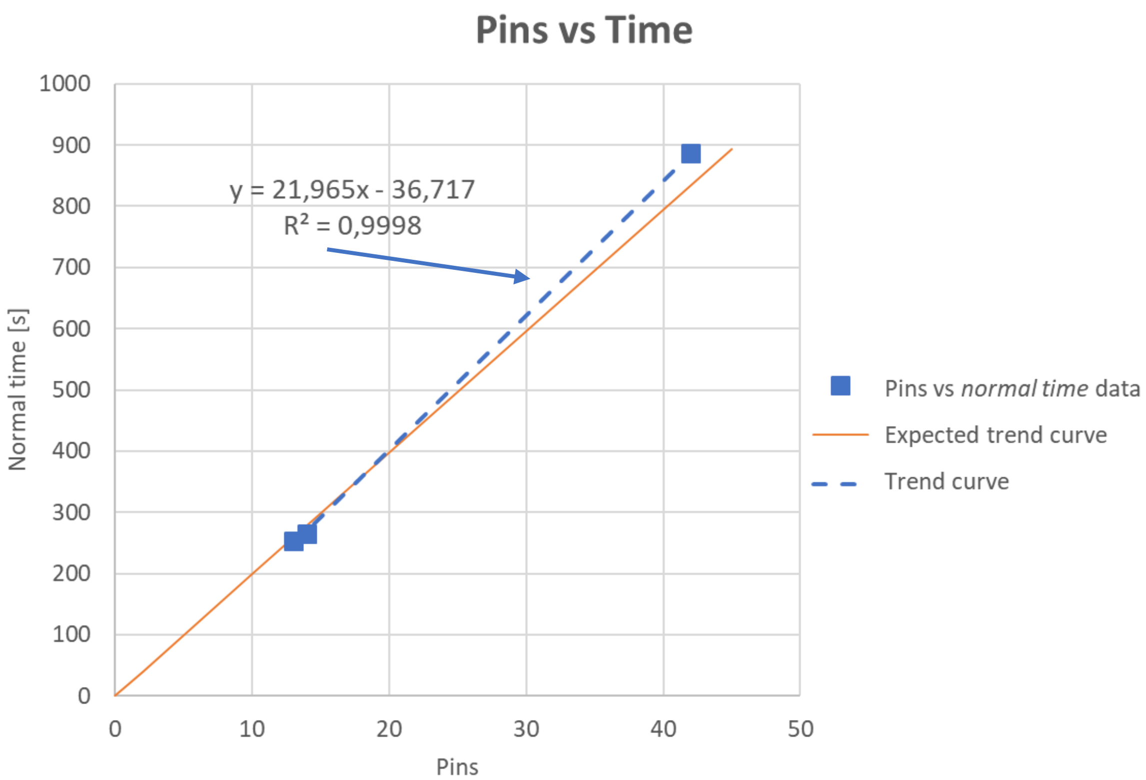


Figure IV.25 Pins vs Time plan and trend curve.

The total average speed evaluated on the speed of each relief (based in turn on *normal time*) is 20 seconds each pin. For this specific model then the expected straight line equation (given the total average speed) was:

$$y = 20x \qquad \{4.5\}$$

Where *y* represents the normal time and *x* the number of pins. In fact it is supposed that, being $20\frac{sec}{pin}$ the total average speed, each new pin (then progressive increase in x axis) will bring an increase of 20 seconds on time (y axis). This expected trend curve is the orange one in Figure IV.25. It is possible to notice that the slope of the expected trend curve and the trend curve is very similar. What is different is the passage for point O=(0;0) in pins vs normal time plane. The dimension of data collected is too low to give a real evaluation: point {42;836} (so 836 seconds for 42 pins) could be an outlier and therefore have no meaning. Up to know with the hypothesis that data collected are correct and will not be refuted by further reliefs, the trend curve deviation from expected trend curve can be justified by operator's stress. In fact the average time in case of forty-two pins is twenty-one seconds per pin, instead with about fourteen pins the average speed is twenty seconds per pin.

It exists, as expected, a strong relation between time and number of pins, therefore the analyst suppose that the number of pins is the main driver for task time duration, then the model that will forecast the time will link the number of pins with the time itself using the average speed (time required to fix a pin). So a model can be constructed using an average speed of twenty sec/pin until the intersection with the trend curve relieved in the Figure IV.25. To simplify the model the trend curve is approximated and therefore the intersection will be found between the curve:

$$\begin{cases} y = 20x \\ y = 22x - 37 \end{cases} \qquad \{4.6\}$$

The intersection point is: $I = (18.5; 370)$. Then the model can be constructed in the form below expressed. The dependent variable represent the normal time and the independent variable represent the number of pins:

$$f(x) = \begin{cases} 20x, & x \leq 18 \\ 22x - 37, & x \geq 19 \end{cases} \qquad \{4.7\}$$

This model means that until eighteen pins the operator can easily work with a speed of twenty seconds each pin, but after nineteen pins the operator will suffer stress and then the speed will decrease and therefore time required will follow the straight line $y = 22x - 37$.

The verification of the model will be done in the last chapter.

4.3.2 MATERIAL FIXING SUB-PHASES

This sub-phase includes all the tasks the operator does to fix the material on the tables, therefore on the template: during the material positioning, the operator places the material on the transparent table pins in order to have the material ready to be fixed; it is a preparation of material to be fixed. Then there are three alternatives:

The possibilities are numerous and it can be helpful the scheme reported in Figure IV.26 to have a visual and fast understanding of all possibilities.

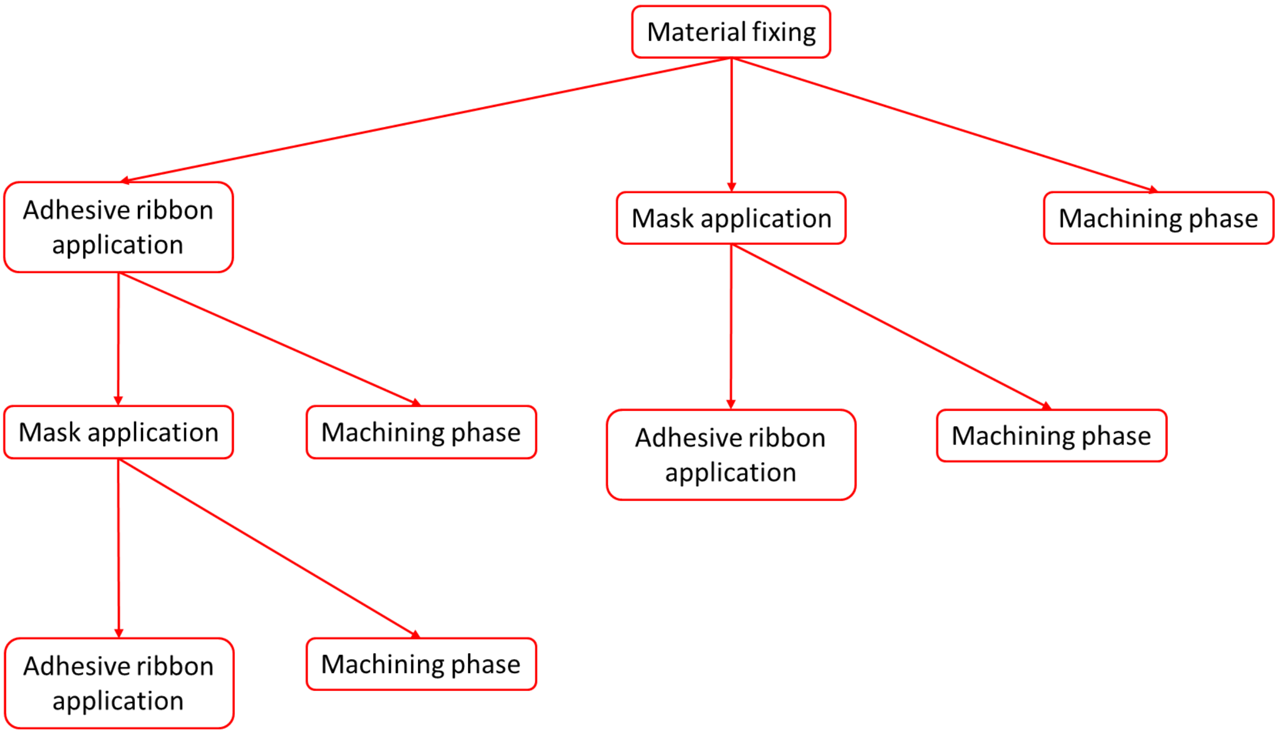


Figure IV.26 A scheme that represents all the possible tasks and their sequence in the material fixing sub-phase.

Each different path followed require different time duration. Now the material fixing tasks are listed from the longest to the shortest:

- Adhesive ribbon application → Mask application → Adhesive ribbon application → Machining;
- Adhesive ribbon application → Mask application → Machining;
- Mask application → Adhesive ribbon application → Machining;
- Adhesive ribbon application → Machining;
- Mask application → Machining;
- Machining.

The fixing time depend on the adopted path, in fact the removal of mask require more time than the removal of adhesive ribbon.

To describe the path chosen by the operator three Boolean indicators were created, which answer can be “YES” or “NO”:

- Mask application: it indicates if mask were applied;

- Under mask adhesive ribbon application: it indicates if there is adhesive ribbon under the mask;
- Over mask adhesive ribbon application: it indicates if adhesive ribbon is applied over the mask

Therefore it is possible to represent all the six paths as reported in Table IV.15:

Table IV.15 The Boolean value to describe the path choosen.

Indicators	Boolean value	Path
Mask application	YES	Adhesive ribbon application → Mask application → Adhesive ribbon application → Machining
Under mask adhesive ribbon application	YES	
Over mask adhesive ribbon application	YES	
Mask application	YES	Adhesive ribbon application → Mask application → Machining
Under mask adhesive ribbon application	YES	
Over mask adhesive ribbon application	NO	
Mask application	YES	Mask application → Adhesive adhesive ribbon application → Machining
Under mask adhesive ribbon application	NO	
Over mask adhesive adhesive ribbon application	YES	
Mask application	NO	Adhesive ribbon application → Machining
Under mask adhesive adhesive ribbon application	YES	
Over mask adhesive adhesive ribbon application	NO	
Mask application	YES	Mask application → Machining
Under mask adhesive adhesive ribbon application	NO	
Over mask adhesive adhesive ribbon application	NO	
Mask application	NO	Machining
Under mask adhesive adhesive ribbon application	NO	
Over mask adhesive adhesive ribbon application	NO	

Table IV.16 shows Boolean value of indicators for each relief. Among these data it will be possible to analyse the drivers of time duration.

Table IV.16 All the information collected on each relief for material fixing sub-phase. L indicates leather and P Padded. U indicates upper and O oval.

Reliefs	1_1	1_2	2_1	3_1	4_1	4_2	4_3	4_4	5_1	5_2	5_3	6_1	8_1	8_1	9_2	9_3	11_1
Code	[redacted]																
Add. Info	U	O			[redacted]		U	O	O	U	[redacted]		U	O	O	U	U
Pins	18	4	82	86	14	14	18	8	8	18	10	10	36	8	8	36	36
Parts	2	2	10	10	1	1	2	2	2	2	2	2	2	2	2	2	2
Stitched	840	146	7818	8302	678	711	870	176	176	870	517	826	881	197	197	881	919
Thikness	L	L	P	L	L	P	L	L	L	L	L	L	L	L	L	L	L
Mask application	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Under mask adhesive ribbon application	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO
Over mask adhesive ribbon application	YES	YES	YES	NO	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

It is important to determine the drivers of the time duration of each path but it is essential to understand the driver of the choice of the path. After interviewed the operator was not able to define in which condition it is possible to opt for one path or another; the only justification the operator gave was that the thickness and the total area of the machining part can influence in the choice. During the observation it was clear that if the material is padded, then the thickness of the material is higher than the height of pins and therefore adhesive adhesive ribbon must be used. But during the relieving procedure the pins used was changed, adopting new application method and furthermore because the height of the pins raises issues during other process, during the last period they were changed again.

