POLITECNICO DI TORINO

Master of Science in Automotive Engineering

Master Degree Thesis

Application of the Lean Manufacturing Method in VRM Assembly Plant

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APPLICATION OF THE LEAN MANUFACTURING METHOD IN VRM ASSEMBLY PLANT

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INTRODUCTION

Nowadays Italian automotive industry is changing.

Under the pressure of the continue economic development of largest countries in the world, the competition to Italy is steadily increasing. For this reason, it is necessary to develop a solid and robust new industrial system able to compete against the global industrial powers. In the last years in Italy an industrial system of high precision and quality has been developing, instead of a mass production system. Thus, the automotive area is specializing in niche products.

Italian industries, born from little craft factories, are struggling to integrate in the international trade, even if their products have high machining quality.

These industries do not produce for mass production, instead are able to produce the best goods found in the world, hence are very requested. As a consequence, the production in the Italian automotive industry is changing its system, adopting the Lean Manufacturing way. The family business, such as Italian companies founded on the decisions of father and son, turn their old views into a new global one. The question however is why does the Italian automotive industry try to implement the Lean Manufacturing based on the Toyota production system?

Even if the answer could be simply to improve the production and the cash flow, in this thesis I will try to explain in detail the improvements that an automotive industry may gain by gradually adopting the Lean Manufacturing.

The example which I take into account to generate this thesis is the study of the assembly department of the Italian VRM SpA industry.

The project will deal with the main problems and obstacles that the assembly department has to fight to reach the complete layout of the Lean Manufacturing. It starts with a global presentation of the factory with a detailed description of the assembly, then it moves to production planning and to the working lines and stations. The study continues with the analysis of the quality of the product and the working quality. Taking into account efficiency and ergonomics, the working performance of the plant can be deduced.

Principal aim of the thesis is to understand the main benefits of applying Lean Manufacturing to the assembly department, in particular the improvements in the production amount and timing.

The final part will evaluate the income statement. An examination will be conducted on the profit from the finished products and if it overcomes the direct costs of the VRM assembly department. This expresses if the Lean Manufacturing is successful inside the plant, and if it can be implemented in the future. This is very important because the current industrial reality is based on the constant decrease of the production timing and on the increase, as much as possible, of the finished products.

Thanks to the help of the Lean Manufacturing theory, the variability, lead time and waste can be reduced.

GOALS OF THE THESIS

An overview of this thesis is necessary to better understand which will be the final goal.
This experimental thesis is based on the application of the Lean Manufacturing method in the VRM assembly plant.
First of all, it is necessary to understand what the VRM reality is, then the Lean Manufacturing theory will be introduced.
Chapter three will discuss the method to deal with the products cycle times timing and with the calculation of the number workers required to respect the production deadlines. These concepts are fundamental for the final conclusions. Indeed, thanks to the cycle times timing and to the number of resources in the assembly department, it will be possible to calculate the production amount and the cost of the required human resources. Equally, thanks to the product sales, it will be possible to calculate the income.
Chapter four and five will consider the product and production quality. An in depth analysis will be conducted on the improvement of the quality, safety, maintenance of the assembly plant and production organization, following the Lean rules found in the literature theory. Therefore, the main final goal is to demonstrate that the continuous application of the Lean Manufacturing system will allow for an increment in the assembly plant revenue, profits and a decrease in costs.
More in general, the aim of this thesis is to observe if the income statement will be positive or negative. In conclusion, it will be possible to deduce if the Lean Manufacturing policy, introduced in the VRM assembly plant, will produce benefits or losses for the company.

CHAPTER 1: GENERAL CONTENTS

1.1 THE VRM SpA COMPANY

VRM SpA is a solid and qualified company situated in the south of Bologna, in the centre of the Emilia Romagna motor valley.

VRM was born in 2004 as an industrial reality specialized in motorcycles. It has been continuously increasing thanks to its enormous competences in:

- Design, building and realization of prototypes;
- Design and realization of processing equipment;
- High precision machining of aluminium, steel and magnesium components;
- Supplying of assembled or preassembled components;
- Tightness tests.

From 2015 VRM bought the Marzocchi plant, granting the company the ability to build a motorcycle from the engine to the chassis and suspensions. Today the VRM's main costumer is Ducati, with VRM's plants producing about ninety percent of the global production components of Ducati. VRM counts 20.000 sqm of production area, divided in seven different plants with various production aims. At its maximum production capacity it counts 600 employees and is able to have a daily plant potentiality production of 280 motorcycles.

The industrial reality of VRM is famous in the world for its high quality and precision of manufacture, thanks to its cutting-edge automated technologies.

Figure 1.1: Main entrance of VRM SpA

1.2 THE VRM ASSEMBLY DEPARTMENT

Having described the seven departments of the plant's division, this part will focus on the assembly department.

The assembly department extends over a space of 5.000 sqm, counting 45 workstations. The workstations are divided in subgroups and they function as small working lines, where workers always have a job to perform and can turn if a location has to be saturated (this last topic will be discussed further in the next chapters).

Each of the 45 workstations has a fundamental activity, which is a part of the entire construction of a motorcycle. All the components are assembled as preassembled units; in this way the complete fabrication of a Ducati motorcycle is guaranteed. The final assembly is done in the Ducati plants in Borgo Panigale, near VRM factory.

It is important to examine in detail the production which happens in the 45 working units: for this purpose, map no.1describes the assembly division.

The information about the assembly department was collected first hand during a period spent in the company, taking notes about each single component produced, studying the differences in term of quality, characteristics and codes of the final products and asking specific information about the task performed in the working area.

In the tables below the number of workstations, the product types and its motorcycles associated are illustrated.

In the following only some workstation tables are illustrated. The others can be found in the Appendix A.

All the data are taken in the workplace.

	WORKSTATION NUMBER 1
DUCATI MULTISTRADA	STGR SWINGARM 1504

	WORKSTATION NUMBER 2
DUCATI PANIGALE V4	CLUTCH COVER 1308R
DUCATI HYPERMOTARD	STGR SWINGARM 1509

	WORKSTATION NUMBER 3
DUCATI PANIGALE V4	STGR REAR SWINGARM 1409

	WORKSTATION NUMBER 4
DUCATI PANIGALE V2	SWINGARM

DUCATI SCRAMBLER DS	SWINGARM 1501

Tables 1.1, 1.2, 1.3, 1.4: Assembled components in the workstations

Figure 1.2: A part of the VRM assembly plant. Some numbered workstations can be noticed

1.3 LEAN MANUFACTURING APPLICATION TO VRM ASSEMBLY PLANT

In the tables above the set-up of the working stations is defined.

In the assembly department the synchronization between selected working locations is very important, as well as the nearness between them.

Synchronization and nearness can guarantee the turn of the workers and the completion of components that require more assembly time and the job of more workstations. What described until now is part of the main topic of this thesis and the application the Lean Manufacturing has the purpose to allow continuous improvement of the activities, enhancement of the quality and of the relationship between working locations, aiming at guaranteeing a final profit.

The assembly department's setting, divided in 45 locations, helps to cut time waste and mostly the material waste. The significant amount of components the department has to consider creates the additional danger of the variability, however the adoption of Lean Manufacturing theory can help carefully monitor this problem.

It is important to apply the principles of Lean Manufacturing in order for the plant to reach its objectives and targeted improvements. The most known Lean instrument is called 5s and must be applied it in the correct way.
These programmes will be mentioned throughout the thesis, applied to different working situations and plant areas.
In the next paragraph the general theory behind the 5s will be explained.

1.4 LEAN MANUFACTURING 5s

The 5s are the main and fundamental principles of Lean Manufacturing.
The 5s must not be imposed by the main directors but should be seen as a collective task, that all the factory workers adopt in order to collectively reach the task improvements.
A list follows:

1. SEIRI (to sort);
2. SEITON (to simplify);
3. SEISO (to scan);
4. SEIJETSU (to standardize);
5. SHITSUKE (to sustain);

Starting by considering the first "Sort", it is important to discard what not used and not necessary. A decision which items can be kept in the workstation must be reached, basing such decision on the criteria of what is used every week, what is necessary to answer in the quickest way to important requests of the customer and finally what is necessary for health and safety. Less frequently used items are, on the other hand, kept on the shelf units or in the buffers [1].
The second principle "Simplify" underlines the need to position the objects in the best place and such a place maintained. Repeated positioning of the items with standard frequency helps to avoid error consequences [2].
The third principle is "Scan". This aims at describing the best method to complete the task. If the work performed produces good results, the procedures should continue to be implemented. This includes keeping the workstation tidy, noticing if something is not in the right place and correcting immediately any error. The Scan Method consists in applying the methodology as a routine where methodology is the cleaning, and cleaning equals to checking. If the worker performs the verification at least five minutes a week, he/she will have a tidier workstation and decrease the

probability of committing a mistake. Scan is also calibration, observation, monitoring, looking for waste, lubrication, dusting, and routine service [3].

The fourth principle is “Standardize”, i.e. the adoption of standard procedures. Standard procedures and standard safety are very important applications of Lean Manufacturing because they have to be applied to the first three principles and to be maintained. Standardized work looks at creating repeatable, reliable and capable processes and procedures, base of the continuous improvement [4]. In fact, Standard work means always repeating the same activity, in order to reduce errors, speed up the production, reduce time waste and component waste thanks to the decrease of variability. Standard work is not static, in fact when a better procedure is found, it can be adopted and developed.

Resuming Standard work must be seen as a job routine and it includes not only the pure work but also measurement, registration, training and working balance. Standard safety is also fundamental because stabilizing and ensuring some standard acts or procedures can avoid serious safety issues in the work-place [5].

Finally, the last principle is “Sustain”. All people take part in the 5s of the Lean theory with constant dedication. Sustain means pushing the participation and improvement in order for the other 5s activities to become a routine. This may be obtained through verification and cleaning. It can be helped with the use of blackboards where the week targets are written and/or with frequent meetings where the managers observe directly and closely the production lines [6].

It is fundamental to underline that the Lean Manufacturing theory, as defined until now, has to be applied in the Italian industrial reality as VRM SpA with consistency in the long run. Short time economic profits should not be pushed, but achieved with patience. An important error that must be avoided when implementing Lean Manufacturing is reducing the number employees, and the cutting of resources in terms of investments, research and development.

Finally, the Lean theory has to be supported by all the members of staff and need to be seen as an opportunity for personal growth [7].

References:

[1] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.84.

[2] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.84-85.

[3] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.85.

[4] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.85.

[5] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.90-93.

[6] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.85-86.

[7] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, cap.2.

CHAPTER 2: VRM ASSEMBLY DEPARTMENT PLANNING

2.1 VRM PRODUCTION PLANNING

Here the production planning in VRM's assembly department will be introduced.
In the past years the company has followed strict and old production rules, not adequate anymore as currently outdated for modern industrials settings.
Therefore, the considerations that emerge from this thesis should be applied to the researched company, in order to keep it in line with the current requirements.
The application of Lean Manufacturing requires thus some considerations: this new industrial approach can upset the normal production system but has to be applied until the optimal results, in terms of resource economy, workers' efforts and revenue increase are obtained. The purpose of this thesis is therefore to analyze the current production system and try to modernize it with the aid of the Lean theory and principles. This requires several hours of study of the assembly department planning and the analysis of ways to introduce and implement changes.
In the next paragraphs the assembly system is examining, considering how the new Lean Manufacturing devices are inserted in the plant.

2.2 VRM ASSEMBLY ORGANIZATION

The assembly department is organized in 45 workstations with different tasks and stage potential, as mentioned in the previous chapter. The assembly production is based on the assembly to order method, where the order is made by Ducati. This is the core of the production strategy of VRM.
In fact Ducati imposes a certain daily production quantity, which varies each day because production is seasonal. The most productive period is from March to June. In the following pages some tables with the production quantity of finished motorbikes will be presented.
It is important to underline that the VRM assembly department does not produce finished motorcycles, but it assemblies most of the components that Ducati needs for the final assembly in the Ducati plant itself, from which the actual finished motorcycle will leave. Hence VRM is Ducati's main supplier and has to match perfectly the time of Ducati's assembly line. The following tables derive from an in depth study of Ducati's requests and of the production capacity of VRM. The numbers indicated are the results of long discussions between the supplier and customer. These numbers may be improved by the constant application of Lean Theory.

In the tables below the expected daily production number for each month of the year 2019 are shown.

Following only the most significant monthly production tables are provided, the remaining can be found in Appendix B.

Figure 2.1: VRM assembly plant production planning

	JANUARY 2019																		
DAY	**7**	**8**	**9**	**10**	**11**	**14**	**15**	**16**	**17**	**18**	**21**	**22**	**23**	**24**	**25**	**28**	**29**	**30**	**31**
DUCATI PANIGALE V2	0	0	0	0	0	5	11	11	11	11	11	11	21	21	21	21	21	21	21
DUCATI PANIGALE V4	11	11	11	11	11	21	21	21	21	21	21	21	21	21	21	21	21	21	21
DUCATI MONSTER	20	20	20	20	20	20	20	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI MONSTER 797	0	0	0	0	0	0	0	0	0	0	5	10	10	10	10	10	10	10	10
DUCATI MULTISTRADA	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
DUCATI HYPERMOTARD	21	21	21	21	21	21	21	21	21	21	21	21	21	32	32	32	32	32	32
DUCATI DIAVEL	0	0	0	0	0	0	0	0	3	0	2	3	10	10	10	10	10	10	10
DUCATI X DIAVEL	0	5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI SCRAMBLER 800-400	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI SCRAMBLER 1100	10	10	10	20	20	20	20	20	20	20	0	0	0	0	0	0	0	0	0
DUCATI SUPERSPOR	0	0	0	0	0	0	0	5	10	10	10	10	10	10	10	10	10	10	10

T																			
TOTAL	122	127	132	142	142	157	163	150	156	173	184	184	184	184	184	184	184	184	184

	MAY 2019																					
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
DUCATI PANIGALE V2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DUCATI PANIGALE V4	22	22	32	32	32	32	32	32	32	32	32	32	32	32	32	32	21	21	21	21	21	21
DUCATI MONSTER	30	30	30	40	40	40	40	40	40	40	40	40	40	30	30	30	30	30	30	30	30	30
DUCATI MONSTER 797	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI MULTISTRADA	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
DUCATI HYPERMOTARD	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	11	11	11	11	11
DUCATI DIAVEL	20	30	30	30	30	30	30	30	30	30	30	30	30	20	20	20	20	20	20	20	20	20
DUCATI X DIAVEL	0	0	0	0	0	0	0	0	0	0	0	0	0	5	10	10	10	10	10	10	10	10
DUCATI SCRAMBLER 800-400	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
DUCATI SCRAMBLER 1100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI SUPERSPORT	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20	20	20	20	20
TOTAL	223	233	243	253	253	253	253	253	253	253	253	253	253	238	243	243	232	232	232	232	232	232

Tables 2.1, 2.2: January and May production quantities

As it can be noticed from the tables above, the total number of finished motorcycles is different per day as is the number of finished motorcycles for each Ducati model. This can be explained because before the start of the year, a special calendar regarding the expected orders is made, and because the production is planned in order to obtain maximum efficiency with no waste of time.

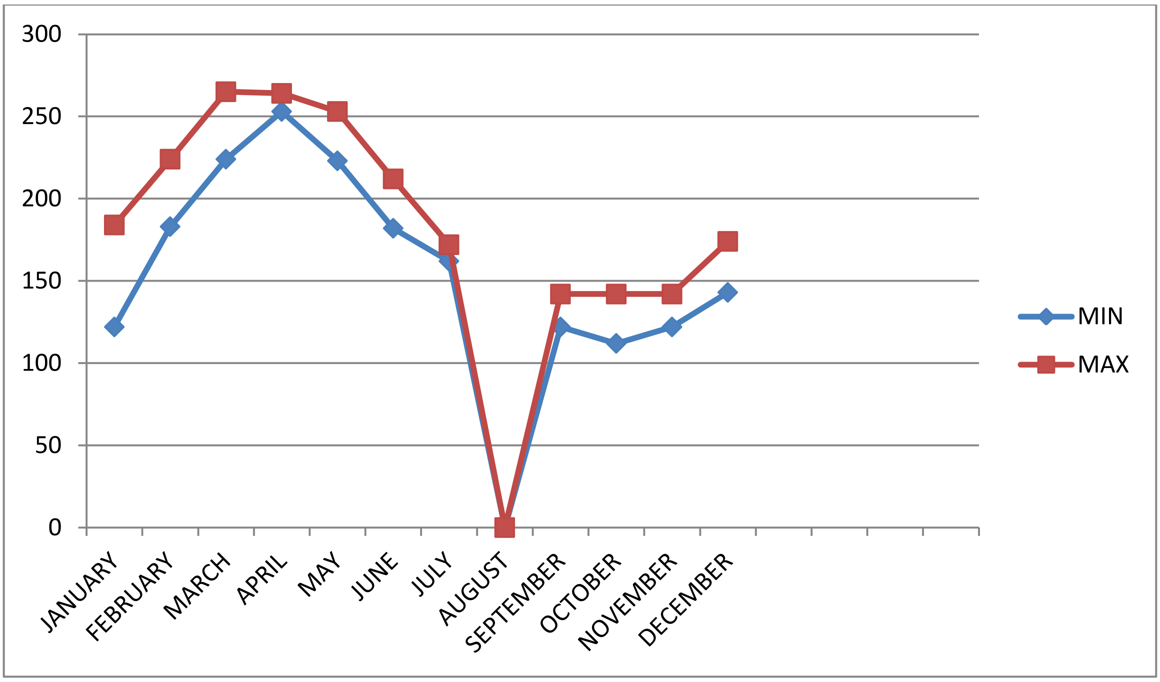
These production numbers are guaranteed by the production capability of the assembly plant, thanks to a good industrial organization which is developing towards the Lean one.

It is very important for VRM to respect these production numbers in order to avoid costly penalties. Another thing to take into account is that during the months of intense production such as January, February, March, April, May and June, the workers are employed nine hours per day instead of eight, hence the number of finished products could increase, but only if Ducati requires an increased

production. Furthermore, these hours should be considered also in terms of efficiency and of the problems that may occur during the process. These nine hours of work are, however, necessary to guarantee flexibility to the plant.
Such flexibility helps VRM to be prepared to seasonal peaks of production. In this way, the 45 workstations although undersized from the point of view of resources, avoid waste and the company manages to saturate the seasonal production without problems.
The final detail to highlight is that each month could have an addition of production, because the customer requires extra components for new finished motorcycles, not foreseen in the calendar provided at the begin of the year. Therefore, VRM has to try to satisfy the such production requests. It can be noticed that, in the months of September, October and November, there are some days where the assembly department does not work, hence it does not produce. Moreover it can be noticed that August does not appear in the previous tables, because of the summer holidays. The reason of this choice is the low production request in that part of the year; making these months less productive.
Thereafter the plant decides to not produce on certain days rather than decrease a lot the job. In this way there is not a drastic production decline in this period, hence the number of employees does not need to be reduced significantly. These results have been achieved thanks to the planning of the assembly department.
The following graph represents the previous production tables. In the graph two lines are visible: one for the maximum and one for the minimum daily production for each considered month. In this way it is possible to broadly see the trend of the year's production quantity, for the minimum and maximum production capability. To size the assembly department it is necessary to take the average of these quantities, thus it is possible to avoid wasting resources or avoid the lack of resources. This is what was previously defined as flexibility.
It is important to say that the inserted data are definitive until June; due to the timing of this thesis. The following months, instead, regard the expected production quantity. It should be noted that the trend in the graph explains the sum of the maximum and minimum daily production quantity for every single month, regarding the total amount of produced motorbikes. If each motorbike model were to be considered, the graph would be complicated, because the finished number of components for each motorbike model changes daily; as shown in the previous tables.
Another important aspect is the management of the employees. In fact, to guarantee a continuous levels of production, training is necessary. This is particularly important because, the VRM production requests are seasonal; therefore new staff must be recruited when the production

requirements increase. It should be noted that a minimum of five days production anticipation has been imposed.