The only clear aspect that emerged from the reliefs with the second kind of pins used, when the material was not padded (and then it was leather), the operator opted for inserting material in pins and start the machining phase. But data are not enough to create a model.

4.3.3 MATERIAL REMOVAL SUB-PHASES

This sub-phase is complementary to material fixing sub-phases and therefore it reports all the issues raised during the analysis of the previous sub-phase (Chapter 5.3.2). Nevertheless a specific analysis for this sub-phases is carried out. Material removal sub-phase occurs after the machining phase is ended, the operator removes the material from the table fixed to the stainless steel frame. It starts when the system signal indicates the end of machining. In fact depending on which path the operator chose to fix the material, the task to remove the material will change. To clarify, the six paths that can be followed to fix the material are now reported:

- Adhesive adhesive ribbon application → Mask application → Adhesive adhesive ribbon application → Machining;
- Adhesive adhesive ribbon application → Mask application → Machining;
- Mask application → Adhesive adhesive ribbon application → Machining;
- Adhesive adhesive ribbon application → Machining;
- Mask application → Machining;
- Machining.

This list is ordered for decreasing total time of fixing material sub-phase but this order is not respected in removal of material. In fact the second last and third last operation are inverted: mask removal is longer than adhesive adhesive ribbon removal. This because mask are fixed with pins through interlocking and the possibility of unlock are decreased by the small dimension of mask and the bulky presence of material. To unlock mask a dedicated tool is used.

In Table IV.17 *A*ll data collected for the analysis of time drivers. Times relieved are reported too.

Table IV.17 All data collected concerning reliefs for material removal sub-phases. L indicates leather and P Padded. U indicates upper and O oval.

Reliefs	1_1	1_2	2_1	3_1	4_1	4_2	4_3	5_1	5_2	6_1	7_1	7_2	8_1	8_1	9_2	9_3	11_1
Code	[redacted]		[redacted]				[redacted]				[redacted]				[redacted]		
Add. Info	U	O			[redacted]		U	O	O	U	[redacted]		U	O	O	U	U
Pins	18	4	82	86	14	14	18	8	18	10	16	14	36	8	8	36	36
Parts	2	2	10	10	1	1	2	2	2	2	1	1	2	2	2	2	2
Stitched	840	146	7818	8302	678	711	870	176	870	826	3224	2240	881	197	197	881	919
Thikness	L	L	P	L	L	P	L	L	L	L	L	L	L	L	L	L	L
Mask application	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO	NO
Under mask adhesive ribbon application	NO	NO	YES	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO
Over mask adhesive ribbon application	YES	YES	YES	NO	YES	YES	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO	NO
Normal time	**53**	**31**	**448**	**495**	**25**	**29**	**93**	**18**	**43**	**24**	**36**	**24**	**23**	**16**	**8**	**23**	**24**

Material removal time strongly depends on material fixing sub-phases because depending on the path selected by operator to fix the material. Due to the fact that there is not a fixed procedure that the operator can follow but he has to choose every time what to do, then it is difficult to forecast which path he will follow. Furthermore the possibility to have fixed sequence of tasks dictated by company management may help operator in creating routines and then increasing efficiency.

To create a model further analysis are needed.

4.4 MACHINE CYCLE SUB-PHASES

It has been already said that the machining fall inside the sub-phases class which requires a model. Due to its importance, difficulties and deep study carried out on this phase, then analyst considered it appropriate to analyse it separately from other sub-phases dedicating the entire Chapter 5.4 to machine cycle sub-phases analysis. Therefore at the beginning a check on the general condition and difficulties will be carried out, then possible drivers for time duration of the machining will be defined and based on them three proposal of model will be explained briefly. After that one by one the model will be explained.

The machining sub-phase starts when the machine lock the stainless steel frame, and this is understood because of a “click” sound. The machining stops when the head get up from the material worked and it is fully stroked, which still is testified by a signal.

The conditions in which the machine operates can be considered stationary, in fact the attributes hardly change, and therefore it is possible to study the time drivers with consistent data along the different reliefs. The boundary conditions that allows this kind of analysis are:

- Speed: the speed is constantly fixed at 600 Pitches Per Minute (PPM). It means that in regime condition, theoretically, the machine is able to seam 600 pitches each minute. The speed can also be changed but the operator in an interview, he said that it is not changed otherwise the machine could jump stitches and the products have to be reworked. Empirically then the company discovered that 600 PPM is the optimal speed at which operate and therefore it is chosen as benchmark speed.
- Wires: wires (internal coil or external spool) can be changed in colour or dimension (diameter of wire). The dimensions range defined by book-machine. Inside the range of possible diameter the change will not influence the machining process, so it can be considered as a constant condition.
- Needle: the needle can be change in term of dimension (diameter). Also in this case the variation does not influence the work (or if it influence the variation is negligible) and therefore it can be considered a constant condition.

Giving constant these conditions, it is possible to determine how the characteristics that has influence on the time duration of machining sub-phase belongs to the characteristics of the single product.

Each product is different from the others from two main different points of view:

- Geometry: the route to stitch change in shape and therefore there are infinite possible kind of path. It is possible for a path to be mainly linear or characterized by curve of different radio or mainly angles. Figure IV.27 give an idea of the different kind of seam that can be machined.
- Length: the number of stitches that the machine has to seam strongly influence the time required to accomplish the machining as it is the main important parameter. This value can vary from just about 170 stitches to 8300 stitches.

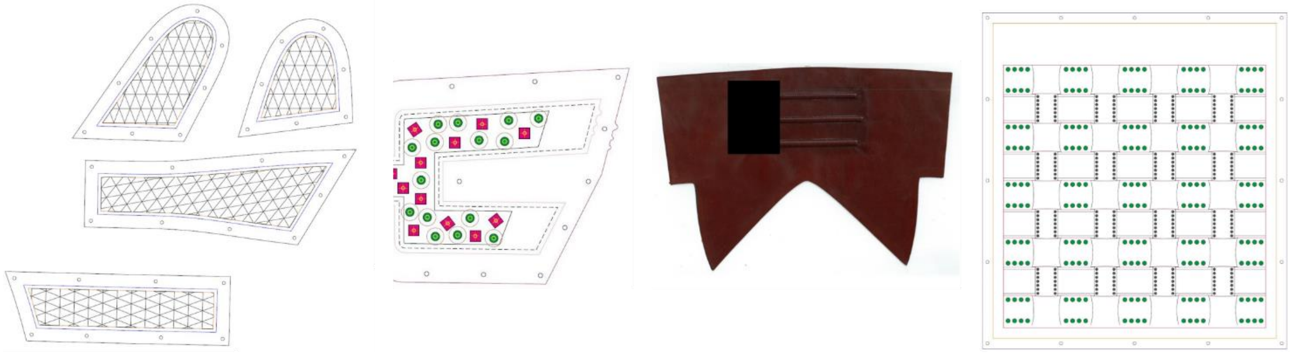


Figure IV.27 Etherogenity of the machining process. First from left it is a quilted, then an upper with a quasi-linear seam but with different fillet/angle and inclination, second last a linear work with curves (in the censored part) and the an interweaving with linear line and curve.

Because this high variability, it is impossible to use collected data and use them for a forecasting model: there is the need of processing data, finds time driver parameters and then construct a model that link these parameters with time. The definition of a discriminant parameter to forecast time duration is difficult because of continuous change in qualitative and quantitative aspects from product to product. Furthermore qualitative and quantitative changes of parameters do not occur only between different machining but also inside the same machining. In fact there is the possibility of having inside the same product changes of curvature radii, of fillet, of angle and of line inclination (Figure IV.28 and Figure IV.29).

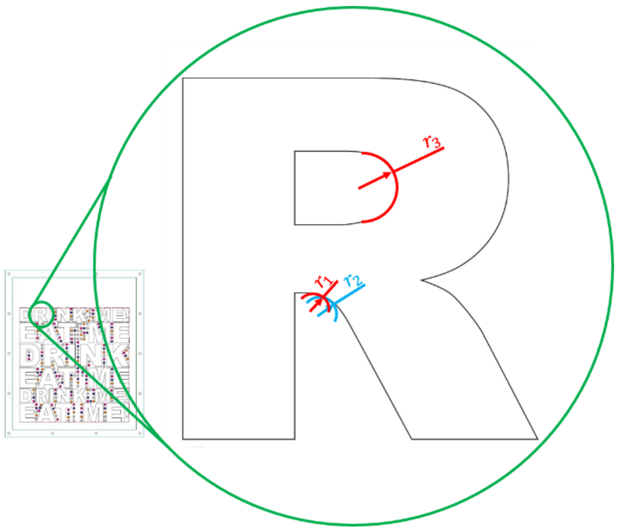


Figure IV.28 The variation of curvature radii insisde the same machining.

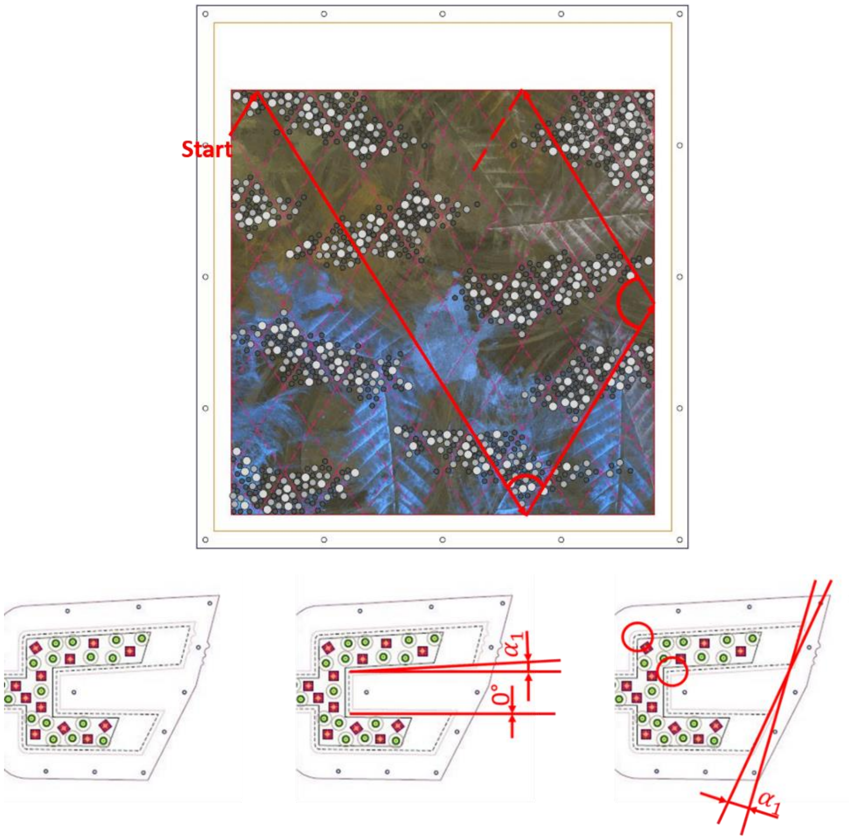


Figure IV.29 Line inclination change inside the same machining.

To follow the variation of these geometrical characteristics inside the same machining, the machinery will need corrections to the head linear path i.e. stop and start after head rotation or speed decreasing as radii function. It means that the speed of the head rarely is near to the regime and that because of this it is impossible only knowing the geometrical characteristics define an average speed of machining phase (and therefore forecast time) and more, the head speed will never be near to the regime one.

It is now needed a representation of all data collected. In order to maintain easy and friendly to read the explanation, the analyst opted to unify all that products within a range of $\pm$ 20 stitches (Table IV.18). Because of similarity some operations were grouped:

- 4_3 group includes: 4_3, 8_1, 9_3 and 10_1;
- 4_4 group includes: 4_4, 5_1, 8_1, 9_2 and 10_2;
- 10_3 group includes: 10_3 and 11_2.

Table IV.18 Data concerning reliefs on machining sub-phase.