The production trend shown in the graph is anticipated for five days. This allows to recruit new workers, guaranteeing the necessary time for training. In this way the assembly plant is not unprepared for the following production rise. This system may initially bring to a sudden increase in costs, but will produce benefits in the long period. The method can be seen as a successful application of the 5s of the Lean Manufacturing Theory.



Graph 2.1:Maximum and minimum daily production for each month of 2019

Next, how the assembly plant is able to guarantee this amount of finished components will be explained in depth.

These results are obtained with the Lean Manufacturing approach throughout the 45 workstations. One of the main tasks of the Lean Theory is taking all what is stationary and transforming it into running and busy. Its application is built by commuting the assembly plant in a continuous production unit. This happens thanks to the creation of subgroups inside the 45 workstations, in order for each of them to produce a specific component for a single motorcycle at a given time.

The creation of these subgroups has several aims, keeping all the workers engaged in the specific processing and ensuring the employees operate continuously without wasting time due to sudden, unexpected breaks. Therefore, all the workers are assigned to a specific work-place. Subgroups are

also created because, when an increase in the production of a particular model is necessary, the workstations can work in parallel, speeding up the manufacture of the same product. This type of work is also called “Production by Parts”.
The 45 workstations can be in fact defined as “little production lines” (in management organization are called “cells”). In this way it is possible to have a flow production, thus respecting the Lean Manufacturing method. This is helpful to maximize the work of each employee, moving them to another workstation when necessary. This is called “staff linearization”.
Last peculiar detail to underline is the choice of the position of a single workstation inside the assembly plant, and the choice to produce those specific components in it. This choice is motivated because each workstation has different components specific to different motorbikes models to assembly, in order to ensure that the workers never stops working. In fact, in each workstation different components have been fitted with similar processing time and the same equipment. This type of workstation organization benefits from the closeness to other workstation: the position of the workstations is based firstly on the space necessary, dictated by the size and encumbrance of the finished products, and by the components to process.
Secondly the workstations relationship of closeness is based on the workers personal job abilities. In fact the workstations location is studied according to the similar job capacities of the employees. In this way the job of the worker is simplified because he/she is more concentrated on his/her task, without losing his/her attention on jobs that are not his/her duty or not useful for the quality of the finished product. There is always the maximum utilization of the resources inside the workstation subgroups, ensuring employees constantly working on the product to assembly.
Accordingly, the time waste for tooling, i.e. the work process of changing a model component, and the movements around the department are reduced.

Figure 2.2: An example of workstations organization

Figure 2.3: The workstation number eleven

2.3 PRODUCTION PLANNING LEAN MANUFACTURING INSTRUMENTS

The next paragraphs will present some Lean Manufacturing instruments, as well as applications that lead to continuous increases of the finished product quantities and of the profits shown in the income statement.

2.3.1 SPAGHETTI DIAGRAM

Spaghetti Diagram can be utilized as a Lean instrument apt to reduce the waste of time, as previously mentioned.

Spaghetti diagram is an efficient tool, helpful for layout modelling. It traces the transportation and movements wastes. It is very easy to use, in fact it consists of drawing the product's physical flow on the plant map, and the workers displacements around the departments, which move for an equipment or for a lack of components.

This tool is very useful to design a predetermined path for material movements, and it is the principal tool for the determination of the best plant paths. The Spaghetti diagram is considered an important Lean Manufacturing method because its main objective is the analysis of the reduction of the set-up time while decreasing the number of movements. [1]

In the VRM assembly department the best application of this Lean instrument is the design of studied paths. This is made through drawing precise lines on the ground of the plant to indicate the paths to follow.

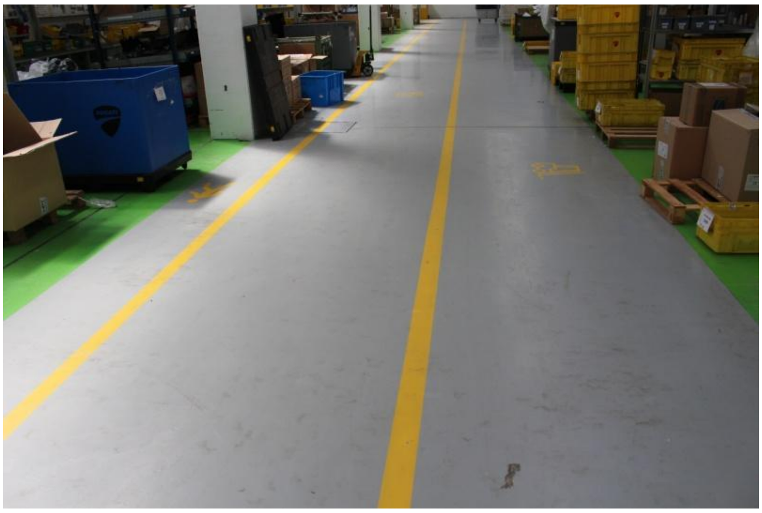


Figure 2.4: Spaghetti lines for the workers and for the material

Figure 2.5: Workers crosswalk

2.3.2 RUNNERS

In the Lean Manufacturing theory a runner is a material handler.
He/she can be also called Waterspider o Tugger. He/she has a fundamental role in a Lean system because he/she is active and repetitive, by no means monotone and stack. He/she has an important task in connecting the various parts of the assembly plant, noticing any problems in flow, and thus regularizing them.
In VRM the material handlers start and end their turn looking at the Kanban instrument, (the Kanban is explained in the next paragraph). They turn at regular intervals, visiting and stopping in the workstations. During the trip, each material handler of the assembly department delivers the

requested parts, following the instructions of the current Kanban. Then he/she comes back to the Kanban box, he/she takes a new Kanban paper, and starts the turn. Firstly, he/she follows the instructions written on the paper, secondly goes to the buffer, thirdly collects the useful parts to be processed, and finally arranges the next deliver to the workstations. It is important to underline that there are several material handlers and not all of them perform the same task. Indeed, there are some who carry out the task previously described; while, others have to pick the finished products, moving them to the delivery area, and finally they release the Kanban paper that has been fulfilled [2].

As explained in the previous paragraph, i.e. the called "Spaghetti Diagram", the material handlers' paths have to be designed correctly and carefully, avoiding time and resources waste during the transportation and the movements of the materials; doing more road of that is necessary.

Instead, it is fundamental to have fixed paths with prearranged task schedules, even if the amount to transport changes. Therefore, it is very important to balance the amount of work during the day; spreading the workload equally throughout the work hours. It is useful to have Lean Manufacturing shrewdness in this job; just like having little boxes always nearby, very helpful to keep material handlers' mean of work tidy.

Another smart action to perform is reporting the activity done with codes, dates, amounts and hours. This allows the work to be performed in a clear and tidy manner, avoiding stops caused by sudden problems or lacks of material in the buffer and in the workstations.

Figure 2.6: A material handler

2.3.3 KANBAN

Kanban is a scheduling principle, briefly it can be considered a “Make to Order” method, i.e. it needs to produce or to assembly only what is written and nothing else.

This is a Lean Manufacturing tool because its fundamental aims are: reducing variability, reducing cycle time, avoiding overproduction, encouraging a more levelled production flow, quality improvement and finally, by implementing it, it is possible to obtain cost reductions. But, before introducing the Kanban in the plant production organization, it is necessary to reduce the amplification demand, to reduce the set-up time, creating more stable manufactures through work standardization, reducing the defect rate and decreasing stops due to sudden failure [3].

Kanban is an effective method to reduce Muda, Mura and Muri. These are three Japanese terms foundation of the Lean Manufacturing thinking, introduced by Toyota. Their meaning is: waste, variability and overload. They are explained in written order. To guarantee the efficiency and foundation of the Lean theory, the Kanban main strategy is One Piece Flow. This means that it has to handle one type of component at a time.

This method is applied as follows.

The Kanban paper is classified in two main base categories: Production Kanban and Handling Kanban. Starting with Production Kanban, it is used in the VRM assembly department. Each Kanban paper acts for the workstations which have similar functions; i.e. where there are the same products to assembly or the same time cycle. Indeed the Production Kanban represents the authorization to start a work cycle, which can consist in the assembly of one piece or the production of an entire components case. The Kanban paper is released from the supply station indicating when a product is requested to assembly. Without authorization there is no production. Some tricks are helpful to better adapt the Kanban method inside the assembly department, such as having a buffer, (as it will be explained in the next paragraph). In this way efficient handlings, time and having materials near the workstations can be possible.

Other aspects, not less important, are having at least one or more parts useful for the next assembly in the appropriate location. They are positioned on the shelves of the workstations, in order to maintain the principles of tidiness and cleanness. In this way the set-up and handling time are reduced.

Very important are the additional Kanban, i.e. additional papers that help a further variation of an increase in production. As said before, there can be months where the production request increases in comparison to what agreed upon at the beginning of the year. Therefore, the additional Kanban satisfies the increase of seasonal demand [4].

The Handling Kanban, instead, concerns the transportation of the Production Kanban papers and the material transportation inside the assembly plant. It indicates which components have to be taken and moved to/from the workstations. Their other task is to deliver the final products to the customers or to pick up the raw materials from the suppliers [5]. This task is performed by the material handlers.
Following a brief summary of the Kanban work sequence:

- The Kanban papers are released by the plant leader;
- The runner collects the Production Kanban papers from the authorization Kanban box, and delivers them to the workstations;
- The material handlers take the pieces necessary for assembly from the buffer and deliver them to the workstation according to the order in the Handling Kanban instructions;
- The employees of the workstations start the process executing the Production Kanban, trying to choose the best sequencing in order to respect the assembly time;
- The amount of products to produce is determined by the lot size written in the Production Kanban, where colored writing is used to identify which components are privileged i.e., which components have to be assembled first;
- After that, the lot has been realized, the material handlers collect the boxes and deliver them to shipment area, following the Kanban. It is important to underline that the boxes have to be full, because if one travels half-empty, it is a waste of time and resources;
- The process repeats [6].

Finally, it is important to draw up some Kanban rules.
These rules perfectly follow the Lean Manufacturing theory, respecting the 5S; as it can be seen in the following points:

1. The downstream operating activities withdraw parts from the upstream operations;
2. The exact quantity indicated on the Kanban must be done;
3. All the requests are put on the upstream operating activities through the mean of the Kanban papers;
4. Only the active parts are permitted to the workstation. Instead the components should have specific locations;
5. The production authorization is released only through the Kanban paper;
6. Each specific Kanban paper flows only between a specific couple of workstations;

7. Quality is a priority: only the perfect components are sent downstream;
8. Decreasing gradually the number of Kanban, permits to reduce the level of stocks and allows to see the problems in order for them to be identified, detecting the causes and thus removing them [7];
9. One-piece flow.

Figure 2.7: Kanban papers

Figure 2.8: Kanban papers collection area

2.3.4 BUFFER AND DELIVERY ORGANIZATION

A further important target of the Lean Manufacturing system is to make the buffer and delivery organization more Lean; that implies better efficiency and less time waste. Following, some VRM Lean approaches are explained.

First of all the buffer is a stock warehouse inside the assembly plant, where all the components and pieces necessary for the tasks inside the department considered in the thesis are placed. The importance of the buffer is to avoid excessive increase of the quantity of products inside it. Indeed, each component that will be processed has a product storage cost, and the finished product is a possible selling object that could generate cash flow.

Accordingly, the products and components that remain in the warehouse too long can become outdated. Another fact to avoid big buffer is the management of an excessive amount of codes, which can be very challenging, and require more employees and resources, wasting time.

To avoid these problems, the Lean Manufacturing approach in the VRM assembly department's buffer is to have a little warehouse, in order to make it easier to manage, with less codes and workers. By having the buffer inside the plant, the picking of the material requires less time, and the material handlers perform less movements. Therefore, the buffer is updated and filled every two days, allowing for an active and busy warehouse.

The adopted buffer Lean Manufacturing system has smart shelves units. In fact, the components loaded on the shelves are filled from behind the shelves units. Instead the components utilized in the assembly, i.e. to be processed, are picked up from the front of the shelf units. In this way the supply is easier and more efficient, because an employee occupies less time to perform this task. When he/she needs a specific component or has to load a component, he/she directly goes to the specific shelf unit marked by a specific code, does the task without wasting time, searching for the component, or having to sort the shelf units.

An important technology adapted in the VRM assembly department, in respects of the Lean Manufacturing theory, is the automated buffer.

It is utilized for small metal parts which have a numerous different codes and are very small. They are difficult to manage and can be easily lost. This automated buffer is organized in floors, in order to occupy less space in width and in length. For its working it requires only two employees. Through a computer they recall the specific codes requested in the assembly, and then the small parts exit from the automated buffer, divided little boxes. In this way the management of these small components is simplified and resources optimized.

The automated buffer may have a significant initial purchase cost, but has multiple benefits and it is well amortized.
Until now, nothing has been said about the finished products buffer. This is because there is not a relevant finished products buffer in the VRM assembly plant; hence it does not need resources. In fact, the finished products are directly delivered to the customers as it will be explained later, improving tidiness and simplification in the control of the assembly department. This respects the 5s of Lean Manufacturing.
Next step is the delivery organization, where the delivery of the finished products is also referred to as “Just in Time”. This term means: as soon as the product has been assembled, it is immediately delivered to the costumer.
In this way, waiting time is approximately eliminated as are the queues, or at least they are reduced, depending on the efficiency of the internal and external logistic.
In such a context, it is important to define the Italian acronym UDC - “unità di carico” (load unit).
This unit permits to know how much has to be produced. These units are simply a box with standard dimensions, which can always contain the same quantity of the same type of components. Knowing the amount of UDC filled every day, it is possible to organize the deliveries.
The VRM assembly plant produces more or less forty UDC per day; hence transport can be easily managed and organized. Transport is conducted by an external company, which delivers the material to be worked and collects the finished products five time per day; trying to optimize transport by being full. Moreover, the UDC transported have to be full of material, because not completely full units are a waste of resources and money. VRM also owns some smaller trucks used for little loads, emergencies and for transportations inside VRM plants.
VRM has the luck that Ducati, its main customer, is very near, only a few kilometers far. In this way the delivery organization is simpler and, in case of problems, they can be rapidly solved.
The fundamentals of the Lean Manufacturing theory are also applied here: the delivery organization with the UDCs, well organized transport and the “Just in Time” system, plus the other Lean tools previously described, ensure work standardization, tidiness and neatness in the workplace, less time waste, with a decrease in the lead time, human and financial resources, and job simplification.

Figure 2.9: Delivery organization

Figure 2.10: Buffer

Figure 2.11: Automated buffer

References:

[1] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.116-117.

[2] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.183-184.

[3] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.169.

[4] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.170-171.

[5] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.173.

[6] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.171-172.

[7] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.174.

CHAPTER 3: METHOD

In this part, further details of the assembly department will be provided, in particular assembly plant needs in terms of employees and resources will be considered. An analysis of the cycle time of each workstation and the number of workers that each of them requires in order to satisfy the production requests will be proposed.
Possible bottle necks will be considered, i.e. that is which workstation is firstly saturated. This requires a precise calculation of the work cycle time of each workstation, done with a chronometer in hand. The definition of cycle time adopted is the time necessary to completely assembly a finished component. The final time cycle results are obtained by adding the various efficiencies. In addition, the calculation of the precise number of workers per workstation is also of significant importance.
The following calculations will be executed through algorithms found in literature.

Figure 3.1: Workstation cycle times indicator

3.1 DUCATI WORK CYCLE TIMES

The work cycle times conditions are stipulated by Ducati, who requires them to be respected at any time. This is a fundamental condition placed prior to any order placed to the VRM assembly department.
VRM has, therefore, to work respecting the times fixed by Ducati in order to fulfill the daily motorcycles production quantity, and be in line in terms of costs for each components assembled. If

these requirements were not respected, VRM is liable to monetary penalties, thus would lose money. In fact, if the VRM assembly plant requires extra time to complete the work cycle, Ducati does not pay the extra costs. Hence VRM needs to apply the Lean Manufacturing method in order to reach the agreed targets, satisfying Ducati's production requests and profiting from the activity.
The following tables shows the work cycle times for each component assembled already increased in efficiency. These tables need to be compared with VRM's own work cycle times studied with the chronometer in hand. The specific requirements for maximizing efficiency will be presented in the next paragraph. All cycle times are expressed in minutes. Only some tables are reported as example to understand the procedure, seen that Ducati's own work cycle times are classified, and they cannot be presented.

	WORKSTATION NUMBER 1	CYCLE TIME
DUCATI MULTISTRADA	STGR SWINGARM 1504	7.36

	WORKSTATION NUMBER 2	CYCLE TIME
DUCATI PANIGALE V4	CLUTCH COVER 1308R	RIL
DUCATI HYPERMOTARD	STGR SWINGARM 1509	RIL

	WORKSTATION NUMBER 4	CYCLE TIME
DUCATI PANIGALE V2	SWINGARM	8.38
DUCATI SCRAMBLER DS	SWINGARM 1501	6.57

	WORSTATION NUMBER 5	CYCLE TIME
DUCATI MONSTER	SWINGARM	13.60
DUCATI SUPERSPORT	SWINGARM 1312 AUSTRALIA	15.52

Tables 3.1, 3.2, 3.3, 3.4: Ducati work cycle times

As shown in the work cycle time of each workstation, some stations that process various components, others instead assembly only single piece.
The motivation behind this are explained both in the second chapter, where production planning is discussed and in this chapter because some products require a lot of time to be processed, hence a dedicated workstation is required. Other components instead need less time to be assembled, thus one workstation can manage more products.

3.2 WORK CYCLE TIME TIMING

One of the aims of this thesis is to research how the application of the Lean Manufacturing theory improves the production results in comparison to the previous manufacture methods. The first step to achieve such comparison is to time the work cycle times of the components that are assembled in the VRM assembly plant.

This requires a specific methodology, thus in this paragraph I will explain how the timing was computed with the Lean Manufacturing method, in order to measure it appropriately.

The timing of the work activities is a very important method to determine the duration of each sub-task. In order to avoid suspicions and time waste, it is useful to employ a member of staff from the specific department, to measure the time.