Reliefs	4_1	4_2	4_3 group	4_4 group	5_3	6_1	8_2	10_3 group	11_1
Code	[redacted]								
Add. Info	[redacted]	U	O						U
Normal time	**203**	**80**	**218**	**47**	**90**	**147**	**72**	**57**	**236**
Stitches	678	486	877	189	517	826	383	213	919

It is clear the need of discover the real drivers of the time and based on that parametrize the machining phase recorded to create a forecasting model. The observation of this phases induced to think as logical consequence of the increase of time, the increasing path length that the head should follow. The machine speed is defined based on stitches and practically the length is a factor multiplied for the number of stitches. The factor is exactly the length of each stitch which can vary typically from 2.5mm to 3mm. Therefore, the analyst opted to consider the number of stitches as measure of the path length and created a first model using as single discriminatory driver of time duration of machining phase the number of stitches. Then in a plane with *stitches VS normal time* where plotted all the points shown in Table IV.18. Figure IV.30 shows the correlation behaviour.

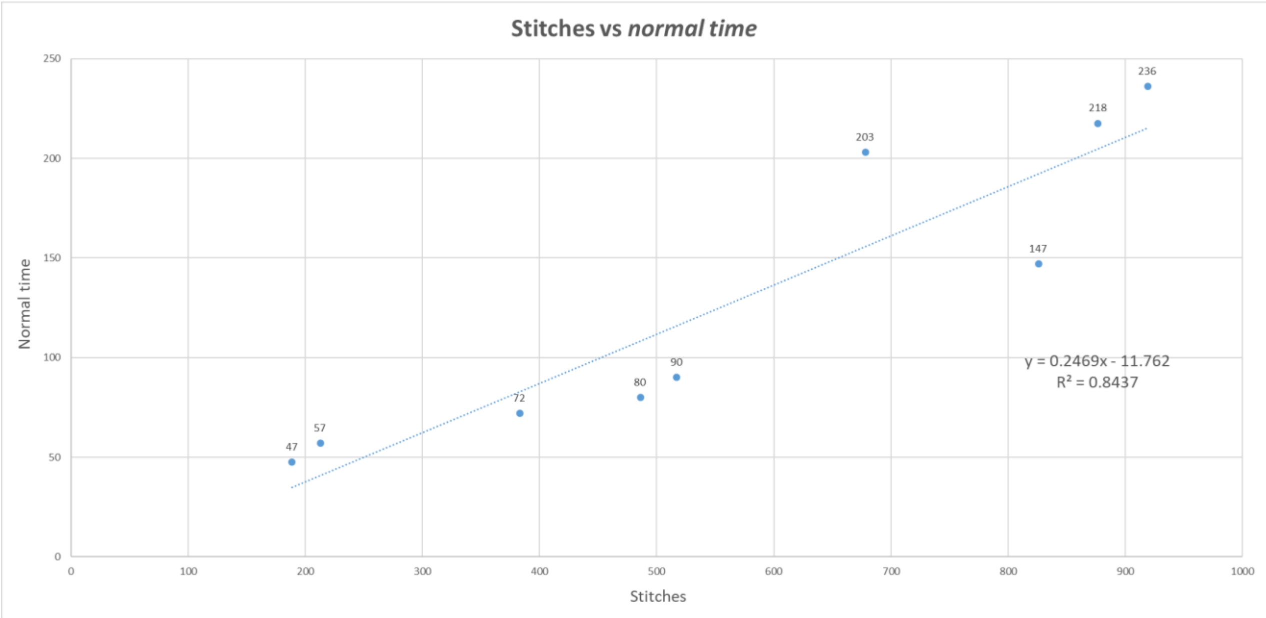


Figure IV.30 It represents the evaluation process of a linear trend curve.

The straight line obtained link together time and stitches, it means that given the number of stitches with this model it is possible to obtain the forecasted duration with the following equation:

$$Expected_{NT} = s * 0.2469 - 11.762 \qquad \{4.8\}$$

Where $Expected_{NT}$ represents the expected *normal time* and *s* represent the number of stitches. It is possible to notice how the value of R^2 is not so high and therefore the model may not represent the real distribution of data. To understand the causes see the chart of Figure IV.30*:* the product on which relief 4_1 and 6_1 was taken (respectively label 203 and 147) has:

- Relief 6_1: 826 stitches and 147 seconds;
- Relief 4_1: 678 stitches and 203 seconds.

Therefore relief 6_1 has higher number of point and lower time. This example shows that even if the model suggests an increase in time every time the stitches increase (less than proportional increase in time), this is not true. Unfortunately for confidentiality agreements the products cannot be showed and then they will be described roughly. Product 4_1 is composed by a set of three curves group, all curves have different ratio and different dimension, furthermore the three blocks are spaced. Product 6_1 instead is composed principally by straight line (even if with different slope), fillets and angles. It could be hypothesized that a longer time of product 4_1 can only be justified by a decrease in average speed due to the high number of curves present. Instead for product 6_1 the high presence of angles and fillets influence less (less than the difference in stitches number) the time.

It is clear that the only number of stitches is not enough to create a model, but there is the need of a numeric value which takes into consideration the geometry of the products. To take into account the different geometry of each product in a numeric form, it has been considered the best option to create an indicator for the difficulties of the product machining. It has been already largely discuss how equivalent lenght model cannot be created (Chapter 4.4.1) and that only an empirical model can be created. Because of this two groups of model have been suggested:

- Variational empiric model which links together *normal time* and an weighted number of stitches obtained processing the number of stitches with an indicator for the geometry (then a difficulty indicator). Then the equation that describes this class of model will be:

  $$Expected_{NT} = WS \cdot \beta_1 + \beta_0 \tag{4.9}$$

  9

  With:
    - $Expected_{NT}$: it is the expected normal time for the machining of a product forecasted by the model;
    - WS: it is the weighted number of stitches;
    - β_0 and β_1: they are regressors for the linear model.

  It is important to notice that WS is itself a function of the stitches $WS = f(s)$, and so the model is a function of a function: $Expected_{NT} = y = f(g(x))$.

  This group of model will be called *Weighted stitches model*.

- Variational empiric model which strongly take cue from the groups technology principle: then products are divided in different groups based on the geometry and data are processed for each group based on the avarege speed. Therefore the equation of the model will be:

  $$Expected_{NT} = f\left(\frac{s}{speed_{group}}\right) \tag{4.10}$$

  This model will be called *Group speed model*.

4.4.1 WEIGHTED STITCHES MODEL

As said the number of stitches is not enough to create a model which can reliably forecast machining time because the geometry, or the difficulty of the product is not taken into consideration. Here it comes the need of introducing inside the model an indicator of difficulties, but first of all it is important to well define what difficulty is to determine the factors that influence it. Then, difficulty, can be defined as each set of stitches which, due to geometry distribution, moves away the machine from regime speed (which is 600 PPM). It is reasonable to assume that for straight line stitches set distribution the speed reached by the machine is the regime one, therefore the sets of stitches which move away machine from 600 PPM are curves, fillets and edges. Each of this set will have a different influence on machine speed which must be defined but for the same reason for which an equivalent length model cannot be created, their influence cannot be quantitative deduced.

Therefore there is the need of a quantitative study which can results in quantitative evaluation of the influence of each set in the speed. In practice three different groups have been created, each group is characterized by a specific set of stitches (even more than one but very similar each other); these groups are:

- Edges and fillets (small radius);
- Curves;
- Straight lines.

The machining difficulty of a product has been expressed in an index called *difficulty index*. The scope of the index is the one of creating a weighted number of stitches, based on geometrical characteristic of product, which makes easier the forecast of machining time. The index has been determined for each product machined and it was determined on the basis of two quantitative evaluation:

- Presence or absence of one or more of the above set of stitches group: it has been assigned a Boolean value to the presence as 1 and to the absence as 0;
- Average speed.

Then, product by product, based on which set of stitches was present in the machining and the value of average speed, it has been determined which group influenced more and which less the machining. The evaluation of the speed has been carried out on a relative evaluation among all reliefs collected. Table IV.19 shows for each product the set of stitches present and the average speed evaluation relatively to other product (represented with a colour).

Table IV.19 It represents the two evaluations carried out on presence/absence of set of stitches groups and average speed.

Reliefs	4_1	4_2	4_3 group	4_4 group	5_3	6_1	8_2	10_3 group	11_1
Code	[redacted]								
Normal time	203	80	218	47	90	147	72	57	236
Stitched	678	486	877	189	517	826	383	213	919
Average speed	200	365	242	239	345	337	319	224	234
Edges and fillets (small radius)	YES	YES	YES	NO	YES	YES	YES	NO	YES
Curves	YES	NO	YES	YES	NO	NO	YES	YES	YES
Straight lines	YES	YES	YES	YES	YES	YES	YES	YES	YES

The average speed evaluation is defined as green the maximum relative speed and red the lowest relative one, all the other colours follow the shading scale from green to red in decreasing speed.

The table above allows to check which set of stitches more influence the average speed. Most of the products cannot be reported for confidentiality agreements but what emerged is that for products with high number of curves the average speed decreases as for products 4_1, 10_3, 11_2; instead if there is a majority of edges and fillets, then the speed is higher as in 4_2, 5_3 and 6_1 products. Logically, straight lines, does not influence this evaluation because of the assumption that in this set the average speed is the regime one. Until now the evaluation of the speed and presence/absence of stitches set, allowed the creation of relative evaluation:

- Edges and fillets decrease speed less than curves;
- Curves decrease the most speed;
- Straight lines (because of hypothesis) decrease less the speed.

In order to assign a numerical value to the *difficulty index*, as already said, the presence/absence of stitches sets is considered a Boolean variable and then presence/absence is converted to yes/no and this is converted to 1/0. Then each group of stitches set can assume a value between: {1;0}.

Each stitches set will be assigned a coefficient based on the relative influence on speed. The decision of the coefficient followed an empirical model as it is described:

- In straight lines sets, because of hypothesis, the speed is the regime one, and then the already constructed model which links time and stitches is valid, therefore there is a proportionality between them. Because of this its influence in the average speed is null. It means that if the speed is maintained constant and the time to accomplish a product is the same, if the product is done only with straight lines set then the number of point is unchanged (otherwise it will increase). Because the *difficulty index* is aimed in creating weighted number of stitches, and because of straight lines sets do not influence the regime speed, then the value attributed to this group is 1;
- Curves sets are the one that decrease the speed the most, then their value. When curves are present the speed is decreased on an average speed of 250 PPM which is the 40% of the regime speed, it means that the sets influence for about a decrease of 60% of regime speed. Because the *difficulty index* works with stitches and not with speed, the reasoning must be inverted and so the stitches must be increased of 60%, then the value attributed to this group is 1.6;
- Edges and fillets are in the middle of the two above value, so should be near 1.3 value for the group. In fact, on average, the speed of machine when these sets are present is 400 PPM which represents about 70% of the speed. Reversing the reasoning from speed to stitches then it means that the number of them should be increased for about 30%; it means that the value attributed to this group is 1.3.

Now it is possible to create the *difficulty index* (*d*) as the product between the Boolean value (then the presence/absence of a set) and the coefficient attributed to that value:

$$d = \sum_{j=1}^{3} a_j \cdot b_j \tag{4.11}$$

In this formula: *d* is the *difficulty index*; *j* represents the groups of stitches set (then edges and fillets, curves, straight lines); *a* represents the Boolean value and *b* represents the coefficient attributed to the specific group. Thanks to this script is now possible to give a numerical value represented the difficulty of a product to each product (Table IV.20).

Table IV.20 The values represent the transformation from Boolean value for different sets, through the coefficient assigned to each sets finally to obtain the difficulty index.