An important rule to actuate before timing is selecting and standardizing the jobs and movements. It is preferable to make a video to time them to better study the tasks, avoiding any distraction of the worker him/herself. It is appropriate to time at least ten times each work cycle time. If there are more than one worker at each workstation, each single worker must be timed, in order to check if there are differences in the way the job is done. This furthermore allows the timing operator to suggest which task is more appropriate for each worker, considering his/her process method. This is a fundamental step to reach work standardization.

In order to obtain a good and efficient timing, it is important to keep separated the hand manual jobs times, the times of movements, the waits and the machining times; all of which have to be counted separately. When the workstations are balanced after the timing, it is opportune to reduce and then eliminating the waits and the movement times. In such manner it is possible to obtain perfect work cycle times, having decreased the phases without added value to the final product. In this way a pure work cycle time without any time wasting, can be obtained, i.e. the actual time required to assembly a piece.

It is a good practice to time ten clean cycle times for each activity, where clean cycle time is a cycle where nothing goes wrong. Another important thing to do is time to the nearest entire second, approximating in excess. After ten timings, a method to choose which work cycle time should be adopted is necessary. Between the ten measured cycles it is fundamental to consider the lowest recorded time with higher presence frequency [1]. After having recorded and fixed these work cycle times, it is fundamental to add the efficiencies, as explained in the next paragraphs, because sudden problems may occur, such as work variability, staff changes, etc.

Finally, the worker’s breaks need to be accounted for, especially considering they are compulsory and they help the employee perform better his/her job.

3.3 WORK SAMPLING

After the work cycle time timing; the study focuses on the work cycle time as a work activity and not only as a time to record.
Work sampling was thus adopted, i.e. a fast and effective Lean Manufacturing method applied in the VRM assembly department to obtain data on resources and time waste and information on how the workers and the machines utilize their time.
This system requires a lot of casual observations to be taken for each employee of the considered workstation during a specific representative period to understand what can happen and change during the work time.
In the case of the VRM assembly plant, it is good practice to sample repeatedly the job activities for all the workstations, in different periods of the production year, seen that the number of finished components changes seasonally. When observing such operations, it is important to separate the activities that add value from those which do not, like walking, observing, stopping and talking. This task has not to be seen by the workers as spying, but as a fundamental process to collect the data required to allow continuous improvement. [2]
The main focuses of the last two sections of this thesis are calculations and sampling of the assembly process activities inside the VRM assembly plant, in respect of the Lean Manufacturing theory, constantly aiming at creating possible improvements and a related department profit.

3.4 EFFICIENCY

The aim of this paragraph is to explain what is intended for efficiency or production performance.
Indeed efficiency is already calculated in the work cycle times imposed by Ducati, as previously examined. These performances are considered also in the work cycle times of the VRM assembly department when the cycle time is timed with chronometer.
It is important to add the work efficiency in the cycle times by multiplying the work cycle time expressed in minutes times the value of the job performance, after having taken each cycle time of every component.
It is fundamental to utilize this tool to avoid production problems, such as sudden process stops or inability to produce the amount of finished components established. In fact, problems connected to undersizing of the VRM assembly plant will arise if the efficiency is not taken into account. In such case the department may not able to produce the wanted amount of pieces. Therefore, it is

appropriate to oversize the production capability, adding the job performances to the timed cycle times.

This allows to respect the production deadlines, avoiding sudden unexpected problems.

Following some considerations on the various aspects of efficiency and how they affect the production system.

It is fundamental to underline that each workstation is built like a synchronous line, i.e. each workstation functions as a single job location, where there is no waiting for materials, the employees work in a synchronized manner and there are no unexpected stops.

This allows for a continuous flow of materials, increasing and improving the number of finished products and the work cycle times. This is also called stage potential. The workstation potential is oversized for every product, applying the efficiencies, in order to guarantee the right number of finished components.

It is necessary to consider every single efficiency to oversize the work cycle time of each assembled piece. Therefore, it is useful to study the single efficiency and then multiplying all the single efficiencies.

This allows us to obtain the overall job performance, which has to be multiplied by the single product cycle time. The sum of the products cycle times allows to oversize the assembly line.

Next step is to consider and analyze every single K, i.e. the single efficiency.

The first one to observe is K_1, related to the quality. It takes into account the wasted pieces, which do not pass quality control. K_1 is an important measurement as it considers the product rejects, which reduce the amount of final components assembled, thus needs to be oversized.

The second unit is K_2, defined as availability. It takes into account the time during which the machinery or the workstation are active or available to process the component. In fact, a formulation has to be calculated to reach the final efficiency. The job performance's formulation is made by the UT, called up time, which is the time during which it is possible to work without interruptions or problems. The other measurement is the DT, down time. It is the time during which it is not possible to operate, because the machinery does not work or the workstation is not able to assembly the pieces due to sudden problems, hence halting the process, wasting time and losing money. The causes for downtime are many, for example maintenance, but this will be discussed in the next chapters. On the other hand, the up time depends on the reliability of the plant. The K_2 efficiency can be obtained through the following formulation:

$$UT/UT \tag{3.1}$$

Third is K_3. This measurement regards the worker, hence it is also called employee job performance. It collects all the problems that can occur should there be an absence of a worker at his/her workstation. This would act in result in production stopping and consequently, delays in assembly.

It is therefore extremely important to consider every single issue that can happen to the employee; such as physiological time, i.e. the time necessary to concentrate and take part in his/her ask, break time for personal issues such as going to the restroom, etc. Other factors need to be considered as well, for example absenteeism, sudden strikes, illness or accident.

All these considerations should be kept in mind in order to foresee problems and avoid delays, allowing to complete the assembly on time. Accordingly workers efficiency will never be one hundred percent, so over sizing the work cycle times is fundamental. In the case of K_3 efficiency, it is also used to oversize the assembly production.

The last efficiency necessary for the final work time cycle calculation is K_4.

K_4 is the theoretical design utilization coefficient. It generally considers the production time, however in this specific study it considers the assembly time, considering the possible use of the workstation. The mathematical formula to obtain this efficiency is:

$$PT/UP \quad (3.2)$$

That is, PT, production time, divided by UP, up time. Therefore, the tooling time, the placement time and the workstation process organization have to be taken into account. These factors waste a significant amount of resources, as the time necessary for the components which must be assembled, making it necessary to oversize also the K_4.

After having explained each job performance individually; they must be collected and analyzed together.

The multiplication of $K_1xK_2xK_3xK_4$ gives the total job performance of the VRM assembly plant, applied in each assembled component.

The final efficiency result, is 0.87. This number will be applied to the work cycle time of each assembled piece to guarantee an oversized production, in order to deal with every problem that could occur during the assembly. The effect of this total multiplication on the work cycle times of every assembled components will be shown in relative tables in the next paragraph, illustrating the differences between the cycle times personally recorded, and those instead, oversized by the total work efficiency.

The results will be that the cycle times multiplied by the final job performance are increased, in order for the production to proceed without unexpected halts.
The Lean Manufacturing theory helps to improve the K coefficients, improving the production performances and therefore increasing the efficiency. The efficiency value of 0.87 is obtained by the assembly department, after years of studies and tests to find the right compromise between speeding up the production and products and job quality.

3.5 VRM WORK CYCLE TIMES

The importance of this paragraph is based on the VRM cycle times.
Here the work cycle time of every single assembled piece at each workstation is illustrated. The calculation of the VRM product cycle times is fundamental because it provides insight in the performance of each workstation, understanding if the cycle times imposed by Ducati are respected and where it is necessary to improve the assembly cycle times, for either some products or for an entire workstation; thus, avoiding production problems and money loss.
This job was feasible by timing the task and work sampling tasks for each workstation of the VRM assembly plant; as explained in the previous paragraph. Each workstation has numerous different components to assembly, hence this type of production department organization is called "Multi Model". Indeed it is adapted to the assembly plant typology.
It is important to underline that each workstation is organized as a single synchronous line respecting the Lean Manufacturing theory, instead the total assembly plant, composed by 45 workstations, is organized as an asynchronous line. Accordingly no workstation is influenced by the other ones, hence the efficiencies are independent and they are owned of each single workstation. In fact every workstation has different values for each job performance, because it is made of different workers and tasks; but at the end the workstations have the same total efficiency of 0.87; as said previously. This value is used as global plant average to simplify the calculations.
Between workstations there are no buffers, another important consequence of the asynchronous production plant organization.
The following tables present the work cycle times measured by hand for every assembled product of each single workstation. In one column there are the products cycle times timed by chronometer, in the other column there are the products cycle times with the addition of the total efficiency.
This allows to see and compare the time difference, between the normal and the oversized ones.
A significant amount of data was collected to ensure the accuracy of it during the permanence at the VRM assembly plant.

The following sequence of the work cycle time tables for each workstation includes all the assembly components cycle times. The cycle times are expressed in minutes.

The calculation of the cycle times increased by efficiency is obtained with: CT x 1.13. It is 1.13, an approximation of the formula 1/0.87; where 0.87 is the total job performance previously studied.

In the following only a short list of work cycle times tables is presented, the remaining can be examined in Appendix C.

	WORKSTATION NUMBER 1	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR SWINGARM 1504	6.1	6.89

	WORKSTATION NUMBER 2	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	CLUTCH COVER 1308R	2.00	2.26
DUCATI HYPERMOTARD	STGR SWINGARM 1509	8.50	9.61

	WORKSTATION NUMBER 3	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR REAR SWINGARM 1409	6.00	6.78

	WORKSTATION NUMBER 4	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	SWINGARM	6.00	6.78
DUCATI SCRAMBLER DS	SWINGARM 1501	6.75	7.63

	WORSTATION NUMBER 5	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MONSTER	SWINGARM	9.6	10.85
DUCATI SUPERSPORT	SWINGARM 1312 AUSTRALIA	10.55	11.92

Tables 3.5, 3.6, 3.7, 3.8, 3.9: VRM work cycle times

It is important to underline some details after having presented the tables about the work cycle times of the workstations.
First it is important to remember that Ducati's work cycle times already include the own Ducati efficiency following their own internal principles.
Then, making some comparison between the job cycle times of Ducati tables and of the VRM tables, it possible to notice the VRM assembly plant often does not respect the cycle times imposed by Ducati, in particular for some components in different workstations.
Therefore Ducati should penalize VRM for not respecting the assigned work time cycles; but VRM has the ability to guarantee the daily quantity of finished products, as per agreements. This ability is a result of the Lean Manufacturing rules; in fact, by avoiding the waste of resources, the VRM assembly plant is able to meet deadlines, thanks to the work, procedures and standardization operations and thanks to employees rotation.
In this way even if some product cycle times are not in line with the Ducati ones, the number of workers is not increased, avoiding money and resource wastes. But with the same number of workers in the assembly department, the agreements are reached.
Obviously the VRM cycle times may differ from those indicated by Ducati: first they were timed by Ducati, then the worker could have different skills respect to the employee when the cycle times have been timed for this thesis.
It is possible to say that in some cases the VRM cycle times vary of only few seconds in comparison to the Ducati ones. Therefore the difference of few seconds can be neglected, saving a lot of useful working time. If a big product cycle time difference is noticed in some assembled pieces, it will opportune to call the Ducati cycle times operator to re-establish correct values. Thus, the help of Lean Manufacturing theory is fundamental to teach how to increment production, without wastes and within the imposed times.
The employees rotation works in this way: when an assembled pieces is finished before Ducati cycle times in a VRM workstation because VRM has the best assembly strategies, as it can be seen from the tables, the worker is moved to another near workstation or in his/her one but taking part to another product to assembly, avoiding that he/she remains still. Accordingly there will be no queues or delays. This tool can be obtained thanks to, as previously mentioned, work standardization and training courses.
The building of the 45 workstations as single cells is the third important aspect, which allows for a flow in production. This aspect can be understood by the products cycle times tables and derives from the Lean Manufacturing method. This choice cells is made because the calculated utilization coefficient K_4, as explained before, of every single workstations is very high. In fact, it is over 80%

of utilization; hence, the assembly has flow. Indeed all workstations should be considered as small assembly lines.

Accordingly the production flow is very important, in order to have linearization of the workstations. In this way the rejection of the finished pieces and their return is reduced, improving the movement of the components during assembly.

The fundamental Lean Manufacturing dictum is “Put everything in flow”.

The continuous attempt to reduce the “Make to Span” is the final aspect that needs to be mentioned. The “Make to Span” is the time spent from the beginning to the end of a production lot. It is applied to each workstation. Following the 5s of the Lean Manufacturing theory is fundamental to reach this objective.

The assembly organization of the VRM department is made by paying more attention to the most expensive components. This signifies that the products that requires more production time and are more important for their final high cost must have a special treatments, such as being produced before or by dedicating more attention to them. This is written in the Kanban papers, as explained previously. These treatments avoid exceeding the imposed Ducati cycle times, retarding assembly, and they try to produce before the mentioned components.

This made job is part of the times and methods subject. The times are the products cycle times studied and described before. Instead the methods are the production methods that have been considered before but in next chapters there will be some important shrewdness to take into account. Obviously all the times and methods utilized devices derives from a careful Lean Manufacturing application.

These demonstrations were after significant time spent timing the products cycle times for each component and the choosing which were the most suitable for the work rotation.

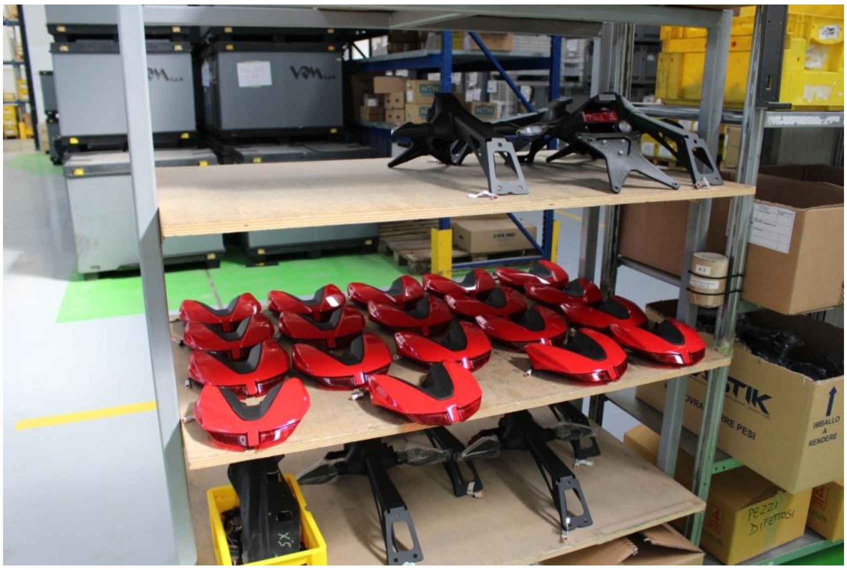


Figure 3.2: Some pieces to be assembled

Figure 3.3: A finished assembled component

3.6 THE BOTTLENECK

For the purpose of this study, it is opportune to analyze the work capacity of each workstation after having discussed the products cycle times.

The term work capacity means the analysis of the specific efficiency coefficient K_4, as explained previously. In brief, the coefficient K_4, also called theoretical utilization project coefficient, expresses the right time of production compared to the available time of the workstation. This factor regards specially the production, taking into account the inferior quantity produced in comparison to the real design capacity.

K_4 is very important because through its calculation it is possible to find the bottleneck of the assembly plant, i.e. which workstation saturates first. The workstation that first reaches the maximum production capability is defined as bottleneck, and it will not able to increase the number of finished components. This event implies that the workstations are in saturation; i.e. they have an high K_4 coefficient, it is always at 100%.
The causes of this phenomenon can be multiple; for example an inefficient worker that slows down production, creating queues and delays; confusion inside the single workstation, with difficulty to find the needed pieces; the tooling can be late or lack in components, or there can be errors.
A problem can rise if a workstation saturates quickly: the production timing may not be respected and various finished products may be between workstations.
Now passing to the thesis job execution, i.e. the calculation of K_4, finding the bottlenecks of the VRM assembly department.
From the previous work cycle times tables, it needs to transform the times from minutes for one pieces to pieces in one hour. Then it is necessary to consider the real number of production, different from the design one. The final calculation to find K_4 is:

$$K_4 = Qu/Qw \tag{3.3}$$

Qu is the real amount of finished components, instead Qw is the design number of finished pieces. This has to be calculated for each workstation; thus, finding which are the principal ones that go first in saturation. Using the amount of resources required in the eight hours work day is another method to calculate the workstation saturation rate. The exact number of resources can be achieved from the tables of the next paragraph. The formula is:

$$K_4 = N_i / 8h \tag{3.4}$$

N_i is the exact number of resources, (see the next paragraph); instead 8h, are the working hours.
The following tables illustrate the coefficients K_4 for each workstation; in order to easily individuate the possible assembly plant bottlenecks. It is important to say that the phenomenon of the bottleneck can be reduced by the application of the Lean Manufacturing method. For the tables the most productive month of the year, i.e. May, is considered. The workstation saturation rate is considered for each work day because the production requests change.
Only some bottleneck tables of the first workstations are presented below, the remaining can be found in Appendix D, to avoid a long list of tables.

WORKSTATION NUMBER 1																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 2																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	4.16	4.16	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.16	2.24	2.24	2.24	2.24	2.24

WORKSTATION NUMBER 3																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	2.80	2.80	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	2.72	2.72	2.72	2.72	2.72	2.72

WORKSTATION NUMBER 4																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	0	0	0	1.04	1.04	1.04	1.04	1.04	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1.04	1.04	1.04	1.04

Tables 3.10, 3.11, 3.12, 3.13: Workstation Bottleneck

An important consideration about the coefficient K_4 is that the calculated values in the previous tables are not the value utilized for the calculation of the total job efficiency. This because its value would be too low, decreasing the global job performance excessively.

The value of K_4 considered for the global efficiency takes into account that each workstation is always working; not only for determined hours as found in the previous tables calculations and that there is no waste of workers, because if necessary they are turned in other workstations.

From the tables it can be seen that some workstations work in saturation for the whole working day; others just for few hours. Therefore some workstations could be stopped during the day, or they could intake other components to process from the nearest workstations in saturation, or they could move their workers to other locations which need more support.

The numbers in the tables express the number of hours that the workstation is active during the eight hours work day. To simplify the calculations, eight hours are used in place of the actual nine hours of the month of May, introduced, as said in the second chapter, for flexibility purposes.
It is important to explain what the numbers in the tables say. Where the number 8 is present, it indicates that the considered workstation works for eight hours, and it is saturated, with the exact number of resources calculated mathematically; hence it works at one hundred percent.
Instead for the other workstations, where the values presented are lower than eight hours, these values indicates that the workstations are not saturated, they do not work at one hundred percent, but work only for the indicated amount of hours during the day. Therefore the actual number of workers necessary for the workstations needs to be calculated, because it is almost impossible to follow the mathematic results of the algorithms.
When the workstations do not work at one hundred percent it can be useful to turn the workers; and it is opportune to round up or down the exact number of resources when the workstations are saturated. This task will be better explained in the next paragraph, where details regarding the sizing of the workstations are presented.