Reliefs (relief_sheet)		4_1	4_2	4_3 group	4_4 group	5_3	6_1	8_2	10_3 group	11_1
PRESENCE/ABSENCE OF STITCHES SETS	Edges and fillets	YES	YES	YES	NO	YES	YES	YES	NO	YES
	Curves	YES	NO	YES	YES	NO	NO	YES	YES	YES
	Straight lines	YES	YES	YES	YES	YES	YES	YES	YES	YES
NUMERICAL VALUE ASSIGNED TO PRESENCE/ABSENCE OF STITCHES SETS	Edges and fillets	1.3	1.3	1.3	0	1.3	1.3	1.3	0	1.3
	Curves	1.6	0	1.6	1.6	0	0	1.6	1.6	1.6
	Straight lines	1	1	1	1	1	1	1	1	1
Difficulty index		3.9	2.3	3.9	2.6	2.3	2.3	3.9	2.6	3.9

It is reported here the structure of the function of function model:

$$Expected_{NT} = WS \cdot \beta_1 + \beta_0 \tag{4.12}$$

Which links a weighted number of stitches to time. As already described, the number of stitches themselves are not enough to create a model; then a coefficient which helps processing the number of stitches to obtain a weighted number of stitches proportional to the difficulty is needed (*difficulty indicator*). Once the coefficient is obtained there is the need of a study on how to link this index to the number of stitches in order to get an appropriated weighted stitches proportional to difficulty. Then two different approach have been carried out on which links *difficulty index* and stitches, which gave rise to two different models: *factors model* and *model power*.

4.4.1.1 Weighted stitches model, Factors model

This model follows the weighted stitches model principle which uses the weighted stitches as auxiliary variables to estimate time: $Expected_{NT} = f(s)$. Specifically in this model the analyst decided to link with linear proportionality time and stitches, but alse linear proportionality between time and *difficulty index*. The analyst wants the model to be a linear function, then

$$Expected_{NT} = g(s,d) \cdot \beta_1 + \beta_0 \tag{4.13}$$

Which returns the $Expected_{NT}$ as a function of function: $Expected_{NT} = f(g(s,d))$.

In order to obtain weighted stitches based on difficulty, the easiest way is multiplying the stitches by the *difficulty index*. In this way the analyst is hypnotising a linear proportionality between:

- $Expected_{NT}$ and weighted stitches (*WS*);
- $Expected_{NT}$ and stitches (*s*);
- $Expected_{NT}$ and *difficulty index* (*d*).

$$\begin{cases} y = Expected_{NT} = f(WS) \\ f(WS) = WS \cdot \beta_0 + \beta_1 \\ WS = g(s,d) \\ g(s,d) = s \cdot d \end{cases} \tag{4.14}$$

$$y = Expected_{NT} = f(WS) = WS \cdot \beta_0 + \beta_1 = f\big(g(s,d)\big) = g(s,d) \cdot \beta_0 + \beta_1 \\ = (s \cdot d) \cdot \beta_0 + \beta_1 \tag{4.15}$$

The regressors β_0 and β_1, and the weighted stitches must be evaluated. In Table IV.21 all data collected are reported about each product during relieving activities and in the last row it has been evaluated the weighted stitches with the following equation:

$$WS = s \cdot d \tag{4.16}$$

Table IV.21 It shows the weighted stitches obtained per each product.

Reliefs	4_1	4_2	4_3 group	4_4 group	5_3	6_1	8_2	10_3 group	11_1
Code	[redacted]	[redacted]						[redacted]	
Normal time	203	80	218	47	90	147	72	57	236
Stitches	678	486	877	189	517	826	383	213	919
Difficulty indicator	3.9	2.3	3.9	2.6	2.3	2.3	3.9	2.6	3.9
Weighted stitches	2644	1118	3419	490	1189	1900	1494	554	3584

The analyst considered necessary an evaluation on data collected to monitor the presence of correlation between weighted stitches and *normal time*, and then the influence of randomness inside the relation. Then a statistical analysis is carried out with excel mathematical software.

- Correlation: it is evaluated with *Pearson correlation index*[44], which represent the linear relation between two groups of variable and higher the percentage of the index is and higher is the correlation. For *Factors model* the correlation value evaluated is: 97.45% which is very high linkage between weighted stitches and normal time relieved.
- Randomness: it is evaluated using *Student T test*, which evaluate the average equality of two groups of variables. Practically what the test suggest is the influence of randomness inside the correlation and higher is the percentage, higher is its influence. For *Factors model*

[44] Stephanie Glen; "Correlation coefficient: simple definition, formula, easy steps"; *StatisticsHowTo.com*

the *T test* returned a value of 0.08% which represent a percentage of randomness influence of sets of data.

Because of the validity of data, it has been proceeded with the evaluation of two regressors. In order to do so it has been used excel mathematical software again plotting on a weighted stitches *vs normal time* plane all data collected in the form: *{weighted stitches; normal time}* (Figure IV.31).

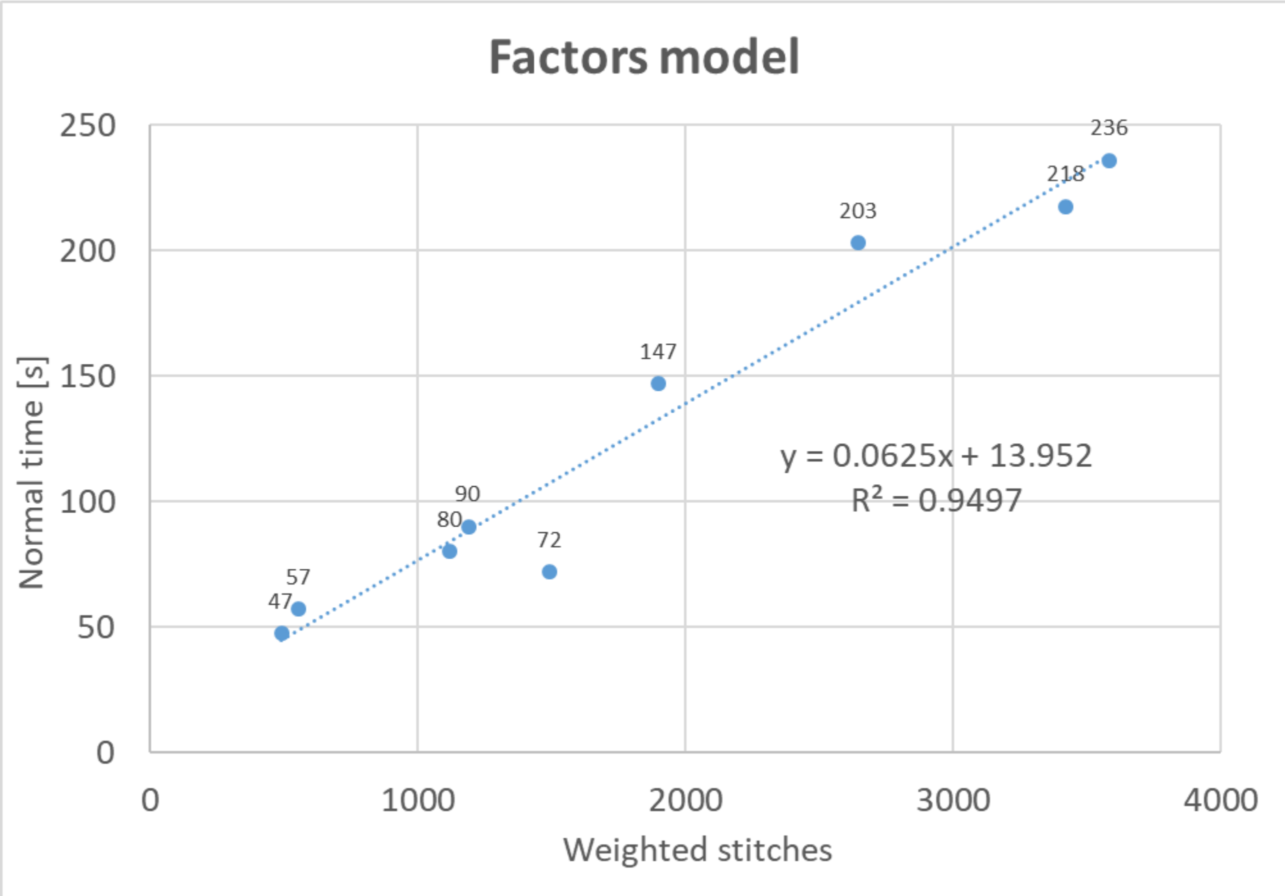


Figure IV.31 The graphical representation of the Factors model with linear proportionality between normal time, stitches and difficulty index.

The regressors value are:

$$\begin{cases} \beta_0 = 13.95 \\ \beta_1 = 0.06 \end{cases} \qquad \{4.17\}$$

The R^2 value acquired a +10% with respect to the model created only with number of points (in which R^2 was 0.84).

Therefore the equation of *factors model* which links linearly normal time, stitches and *didfficulty index* is given by the eqution:

$$Expected_{NT} = \left[s \cdot \left(\sum_{j=1}^{3} a_j \cdot b_j \right) \right] \cdot 0.06 + 13.95 \qquad \{4.18\}$$

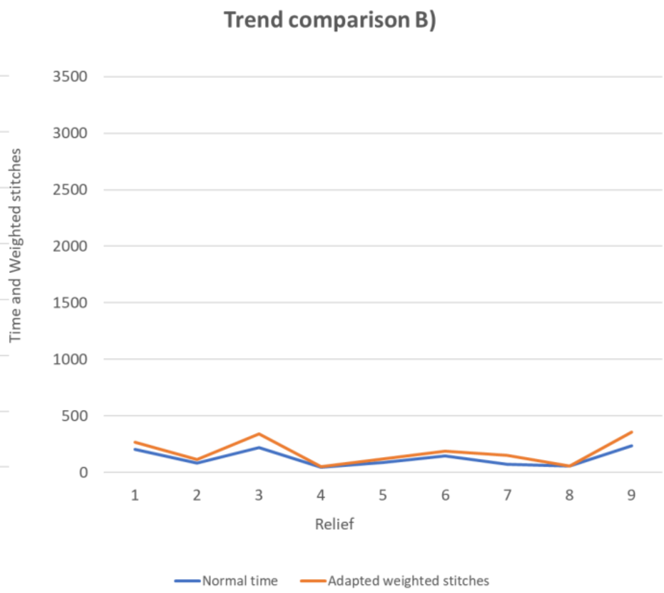
With:

- *S* as stitches;
- *j* represents the groups of stitches set (then edges and fillets, curves, straight lines);
- *a* represents the Boolean value {1; 0};
- *b* represents the coefficient attributed to the specific group.

4.4.1.2 Weighted stitches model, Power model

Power model, because it is a weighted stitches *model*, still maintains a linear proportionality between time and weighted stitches $Expected_{NT} = f(WS)$ but not linear proportionality between stitch, *difficulty index* and time. The analyst would have a trend as similar as possible between time and weighted stitches. In order to do so, the value of time and weighted stitches were plotted for each relief and a trend curve was added too (Figure IV.32). In this case, weighted stitches are still evaluated as a product between *difficulty index* and stitches, as in *Factors model*. Figure IV.32 shows trend *comparison:*

- A) reports the trend between weighted stitches and *normal time,* the order of magnitude of the two datasets is highly different (deviation in Figure IV.33)*;*
- *B)* the order of magnitude of the weighted stitches is reduced by one order (then divided by ten)*;*
- *C)* it is reported a zoom of *Trend comparison B)* In this way the datasets are more easily compared.