3.7 WORKSTATION SIZING

In this part, the workstation sizing will be explained.
The VRM assembly plant comprises 45 workstations, and their sizing, in terms of employees, needs to be taken into account. Indeed the sizing regards the number of workers necessary to assembly the designed number of finished components for each single workstation.
This will be performed only by mathematic calculations and observations. Mathematic calculations because the exact number of workers, necessary to compute the specific process imposed for the eight or nine hours of daily work, can be derived from the work cycle times tables. The dedicated number of necessary workers is found from each product cycle time of each single workstation. Then it is possible to find the exact number of workers for one workstation summing the number of employees calculated for each finished piece with the total ones for the overall components assembled in that workstation.
It is called exact number of workers, because normally the resultant number is not a whole number but it is a decimal one. Next step is to find the whole number of employees, because in real life is not possible to have half a worker.
The observations are required to determine in which workstation it is better to round up or to round down. Obviously, it is fundamental to take into account the workstation efficiency; because if the

efficiency is low, rounding up is better, instead if the efficiency is high, is better to round down. To speed the calculations and for the personnel management, normally it is better to take an average of the workers required per month.

Next step is to explicit the mathematic calculations needed to find the exact number of resources for each product in each single workstation. From the products cycle times tables T_i is extracted, i.e. the minutes required to assembly the i-esimo piece. Then there is Q_g , the amount of daily finished products per specific type of motorbike. The formula is:

$$N_i = [T_i \times (Q_g / 60)] / 8h \quad (3.5)$$

Where by 8h eight working hours are intended. The result N_i of this formula are the exact number of workers necessary for a specific amount of product in a work day. This algorithm is used because it divides the total amount of finished products of a single type motorbike for the overall pieces that make the motorbike; resulting, in the exact number of workers per single type of component to process in eight or nine hours, according to the seasonal work shift. This task was conducted in the months of April, May, June and July for the purpose of this study. They are the most productive months, so this period is the most difficult to manage, hence the need to study the period in detail and suggest improvements. It is important to also consider the coefficient UT_j. UT_j is a utilization coefficient that takes into account the workers resources utilization in each single workstation. It should be noted that this utilization coefficient changes if the exact number of required resources is rounded up or rounded down.

Utilizing the following formula, it is possible to know if the workstation is in defect or excess of employees. Accordingly the UT_j can be considered as a specific efficiency. This considered coefficient can also be called workstation saturation rate, as that in the previous paragraph, although this coefficient takes into account the real number of resources in a workstation. Obviously if the formula is rounded down the workstation has to work at one hundred percent, instead if the formula is rounded up, the result is an utilization coefficient that could vary accordingly to the situation. It is important to underline that with UT_j it is possible to pinpoint the workstation bottlenecks of the assembly plant. The formula is:

$$UT_j = N_i / N' \quad (3.6)$$

It is simply the exact number of resources, obtained from the previous formula, divided by the rounded number of workers. The rounding of the workers is in not a simple task; because it needs to take into account the management of the employees for every single workstation, their job capacities and their turning between the workstations, when necessary. The best solution is to have all the workstations working in saturation, thus, no resources are wasted; but it is difficult to reach this organization level because the workers are always a whole number.

Thanks to the help of the Lean Manufacturing theory it is possible to reduce the required resources improving efficiencies.

Following some tables are presented, where the exact number of resources are written for each single workstation, as required for a single day during May, the most significant productive month of the year. For practical issues, the exact number of resources for each single assembled piece are not written in the tables, as it has been done to find the total number of daily necessary workers; but the tables have been simplified, inserting only the total daily number of employees for every single workstation.

The same has been done for the other months considered during the job thesis, but not presented here for issues of length.

The results found in the following tables are the sum of each component resource. The rounded number of employees is also presented, i.e. the real number of workers present inside the VRM assembly department during the month of May. In this way it is possible to compare the exact and actual number of resources, taking into account the workers utilization coefficient.

Obviously to know the total daily production, to utilize the previously written formula, and to find the exact number of required resources, the production month of May was considered. The May table is in the second chapter; there, it is possible to see the expected daily total number of finished components.

Following only some workstations sizing tables are drawn up, while the other tables are illustrated in Appendix E.

WORKSTATION NUMBER 1																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
TOT	55																					

WORKSTATION NUMBER 2																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0.2	0.2

RESOURCE	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	8	8	8	8	8
TOT	55																					

WORKSTATION NUMBER 3																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.35	0.35	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.34	0.34	0.34	0.34	0.34	0.34
TOT	55																					

WORKSTATION NUMBER 4																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0	0	0	0.13	0.13	0.13	0.13	0.13	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.13	0.13	0.13	0.13
TOT	55																					

WORKSTATION NUMBER 5																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.07	1.07	1.07	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.07	1.07	1.07	1.07	1.35	1.35	1.35	1.35	1.35
TOT	55																					

Tables: 3.14, 3.15, 3.16, 3.17, 3.18: Workstation sizing of human resources quantities

After having written the resources tables, it is important to underline some aspects. The illustrated tables regard the month of May, because it is the most productive month and the most important to consider. The other month tables are not written to avoid a long list of more or less similar tables; however accurate data was collected and analyzed for this study. Other important consideration is the meaning of the number of zero resources in some tables. In the month of May, the Ducati Panigale V2 model is not produced, a choice of Ducati factory. Therefore in the workstations dedicated to this model there is the number zero for each production day. This means that there is not the need of workers. Accordingly, the VRM assembly department does a revision of the occupied employees and where they have to work. These workstations could be applied for the processing of other motorbikes components, or could be considered as support, but in this case they are inefficiencies.

In the tables, the real number of resources for each workstation has been neglected, and also the utilization coefficient, because the number of workers in the workstation is almost never fixed, only in rare cases. In the section TOT only the real number of employees in the whole assembly plant is presented; it is the only number that cannot change during the month.

Summarizing what has been said previously, about the rounding and personnel management, now it needs to go more in detail.

In some tables can be seen that, there are the calculated exact number of resources under the number one, hence, obviously, in this case the real number of workers will be rounded up to one presence.

Instead in the case of numbers over the number one, the actual employees present in the considered workstation will be rounded up or down, secondly the mathematic calculated number is nearer to the superior or inferior number.

In the tables the real number of resources present in each workstation cannot write, because part of employees do not stay always in their workstation, but they turn.

In easy words, if in one workstation the number of workers is rounded up, after a certain production period, they will be redundant, because they risk to produce more than the necessary. Therefore these workers will be turned in other workstations, where there has been previously a rounding down of resources. Hence, after a certain period, a lack of employees, and less finished products than expected will be present in these workstations. With the considered resources turning, the assembly will be always stable, respecting the deadlines.

In this way the production timing is respected, without having redundant or missing number of resources. Accordingly, there is a respect of the Lean Manufacturing theory, because the waste of resources is kept low.

This system is permitted thanks to the organization of the VRM assembly plant. In fact, the subgroups, mentioned in the second chapter, are very useful for this task.

A subgroup is simply a sum of workstations. There are some workstations near each others, i.e. they are organized in one corridor. Thus, working with corridors, long movements are avoided, the workers with same abilities are put together, and they can turn more simply.

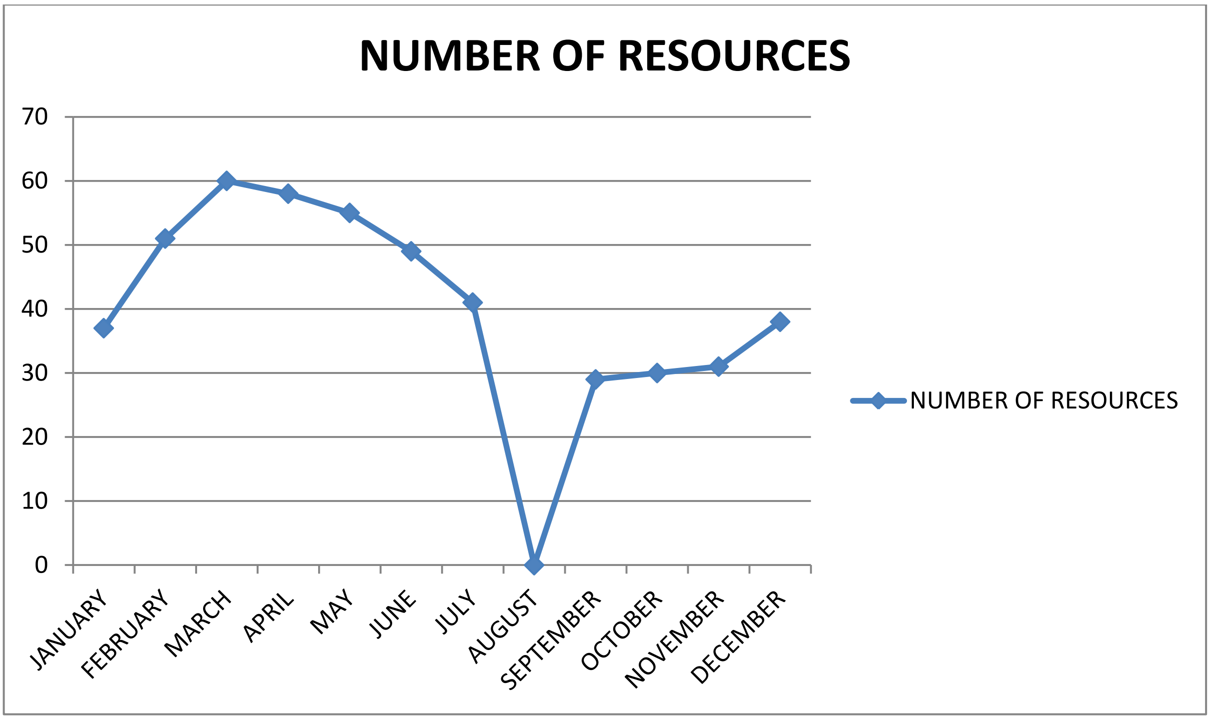
In this way the employees are always engaged in their work, and the overall worker efficiency (K_3) increases. Accordingly, in the VRM assembly department there are more subgroups organized in corridors.