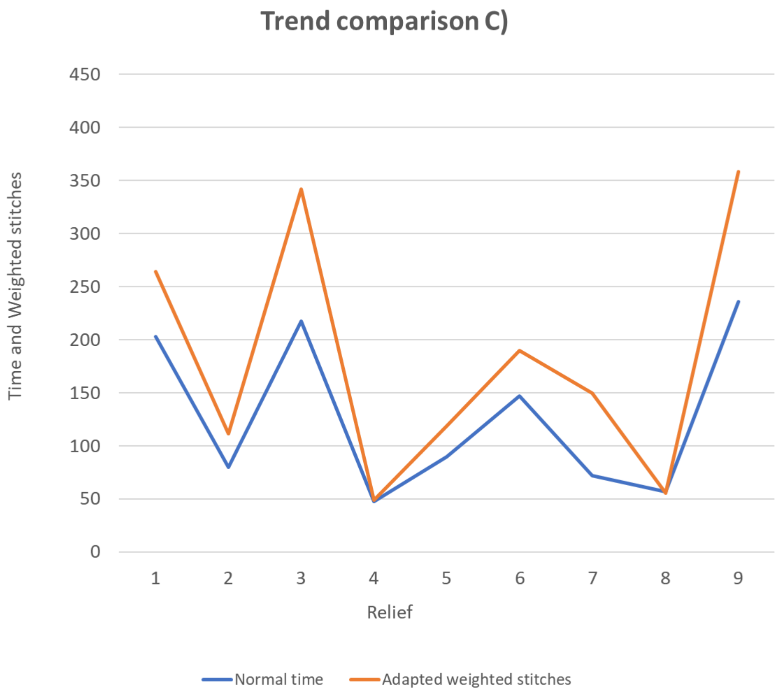


Figure IV.32, Trend comparison A) reports the trend between weighted stitches and normal time, but how it is possible to notice the order of magnitude of the two datasets is highly different, therefore in Trend comparison B) the order of magnitude of the weighted stitches is reduced by one order (then divided by ten), then in Trend comparison C) it is reported a zoom of Trend comparison B).

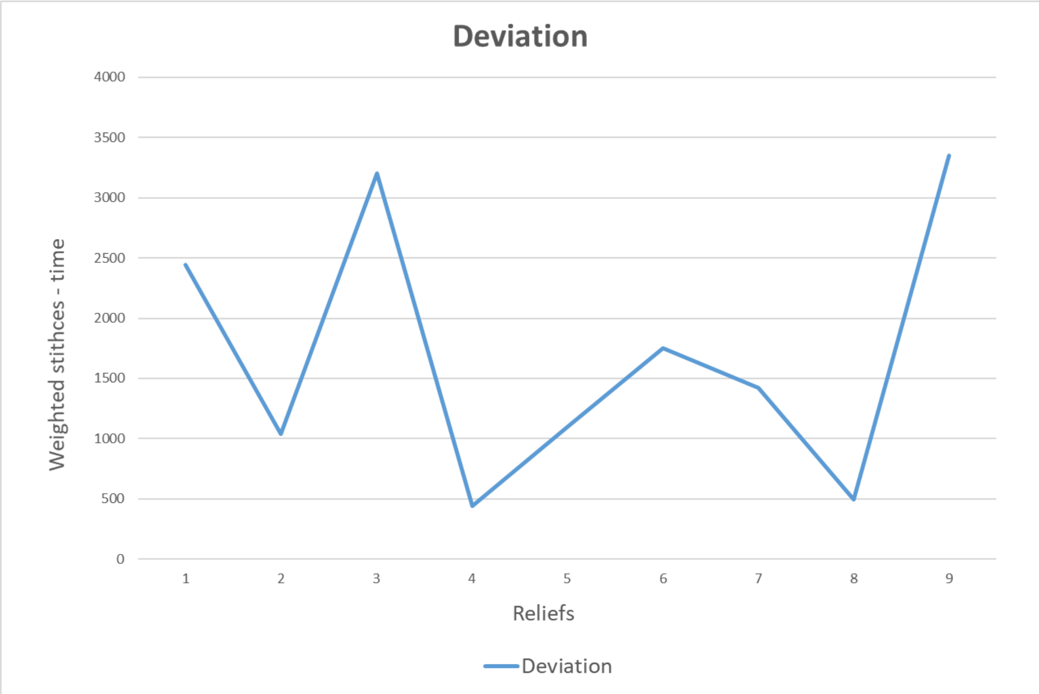


Figure IV.33 Deviation between a value estimated by "weighted stitches – time" in different reliefs.

Because of the model would be as much reliable as much the deviation is maintained constant, the analyst decided to create this model empirically discovering the value of a power that create the expected result. Therefore this model still links time and weighted stitches with a linear proportionality but the relation between time, *difficulty index* and stitches is no more linear, instead it is a power proportionality. It means that the plant of the model is similar to the *Factors model* but the function that constitute *WS*, then $g(s,d)$ is not $g(s,d) = s \cdot d$ but it will be $g(s,d) = (s \cdot d)^n$. To make easier the understanding a mathematical discussion is now carried out.

$$\begin{cases} y = Expected_{NT} = f(WS) \\ f(WS) = WS \cdot \beta_0 + \beta_1 \\ WS = g(s,d) \\ g(s,d) = (s \cdot d)^n \end{cases} \qquad \{4.19\}$$

$$y = Expected_{NT} = f(WS) = WS \cdot \beta_0 + \beta_1 = f\big(g(s,d)\big) = g(s,d) \cdot \beta_0 + \beta_1 = (s \cdot d)^n \cdot \beta_0 + \beta_1 \qquad \{4.20\}$$

The first step will be now the discovering of *n* parameter. It has been found out with *trial and error* methodology, which returned:

$$n = 0.73$$

The graphical representation of trend comparison is reported in Figure IV.34.

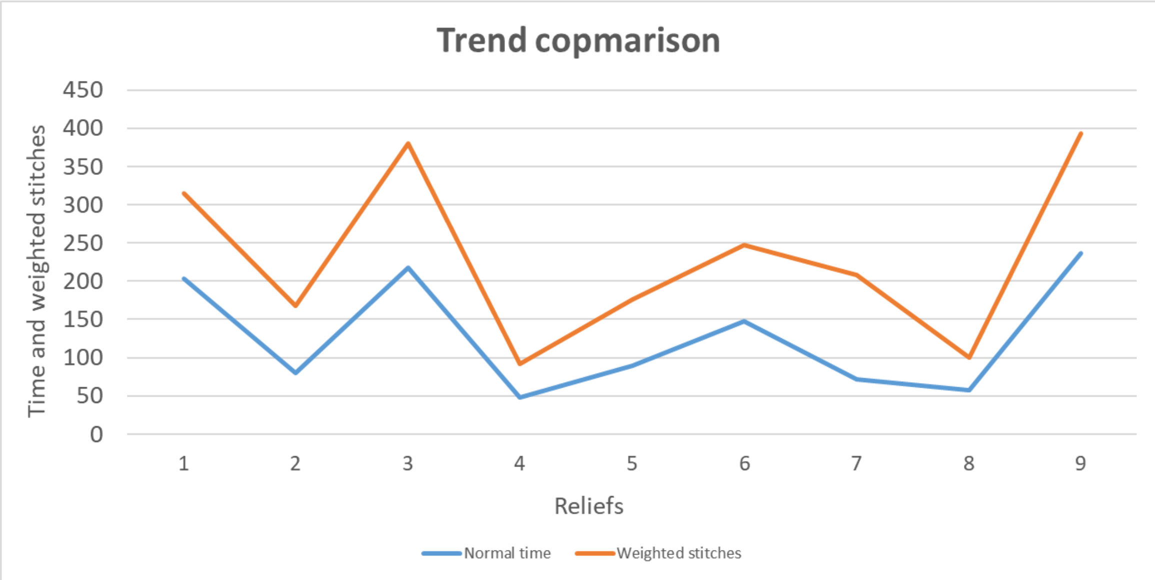


Figure IV.34 The trend between time and weighted stitches evaluated as $(s \cdot d)^{0.73}$ *and normal time on left.*

The procedure adopted now are the same of *Factors model*. Therefore first of all the weighted stitches of each product are evaluated through the equation:

$$WS = (s \cdot d)^{0.73} \tag{4.21}$$

In Table IV.22 all the data are reported and in the last row there is the value of weighted stitches.

Table IV.22 It shows the weighted stitches obtained per each product.

Reliefs	4_1	4_2	4_3 group	4_4 group	5_3	6_1	8_2	10_3 group	11_1
Code	[redacted]								[redacted]
Normal time	203	80	218	47	90	147	72	57	236
Stitches	678	486	877	189	517	826	383	213	919
Difficulty indicator	3.9	2.3	3.9	2.6	2.3	2.3	3.9	2.6	3.9
Weighted stitches	315	168	380	92	176	247	208	101	393

As for the previous model also here the analyst considered necessary a statistical evaluation on data collected concerning correlation between weighted stitches and normal time and then an evaluation on the influence of randomness inside the relation. Correlation is evaluated with *Pearson correlation index*, which value evaluated is 97.07%. Randomness is evaluated using *Student T test*, which returned a value of 0.005%. With respect to the *Factors model* the *Pearson correlation index* is decreased by 0.7 percentage points which is a small amount, but the *Student T test* is decreased by a magnitude order which is a consistent amount. Data can be considered reliable and then the analysis can be carried out further.

The analyst has proceeded with the evaluation of the two regressors. Figure IV.35 *shows weighted stitches vs normal time graph*. It has been required by the analyst to the software to evaluate a trend curve with straight line shape. In this way the software automatically evaluates the regressors value.

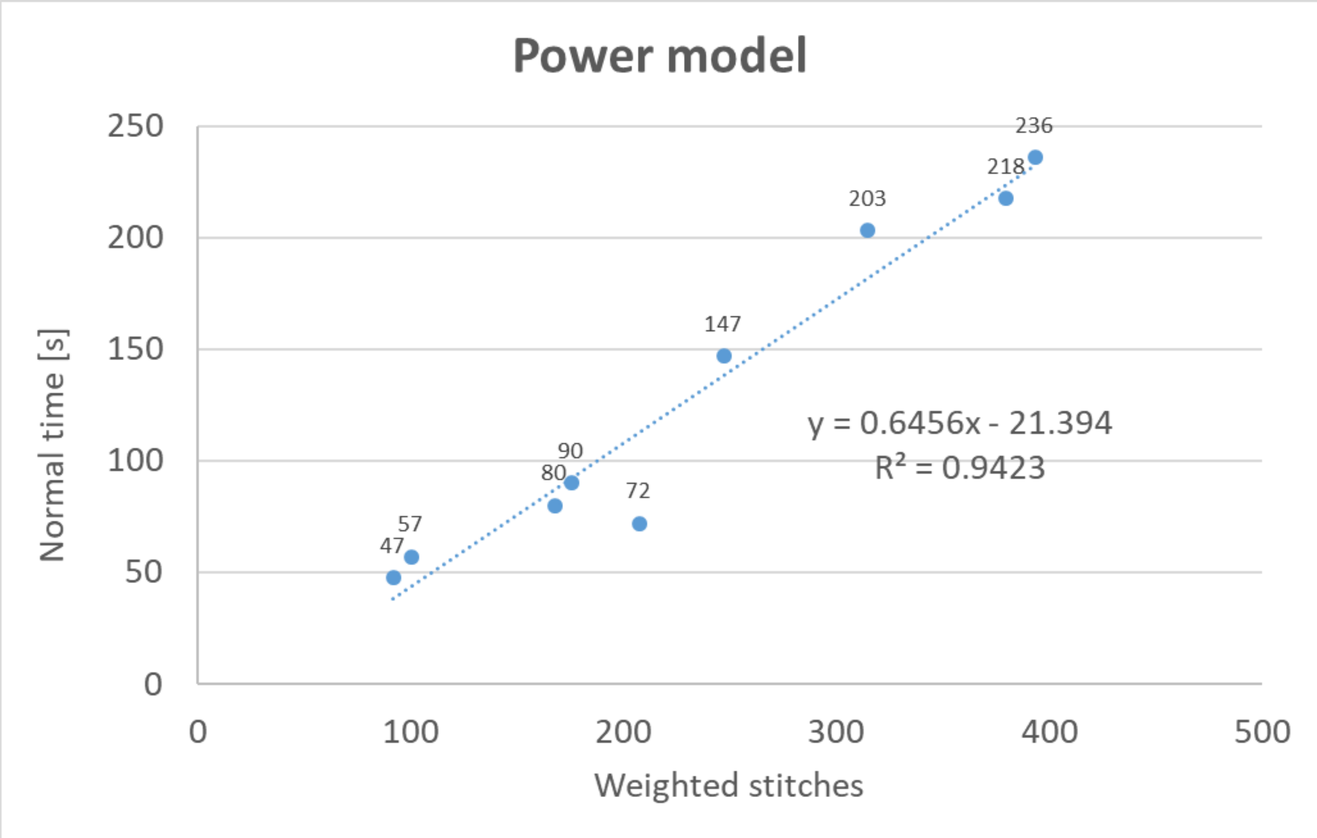


Figure IV.35 It is the graphical representation of the Factors model with linear proportionality between normal time, stitches and difficulty index.

The regressors value are:

$$\begin{cases} \beta_0 = -21.39 \\ \beta_1 = 0.65 \end{cases} \qquad \{4.22\}$$

R^2 value losses about 1% with respect to the *Factors model*, but still it is a very high value.

Finally the equation of *factors model* which links linearly normal time, stitches and *didfficulty index* is given by the eqution:

$$Expected_{NT} = \left[s \cdot \left(\sum_{j=1}^{3} a_j \cdot b_j \right) \right]^{0.73} \cdot 0.65 - 21.39 \qquad \{4.23\}$$

With:

- *S* as stitches;
- *j* represents the groups of stitches set (then edges and fillets, curves, straight lines);
- *a* represents the Boolean value {1; 0};

4.4.2 GROUP SPEED MODEL

This group of model is totally different from the weighted stitches model, in fact the basic hypothesis on which the model is based are different. This model strongly take inspiration from *group technologies*, and therefore similar machining are collected: the basic hypothesis is that product with similar geometrical characteristics will have similar average speed. Then after having grouped several cases by geometry, the average speed for the group is evaluated and it is hypnotized that future products with the same characteristics will have an identical average machining speed. This approach is inspired by group technology philosophy. Once the system is able to determine the average speed, because of the stitches number is easily obtainable, the forecasted time will be evaluated as:

$$Expected_{NT} = f\left(\frac{s}{speed_{group}}\right) \qquad \{4.24\}$$

In order to complete this model there is the need of high amount of data and group classification method.

The data collected, which are the ones already exposed, were limited by the availability of machine, the presence or absence of products and the production phases. Then the amount of data collected during thesis period are not enough to accomplish this model. Neither the less the model is started so that if the company is willing to carry over the processing activity can already rely on a series of data processed and reliable.

The group classification method should be studied in order to have an easy method that can be used without the support of a software to identify similarity. Therefore the analyst decided to use the same group individuated for the definition of the *difficulty index* and create group based on the presence/absence of that parameter. Reminding that the three groups are: angles and fillets, curves and straight lines, then the groups created to classify the products are 8 (reported in Table IV.23).

Table IV.23 It represents all the possible combination of the 8 groups in which products can be classified.

	Groups							
Parameters	1	2	3	4	5	6	7	8
Angles and fillets	YES	NO	NO	YES	YES	NO	YES	NO
Curves	YES	NO	YES	NO	NO	YES	YES	NO
Straight lines	YES	NO	YES	NO	YES	NO	NO	YES

It is now possible to apply this classification to the data collected, to know how the actual product are divided. The classification carried out by the analyst cannot be represented by real examples of machining part for confidentiality agreements.

- Group 1: product 4_1; product 4_3, 8_1, 9_3, 10_1 (which have been grouped together);
- Group 2: no product;
- Group 3: product 4_4, 5_1, 8_1, 9_2, 10_2 (which have been grouped together); product 10_3, 11_2 (which have been grouped together);
- Group 4: no product;

- Group 5: product 4_2; product 5_3; product 6_1;
- Group 6: no product;
- Group 7: no product;
- Group 8: no product.

It is easy to understand how the model is not fully developed. Now the analysis for each group is carried out. Group 1 data are reported in below table (Table IV.24). Speed is evaluated as $\frac{stitches}{normal\ time\ [s]}$ so it is already an average speed of machining. Then an average is carried out on all speeds. This average speed will be the average speed (as stitches per second, so PPS) of the group, it means that every product which will have as geometrical characteristics: curves, fillets or/and angles and straight lines, will have an average speed of 4 PPS in the *Rodella* machining phase. It can be interesting to analyse also the standard deviation given to understand how good the distribution and average speed representation is. The standard deviation is: 0.82 which is a good value, but still the data are too low to have a good representation of all possible product.

Table IV.24 It shows all data concerning Group 1 and average speed.

Group 1				
Reliefs (relief_sheet)	4_1	4_3 group	8_2	11_1
Code	[redacted]			
Normal time	203	217.6	72	236
Stitches	678	877	383	919
Speed	3	4	5	4
Average speed				4

Group 3 followed the same procedure of Group 1, therefore all information on products inside the group were collected and based on that data it was evaluated the average speed. Group 3 is characterized by the presence of curves and straight lines and then, also as already discovered and explained during the treatment of *difficulty index,* they represent the lower speed group, in fact, even if also in this case the average speed is 4 (Table IV.25) it is important to highlight how this data has no real value and it is not reliable because of the collection of data include only two products. A much larger study should be carried out.

Table IV.25 It shows all data concerning Group 3 and average speed.

Group 3		
Reliefs (relief_sheet)	4_4 group	10_3 group
Code	[redacted]	
Normal time	47.4	57
Stitches	188.6	213
Speed	4	4

Average speed	4

Group 5. Also in this case the average speed has been evaluated (Table IV.26). This group is characterized by the absence of curves and therefore, as treated in *difficulty index* chapter, this is the fastest group. In fact what emerged from the analysis, the average speed is 6 PPS. Data are logically too low to have a possible deeper analysis.

Table IV.26 It shows all data concerning Group 3 and average speed.

Group 5			
Reliefs (relief_sheet)	4_2	5_3	6_1
Code	[redacted]	[redacted]	[redacted]
Normal time	80	90	147
Stitches	486	517	826
Speed	6	6	6
Average speed	6		

The way in which this model would be applied and insert in company procedure is easy: after the modelling office draw the product, there is a software which ask the presence or absence of each of the three parameters (fillets and angles, curves and straight lines), then, based on the answered, the software automatically returns the average speed for the group individuated. Dividing the number of stitches by the average speed it will be obtained the duration of the machining sub-phase. If the average speed is evaluated as PPS then the duration will be expressed in seconds, otherwise if the average speed is evaluated as PPM, then the duration will be expressed in minutes.

4.4.3 SUMMARY OF MACHINING CYCLE SUB-PHASES MODELS

In order to have an easy way to sum up all the models created for the machining sub-phase it can be useful to have a graphical and schematic representation (Figure IV.36) with a brief and generic description.

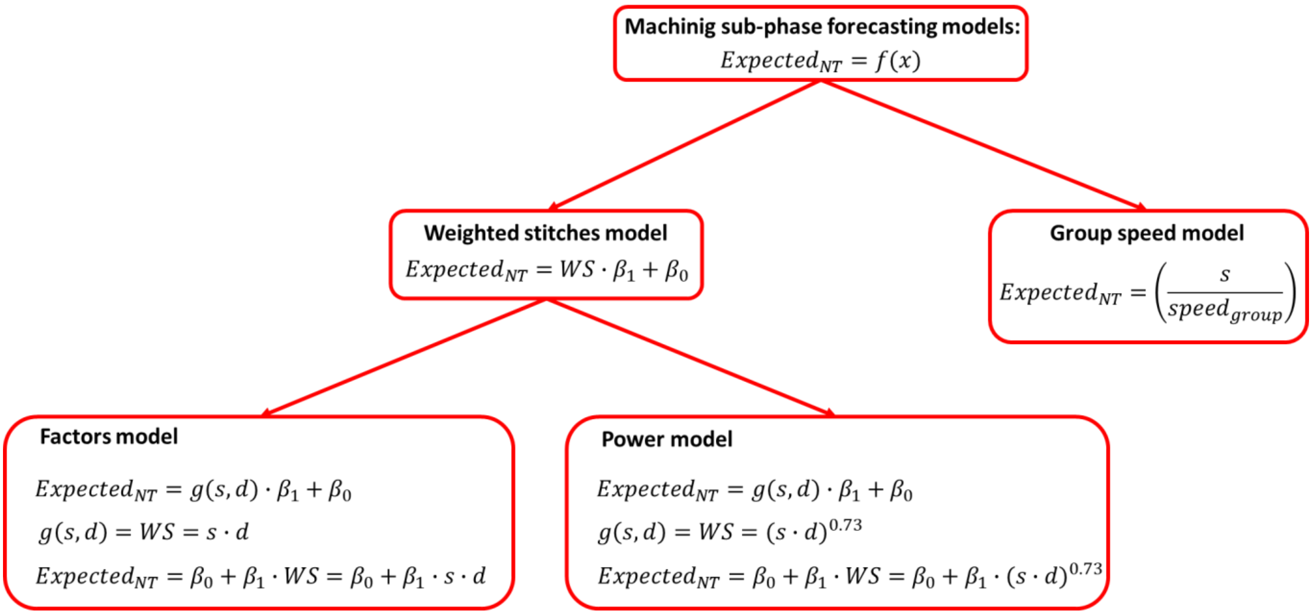


Figure IV.36 It is a schematic representation of the models constructed for the machining sub-phase of Rodella.

All forecasting models were constructed in a way that logically the expected *normal time* ($Expected_{NT}$) would be the dependent variable and so the output of the model. Then two different classes of model were created with different logic framework:

- Group speed model: the products are divided for geometry similarity in eight groups based on the presence/absence of: angles and fillets, curves and straight lines. For each group it is evaluated the average speed. It is hypnotised that future products of each group will have the average speed of the group because of similar geometry.
- Weighted stitches model: the model is constructed as a linear proportionality between a value of weighted stitches (WS) and expected *normal time*. The weighted stitches are evaluated as a processing of the real number of stitches and the *difficulty index* which was created in order to evaluate the machining difficulty level. Depending on the kind of processing of stitches and *difficulty index* to evaluate the weighted stitches, two models were created:
    - Factors model: in this model the weighted stitches are evaluated as the product of stitches number and *difficulty index*, then the weighted stitches obtained are introduced in the linear proportionality. Together with regressors found out with trend curve for *WS* and *normal time*, the model is created.
    - Power model: in this modetl the weighted stitches are evaluated as a power of the product between stitches number and *difficulty index*, then the weighted stitches obtained are introduced in the linear proportionality. Together with regressors found out with trend curve for *WS* and *normal time*, the model is created.

4.5 CHAPTER SUMMARY AND FINAL MODEL

Until now the analyst designed the model to forecast the time of each operation, now it is possible to collect all the forecasting model together to define the time duration of the *Rodella* working station. Because orders and production are different phases of a product lifetime, different approach will be used for orders and production in fact the need of monitoring is opposed and there are the presence of hidden times in one phase and not the other. Then now both phases will be analysed singularly.

4.5.1 FINAL ORDER MODEL

An order usually require small amount of product, as one, two or at least three product, then the table produced during this phase is one pair in order to produce one product a time. Furthermore during the orders there is an high need of monitoring, to control if the machining proceed as it should and if there are issues. Monitoring the activity helps the operator to know where the problems raise and generally also why. Because of the small product required, because a will of under-dimensioning the production capacity (and therefore the creation of one table) and because the need of monitoring, cyclical and acyclic operation must be done one by one without overlapping tasks and therefore with no hidden times. This logically bring to low saturation of operator and low machine saturation. In Table IV.27 it is reported the list of task with a chronological order, which times added together will result in the total order forecasted time there are also information on cyclicity of tasks and number of repeated steps per cycle considering the presence of two pairs of tables.

Table IV.27 The sub-phases and relative time for the benchmark.

N.	Sub-phases	Cyclical/ Acyclical	Number of repeated step	Forecasted time	
				Assigned time [sec]	Normal time [sec]
1	Pins application	A	2		$\text{Expected}_{\text{NT}} = \begin{cases} 20\text{s}, & s \leq 18 \\ 22\text{s-}37, & s \geq 19 \end{cases}$ With *s* the number of stitches
2	Transparent table positioning	A	2	N.A.	
3	Tables adhesion	A	2	N.A.	
4	Pins coverage	A	2	N.A.	
5	External wire change	A	1	99	
6	Needle change	A	1	86	
7	Internal wire coil change	A	1	N.A.	
8	Machining file selection	A	0	26	
9	Material fixing	C	1	N.A.	
10	Machine commissioning	C	1	7	
11	Machine cycle	C	1		$\text{Expected}_{\text{NT}} = \left(\frac{s}{\text{speed}_{\text{group}}}\right)$ or $\text{Expected}_{\text{NT}} = \text{WS} \cdot \beta_1 + \beta_0$
12	Frame load	C	1	6	
13	Frame unload	C	1	6	
13	Material removal	C	1	N.A.	
14	Template marking	A	2	N.A.	

Converting *normal time* obtained by the models and summing together all the time it is possible to define the total assigned time and the total standard time for accounting scopes. In this way all sub-phases concerning machine set-up are considered: in fact usually when a new product is ordered the wires are changed and usually the needle too.

4.5.2 FINAL PRODUCTION MODEL

The production phases instead is the moment where more products are produced, from a hundred to some thousands. In this phases the monitoring is not strictly needed as during the order phase and furthermore there are cyclical sub-phases which can be overlapped and the creating hidden times, increasing machine and operator saturation. The duration is the same exposed above but there is a difference depending on the number of tables created to sustain the production. In most cases two pairs of tables is enough to reach reasonable level of saturation.

An analysis is needed to better understand some procedure: machining file selection sub-phase will never be carried out because during production, as already highlighted, the file selection is done through a bar-code positioned on the parts; the acyclic operation regarding tasks with tables will be repeated twice because of the hypothesis of two pairs of tables.

Acyclic sub-phases cannot became hidden times and this because of their nature, then their time must be considered evaluating the total required time even if in a production of one thousands units they occur twice. Instead all the other preparation sub-phases can occur during the machining sub-phase, then material removal and material fixing can occur also during machining sub-phase. Therefore, the cycle time can be evaluated as the table below shows (Table IV.28).

Table IV.28 It represents the tasks distribution in a cycle.

Time

Sub-phases for product A	Time	Sub-phases for product B	Time
9. Material fixing		11. Machine cycle	
		12. Frame shift	
13. Frame load			
10. Machine commisioning			
11. Machine cycle		13. Material removal	
		9. Material fixing	
12. Frame shift			
		13. Frame load	
		10. Machine commisioning	
14. Material removal		11. Machine cycle	

It is easy to understand that the cycle time will be the sum of the duration of the subphases of: material fixing, frame unload, machine commissioning, machine cycle, frame load and material removal. This cycle time will be repeated for every couple of products: the productivity is 2 products each cycle using two pairs of table. To this time which depends on the commissioned production, it must be added the time of the sub-phases: pins application, transparent table positioning, tables adhesion, pins coverage, external wire change, needle change, internal wire coil change and template marking. The duration of these phases must be considered twice as already explained only for those which multiplicator was two in the Table IV.27. Finally summing twice the acyclic sub-phases time and the cycle time times half the production amount, the result will be the total time required for the production. Also in this case the machine set-up sub-phases are considered as to do because usually this is what happen during a production.

CHAPTER V CONCLUSION

The thesis focuses on the forecasting model for an SME (*Goretti S.r.l.*) operating in the luxury fashion market. Now a brief recap of all the information exposed in the thesis is done.

5.1 EXTERNAL ENVIRONMENT

Goretti S.r.l. is a textile company which operates in the luxury fashion segment. It is located in Serra de' Conti (Ancona, Italy). The company handles the application of decorations on shoes and accessories for luxury fashion. The segment in which Goretti S.r.l. operates requires high ability of adaptation to stay competitive with the market maintaining profits and high-quality standard.

It emerged from the analysis is that the fashion market is a very important market in Italy. In 2018 with about fifty billion turnover it influenced for 1.2% the Italian gross domestic product (GDP). In Italy SMEs operating in fashion market are 55,491; and only considering SME, employees amount 311,697 units. The numbers above reported place Italy as first country in Europe for workers and copmanies number in fashion market. In particular, the region in which Goretti S.r.l. is located (Marche) is second placed in Italy for workers quota: 6% against 7.5% of Tuscany and 1.8% of national average.

France is the first European fashion market country for net sales and turnover because in France are located big fashion groups (LVMH which is the biggest fashion group in Europe with about forty-seven billion of sales), the same time France has low level of production. Italy is exactly the other way around: there are not big fashion groups but high production companies[28]), in fact Italy comes out as the biggest producer in Europe (followed by France and Germany[26]. About export Italy is the leader with twelve billion of export, about 34% of all Europe[27].

5.2 INTERNAL ENVIRONMENT

The fashion market is characterized of a highly checkered demand which brings to a diversified range of product. Brands (*Goretti S.r.l.*'s clients) have difficulties in determine customer will therefore a creative job is needed. Then brands produce lots of samples ordered to cluster of suppliers. Suppliers cannot or can hardly predict in advance what requests brands will do within few days. This mean managing difficulties in planning the production or the humane resource needed in mid-long term. For suppliers these conditions mean having ability to highly diversify the production both in terms of production process (physical product path) and in terms of raw materials and machining. Another important factor that influence the planning difficulties and forecasting process is the level of craftsmanship. Due to the high number of variables, forecasting process (for cost or product flow) is difficult.

5.3 DESIGN OF EXPERIMENT

Goretti S.r.l. is willing to create a system to become aware of production time of orders also to overcome difficulties in estimating cost to client. The solution was identified by management in the time relief carried out by operators during the machining phase of an order. This method led to estimation that shift during the production process due to variables difficult to predict.

To create a robust method, with the management it has been chosen as technological benchmark the automatic seam machine: *Rodella* on which operate during the thesis period. The methods that can be used to create a forecasting model fall inside two groups: generative model and variational model (which, in this specific case, can be empirical model).

- Generative model: equivalent length model. An equivalent number of stitches in a linear path is substituted to any variation from a linear sequence of stitches. In this way the model will create an equivalent number of stitches to the one of the real path covered by the the machine. Because of equivalent number (linear) distribution the time will be given dividing the number of stitches over the stitches per minute (PPM) obtained the minutes of the machining time. There is the need of developing a software to embrace the machine software and the technical software. In both case the information included are not enough. The last important aspect to be analysed concerning the software is the cost and therefore an economic evaluation of the investment.
- Variational models: empirical models. They forecast the machining time by the evaluation of historic data storage and these data it is possible to define indexes which will act as drivers to forecast machining time. Two different condition bring to two different empirical model: with existing data storage and without.
    - In this case there is already a data storage, it is enough the analysis of the data collected, but this method is not viable: methodologies used until now in the company to collect data do not bring relieved time homogeneous with respect to the determination methodology.
    - In the case in which the historic data storage is absent there is the need of creating it.

The model selected is a variational model: empirical model without data storage. The acticity of collecting data must be carried out in a standard and well known way to maintain the statistical validity of data. It exists different technics to collect time data, the most famous are *chronotechnical technique* and t*able technique.*

- *Cronothecnical technique* is based on the relieve of times by analyst with a chronometer. Time relived are then weighted (*Normal time)* with an operator efficiency value called *pitch;* this value can be determined through two methods: *Bedaux* or *levelling.*
    - The *Bedaux method* an efficiency scale is created with a minimum value, a *normal* value and a maximum value.
    - In the *levelling cronothecnical technique* the analyst will relieve only the time but not the efficiency. It will be evaluated at the end of the relief using some specific tables.
- *Table technique* is also called *Methods-Time Measurement (MTM).* The analyst obtains directly a weighted time (*Normal time*) based on tabled value without defining the *pitch* neither relieving time.

To collect data the method chosen is the *Bedaux cronothecnical technique.* The technique has been preferred to the levelling technique because the initial process of studying the machine helped evaluating a wide range of different production type: samples, orders, trials and production, so the analyst learned a heterogeneous spectrum of operator's speeds and efficiencies that allowed a calibration of *Bedaux*. Therefore the analyst proceeded in: defining the sub-phases of machining process and their cyclicity, then defining the add-ons and finally data relief (time and *pitch*) and an analysis of the database created.

5.4 RESULT AND DISCUSSION

All the sub-phases created in order to relieve time can be classified in three classes with model creation purpose:

1. Data deficit sub-phases: these sub-phases cannot be analysed neither a model can be created because the lack of data do not allow to recognize a pattern in data;
2. Independent data sub-phases: sub-phases with a time not depending on the characteristic of the product, then the time of this tasks can be compared with the same data relieved for other reliefs;
3. Model needed sub-phases: the time required to accomplish the sub-phases strongly depend on the characteristics of the product and therefore a specific study is needed.

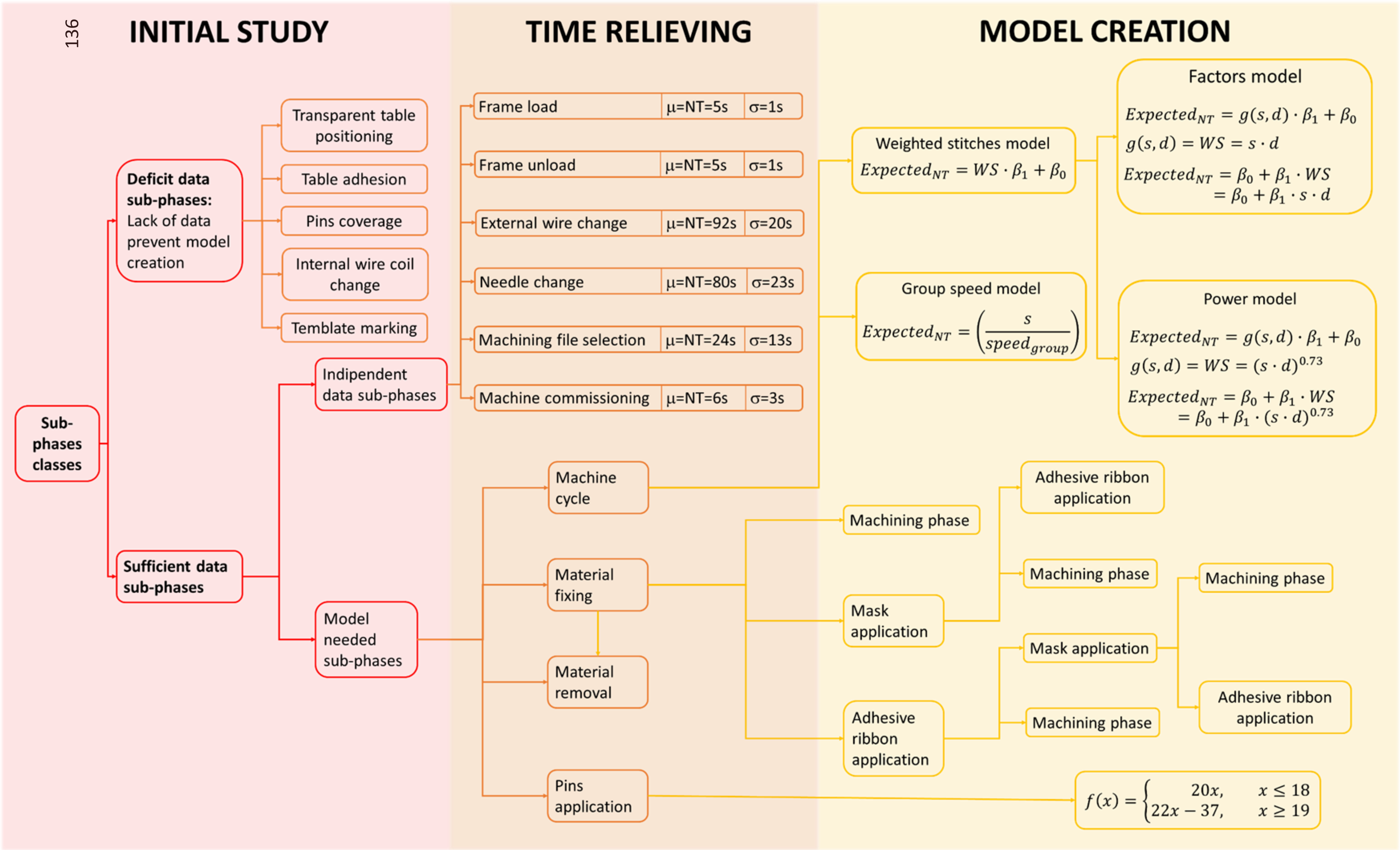
To facilitate the understanding of the sub-phases classification and the model created, a schematic sum-up is reported in the next page. Here the legend:

- Red line indicates sub-phases classes;
- Orange line indicates sub-phases;
- Yellow line indicate models.

About *independent data sub-phases*, aside each one is reported the average value (μ) and the standard deviation (σ).

All the subphases, reliefs and models will be explained singularly but to have an easy read of the models' sum-up here a brief legend of symbols:

- $Expected_{NT}$ is the expected normal time, output of the model;
- WS is the *weighted stitches* used as auxiliary variable;
- β_i are regressors;
- s is the number of stitches;
- d is the *difficulty index* which is used as weight for the number of stitches;
- $speed_{group}$ is the average speed of a products group;
- x is the number of pins.


INITIAL STUDY
TIME RELIEVING
MODEL CREATION
Sub-phases classes
Deficit data sub-phases: Lack of data prevent model creation
Transparent table positioning
Table adhesion
Pins coverage
Internal wire coil change
Temblate marking
Sufficient data sub-phases
Indipendent data sub-phases
Model needed sub-phases
Frame load | μ=NT=5s | σ=1s
Frame unload | μ=NT=5s | σ=1s
External wire change | μ=NT=92s | σ=20s
Needle change | μ=NT=80s | σ=23s
Machining file selection | μ=NT=24s | σ=13s
Machine commissioning | μ=NT=6s | σ=3s
Machine cycle
Material fixing
Material removal
Pins application
Weighted stitches model
$Expected_{NT} = WS \cdot \beta_1 + \beta_0$
Group speed model
$Expected_{NT} = \left(\frac{s}{speed_{group}}\right)$
Factors model
$Expected_{NT} = g(s,d) \cdot \beta_1 + \beta_0$
$g(s,d) = WS = s \cdot d$
$Expected_{NT} = \beta_0 + \beta_1 \cdot WS = \beta_0 + \beta_1 \cdot s \cdot d$
Power model
$Expected_{NT} = g(s,d) \cdot \beta_1 + \beta_0$
$g(s,d) = WS = (s \cdot d)^{0.73}$
$Expected_{NT} = \beta_0 + \beta_1 \cdot WS = \beta_0 + \beta_1 \cdot (s \cdot d)^{0.73}$
Machining phase
Mask application
Adhesive ribbon application
Adhesive ribbon application
Machining phase
Mask application
Machining phase
Machining phase
Adhesive ribbon application
$f(x) = \begin{cases} 20x, & x \leq 18 \\ 22x - 37, & x \geq 19 \end{cases}$

About the machine cycle models they were constructed so that the *expected normal time* ($Expected_{NT}$) would be the dependent variable and so the output of the model. Then two different classes of model were created with different logic framework:

- Group speed model: the products are divided for geometry similarity in eight groups based on the presence/absence of: angles and fillets, curves and straight lines. For each group it is evaluated the average speed. It is hypnotised that future products of each group will have the average speed of the group because of similar geometry.
- Weighted stitches model: the model is constructed as a linear proportionality between a value of weighted stitches (WS) and expected *normal time*. The weighted stitches are evaluated as a processing of the real number of stitches and the *difficulty index* which was created in order to evaluate the machining difficulty level. Depending on the kind of processing of stitches and *difficulty index* to evaluate the weighted stitches, two models were created:
    - Factors model: in this model the weighted stitches are evaluated as the product of stitches number and *difficulty index*, then the weighted stitches obtained are introduced in the linear proportionality. Together with regressors found out with trend curve for *WS* and *normal time*, the model is created.
    - Power model: in this model the weighted stitches are evaluated as a power of the product between stitches number and *difficulty index*, then the weighted stitches obtained are introduced in the linear proportionality. Together with regressors found out with trend curve for *WS* and *normal time*, the model is created.

Then it is necessary to collect all models together in order to have a total model to forecast the working station procedures duration. Because orders and production are different phases of a product lifetime, different approach will be used for orders and production in fact the need of monitoring is opposed and there are the presence of hidden times in one phase and not the other. Then now both phases will be analysed singularly. In Table V.1 it is reported the list of task with a chronological order and all the information concerning the models (if it exists) created.

Table V.1 The sub-phases and relative time for the benchmark.

N.	Sub-phases	Cyclical/ Acyclical	Number of repeated step	Forecasted time	
				Assigned time [sec]	Normal time [sec]
1	Pins application	A	2		$\text{Expected}_{\text{NT}} = \begin{cases} 20s, & s \leq 18 \\ 22s - 37, & s \geq 19 \end{cases}$ With *s* the number of stitches
2	Transparent table positioning	A	2	N.A.	
3	Tables adhesion	A	2	N.A.	
4	Pins coverage	A	2	N.A.	
5	External wire change	A	1	99	
6	Needle change	A	1	86	
7	Internal wire coil change	A	1	N.A.	
8	Machining file selection	A	0	26	
9	Material fixing	C	1	N.A.	
10	Machine commissioning	C	1	7	
11	Machine cycle	C	1		$\text{Expected}_{\text{NT}} = \left(\frac{s}{\text{speed}_{\text{group}}}\right)$ or $\text{Expected}_{\text{NT}} = \text{WS} \cdot \beta_1 + \beta_0$
12	Frame load	C	1	6	
13	Frame unload	C	1	6	
13	Material removal	C	1	N.A.	
14	Template marking	A	2	N.A.	

5.4.1 FINAL ORDER MODEL

An order usually require small amount of product, as one, two or at least three product, then the table produced during this phase is one in order to produce one product a time. Furthermore during the orders there is an high need of monitoring, to control if the machining proceed as it should and if there are issues. Monitoring the activity helps the operator to know where the problems raise and generally also why. Then there is no toom for hidden times. Then the operation must be added in chronological order one after the other. This brings to low saturation of operator and low machine saturation. Converting *normal time* obtained by the models and summing together all the time it is possible to define the total assigned time and the total standard time for accounting scopes. In this way all sub-phases concerning machine set-up are considered: in fact usually when a new product is ordered the wires are changed and usually the needle too.

5.4.2 FINAL PRODUCTION MODEL

The production phases consider from a hundred to some thousands units produced. In this phase the monitoring is not strictly needed as during the order phase and furthermore there are cyclical sub-phases which can be overlapped and the creating hidden times, increasing machine and operator saturation. The duration depends on the number of tables created to sustain the production. In most cases two pairs of tables is enough to reach reasonable level of saturation and therefore the model is constructed based on this hypothesis. An analysis is needed to better understand some procedure: machining file selection sub-phase will never be carried out because during production, as already highlighted, the file selection is done through a bar-code positioned on the parts; the acyclic operation regarding tasks with tables will be repeated twice because of the hypothesis of two pairs of tables. All cyclical sub-phases can occur during the machining sub-phase. Therefore, the cycle time can be evaluated as the table below shows (Table V.2).

Table V.2 It represents the tasks distribution in a cycle.

Time

Sub-phases for product A	Time	Sub-phases for product B	Time
9. Material fixing		11. Machine cycle	
		12. Frame shift	
13. Frame load			
10. Machine commisioning			
11. Machine cycle		13. Material removal	
		9. Material fixing	
12. Frame shift			
		13. Frame load	
		10. Machine commisioning	
14. Material removal		11. Machine cycle	

It is easy to understand that the cycle time will be the sum of the duration of the subphases of: material fixing, frame unload, machine commissioning, machine cycle, frame load and material removal. This cycle time will be repeated for every couple of products: is two products each cycle using two pairs of table. To this time which depends on the commissioned production, it must be added the time of the sub-phases: pins application, transparent table positioning, tables adhesion, pins coverage, external wire change, needle change, internal wire coil change and template marking.

5.5 MACHINE TUNING

After the construction the data storage, the analysis of the statistical evaluation and the construction of the model, it is needed the verification of the model, then it is required if the model is really able to forecast the time duration of the *Rodella* phase and therefore can be used by the company.

Some issues prevent the analyst to carry out the verification process which is anyway described in order to leave the possibility to the company to carry out the verification by itself. In fact during the last period of the thesis project, due to covid-19 pandemic and to production condition the analyst was not able to start the verification procedure. The machine was busy for a production and in order to start the verification there was the need of machining benchmarks which therefore could not be accomplished.

The procedure the analyst is willing to adopt consists in relieving different machining time, multiple time, and compare the time relieved with the times forecasted by the three models. The reliefs should be carried out on a number of products to interpolate the solution. In fact in the case in which the models created are not able to predict the machining time, thanks to the interpolation, it will be possible or to create a new model or to calibrate the existing ones. The number of reliefs for each product should be the minimum possible to eliminate the random component of the mistake.

Then what is suggested is to use from a minimum of six to a maximum of ten benchmark products on which carry out the relieving activity, and for each product a minimum of five reliefs. The product benchmarks must be at least six. More reliefs must be carried out on each product because each relief is characterized by a shift with respect to real value composed by two components: a random and a systematic component. In order to reduce the random component it is needed to carry out more relief and then use the average value. After the reliefs for each product have been done, during which all data that will be used to extract results from models have been collected, the time relieved and forecasted will be drawn in graph *forecasted time vs relieved time*. The pattern of the points cloud in this graph could be different, here are summed up the principal conditions, if the pattern is different from these exposed, the meaning of the pattern can be determined by interpolating the meaning of other distributions.

5.6 COMMENTS AND SUGGESTIONS

During the period spent in the company, some inefficiencies have been relieved from the production management point of view. In fact the analyst being close to operators was able to detect the difficulties that brought the operators to fail working procedures or fail the procedures to relieve their time (method currently adopted by the company to relieve time).

The first problem detected was inconsistency between the working cycle indicated by the technician office and the real working cycle. This brings lack of confidence from the operator point of view on the procedure communicated. In fact the company has a tailored management system that allow: to communicate to operators the task to accomplish in each machining center, to relieve time, to communicate issues or notes and to control the state of the order. The system notifies to each working station the work that it must accomplish. It means that even if an operator does know if the product will return on his/her specific working station because of experience, he/she does not know if the technician office insert the second passage (in the same working station) inside the management system. This because sometimes the technician office lack in inserting the correct procedure and because the operator does not trust completely what communicated. The consequence is that the operator works in the way he/she thinks is the best but providing drop-down other issues, for example in the relief of time or in the monitoring of production phase accomplished.

Any condition of the above reported will cause mistrust of operators in technician office and vice versa. In order to solve this issue it is suggested the definition of a company policy concerning the way of inserting working cycle in the management software and it is suggested to implement further information about the working cycle in the operator's terminal. Finally it is suggested to adopt a standard mechanism of reporting issues between employees and management through pre-compiled sheet left in specific spot of the plant where the operator can indicate the class of problem (e.g.: management software, working cycle, machine, communications…). Then the management should individuate a figure of the company aimed to analyse and propose solution for the specific issue class.

Another problem detected is the absence of routines in the machine studied. In fact the procedure followed by the operator does not have a strict order. Instead if a precise procedure is agreed between the management and the operator to be followed every time, the procedure will be standardized and the operator will create a routine therefore the efficiency accomplishing the tasks will increase.

A last detected issue is the absence of systematic procedure to accomplish task. It often happens that operators do not have praxis to solve issues occurred in production line, and because of this operators often decide by themselves how to operate. Working out by themselves, the operators, may solve the issues but they may also solve only the specific issues while they create other issues (for other steps of production line or for the technician office). It is suggested to create a specific procedure to follow when an issue is relieved in each area and which may include communication with the responsible for the product. When the solution is found, it is suggested to create a methodology based on the solution method found for every similar issues.

FIGURES INDEX

TABLE INDEX

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In first position, my rapporteur Engineer Professor Iuliano, without which it would not be possible for me to fulfil this inspiring project.

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To conclude this elaborate and in first place in my heart, a huge thank to my family. To them, a piece of my mind.