The Kanban papers help the workers turning tool functioning. Indeed the Kanban imposes the job has to be started in every single workstation, but it is also able to organize the assembly processes inside each subgroup. In this way there are no workstations which use too much or half energies.
It is possible to see the corridors organization in the next department map.

Map 3.1: Assembly plant map

It is important to underline with a graph what has been said until know regarding the number of resources sizing, inside the VRM assembly plant.
The next graph shows how the real number of employees varies during the year. Obviously the number of workers changes every month, because the production request increases and decreases seasonally, as imposed at the beginning of the year. Therefore it is opportune a careful personnel management, ensuring the correct number of workers, to satisfy the production variation.
As the production is seasonal, also the workers management is seasonal. Indeed some employees are fixed during the year, instead others are recruited seasonally following the production trend.
It needs to take into account that the resources recruited seasonally have to be trained. Accordingly, it is necessary to recruit the workers before the increase of the production, in order the assembly department is able to follow the production peaks.
The data of the first current year semester are obtained during the job thesis, instead the ones of the other months, are expected data, stipulated at the beginning of the production year.
It is important to underline that the real number of workers in the VRM assembly plant derives from an average of the monthly exact number of required resources, calculated with the mathematic algorithms introduced previously.

It can be noticed that in the month of August there is a decreasing peak, because the plant is closed for holiday.



Graph 3.1:Annual human resources

Figure 3.4: A Lean production workstation

References:

[1] John Bicheno, Alberto Portioli Staudacher, “Metodologie e Tecniche per la Lean”, 2009, pp.82.

[2] John Bicheno, Alberto Portioli Staudacher, “Metodologie e Tecniche per la Lean”, 2009, pp.145.

CHAPTER 4: VRM PRODUCT QUALITY

In this chapter some aspects regarding the quality of the product will be examined.
The study of the product quality starts from the product design, until its production, assembly and quality analysis.
VRM assembly department invests a lot of time dedicating to the control and analysis of its finished assembled components. VRM activates numerous quality checks on its products because it must respect high quality standards imposed by its main customer Ducati. Therefore the VRM assembly plant tries to improve its quality with expensive methods, in order to benefit the company.
In the following paragraphs some Lean Manufacturing quality methods applied by the VRM assembly plant will be explained, in order to reach its main economic goal.
A further task of this study is also to apply the Lean Manufacturing theory on the product quality. Indeed the continuous study and application of quality production methods and checks to the assembled products can brings improvements to the VRM company; because VRM by producing high quality products can require more economic resources from its customers.
Initially the application of new and modern Lean Manufacturing quality methods brings to an increase of the assembly department costs, but then the main thesis goal may be reached. In fact increasing the product quality, it is possible to ask for a better payment standard. Accordingly, the income statement could bring positive results, ensuring profits to the company; indicating if the Lean Manufacturing quality methods are successful.
The hypothesis behind this study will be demonstrated in the last chapter. All the data was collected directly in the workplace.

4.1 QUALITY CHECKING

One of the first quality control method actuated in the VRM assembly plant is the checking.
This is useful to understand if a product can be accepted or must be rejected. This instrument is utilized for the products that have to be processed and arrive from a supplier, for example the foundry, or for the finished components that have to be delivered to the customer.
The quality checking process is divided in two steps. First: acceptance. The acceptance is made by a computer, thanks to an identification code written on each product, which is recognized by the computer itself. A worker has the task to scan each code under the computer, the computer thus identifies the type of product and specifies what has to be checked on the product and when it is necessary to apply the control.

Not every product is checked, because it would take too much time, but the computer is programmed to verify quality according to the failure probability rules. The computer is programmed to give the employee some checking suggestions. In fact, the computer recognizes the type of product and suggests which quality control should be performed.
VRM company has different quality machines, that these can satisfy the high product quality requests.
The second quality step is the product quality verification, in order to understand if the component has to be accepted or rejected. This step is done by the quality machines. There are three main different quality machines: the 3D machine, the reliability machine, the hardness test machine and the tightness test machine; obviously these quality control systems have different aims and they are managed by specialized quality workers.
The computer necessary for the first step, as described above, recognizes the type of product thanks to the codes, it directs the product to its most appropriate quality control machine, according to the failure probability parameters. Therefore, the products may be subjected to different quality checks.
First I would like to start with an explanation of the 3D machine. The 3D machine is used to conduct quality controls on the main dimensions of the product. Its principal quality tests are the verification of the parallelism, eccentricity, circularity, planarity, distance between holes and the respect of the product overall dimensions. The 3D machine works for discrete or continuous processing on each piece measurements.
Passing to the verification of the component hardness, VRM utilizes the machinery that adopts the HRC scale. The HRC is a measurement scale in the Rockwell hardness test. In the HRC scale the indenter has a cone shape, because it is more adapt for the hard material like the alloy steel and the aluminium alloy utilized for the motorcycle components.
Then there are reliability machines; they are machineries that verify the product quality as reliability. The reliability is the duration of the component life with sudden failures. The reliability machine has to reproduce the strength cycles during the component cycle life of the certified warranty period of a component.
Finally, the tightness tests machine is the last machinery used for the product control quality in the VRM company. The tightness test is utilized to verify if a component has fluid dynamic losses, regarding either the air, for compression tests, or the water, for internal motorcycle circuits.
The product quality checking described above ensures the correct working of the considered component, the maintenance of the product integrity during its life and finally it concurs to the total product quality, improving the VRM consideration between the companies with high quality and precision manufacture.

Figure 4.1: Quality checking area

Figure 4.2: Hardness test machinery

Figure 4.3: 3D continuous machine

4.2 TOOLING VERICATION

The product quality control then shifts to the maintenance and efficiency of the tooling utilized to assembly the components in the VRM assembly department. Indeed, it is important for the tooling to always be at their best, in order to guarantee high quality standards. It is thus fundamental to continuously check and maintain all the work instruments.

The tooling verification case of the electric screwdrivers is considered in this thesis. In fact, the electric screwdriver is the most important and used tooling instrument in the VRM assembly plant, because it is fundamental to assembly most of the pieces. The screwdrivers are continuously used during the working days, therefore there is a high probability that the instruments loose their calibration. Accordingly, it is necessary to constantly check them and, if requested, also calibrate them.

The screwdrivers calibration is fundamental in order that the product quality can be maintained but more important is the keeping of the product safety.

Indeed the electric screwdrivers have an internal spring that tends to discharge its compression and it can happen that the spring breaks suddenly, if the screwdriver falls on the ground or takes a blow. This problem can create serious damages to the assembled products. Hence, it is important to verify and calibrate the tooling functioning with periodic status verification.

The new quality working tool is called “Double Check”.

“Double Check” is a safety verification that has been introduced during the thesis period, to avoid product quality problems. The “Double Check” method is simply the utilization of two electric screwdrivers together. In this way it is not possible to have incorrect tightening, thus, avoiding

quality product problems on the finished assembled pieces. Therefore utilizing two electric screwdrivers is not possible to commit assembly errors, because if one screwdriver is not well calibrated the second one will adjust the tightening damage.
The "Double Check" system is mostly used on safety tightening, because these tightening are structural parts of the motorbike. Accordingly, an error cannot happen during the assembly, because if a motorbike structural component collapse it could be very dangerous for the motorcyclist's safety.
The brake pedals, gearbox pedals and components, screws and bolts that tighten the main motorbike chassis structural parts are an example of motorbike structural components that are assembled with the "Double Check" method.
The "Double Check" system is useful and important because after the product assembly, it gives some tightening certifications to the finished piece. These tightening certifications ensure the safety and quality of the product construction, giving the customer the manufacture warranty.
The method permits to increase the final product quality, in order for the customer to feel the high standards of VRM assembly quality. The new system implementation in the VRM assembly plant requires the set of new workstations with specialized workers.
This approach brings high product quality but it increases the price of the particular components described above. Its cost is considered as a normal product cycle time, made by paid employees, that work on new expensive workstations.
The introduction of the "Double Check" system has two important consequences, in fact the method acts both as tooling calibration, and as a product quality check.

Figure 4.4: A double check instrument

Figure 4.5: Double check certification

The suitability check of the working instruments is a further important tooling verification for the VRM assembly plant product quality. Suitability is intended as the capacity to work the components, it is the authorization to start the process. Indeed it is important to conduct a periodic and constant verification of the tooling wear.
The worn tooling can be considered as a working instrument that is not able to do its job and requires the replacement of the wear material. In this way it is not possible to make errors in the product process, thus, avoiding material waste and waste of time.
Therefore, this checking, which must be done by the employees, is part of the Lean Manufacturing foundations. Accordingly, applying the Lean Manufacturing tooling verification is possible to always guarantee a constant high product quality, achieving customers satisfaction and approval.

Figure 4.6: Tooling verification

Finally the periodic assembly instruction checking are a further important tooling verification, that can be taken into account to improve the product quality.
The assembly instructions are useful to assembly a component, because they show and describe the main steps that the worker has to follow during the piece assembly. The final assembled product will have some manufacturing defects and malfunctions if the assembly instructions are not executed correctly, if the indicated order is not followed correctly and if each assembly step is not well concluded.
Therefore, it is fundamental that a worker in charge of the assembly product quality, periodically verifies the assembly instructions, for every products, at each workstation, in the VRM assembly plant.
It is important to periodically check the components assembly instructions because the products can have some updates during their life span. Hence, the worker in charge of the product quality has to verify that the new component instructions adapted for the updated products are present in each workstation.
The instruction model checks are a further component instruction verification method utilized in the assembly department. This system takes into account that the assembly instructions for a specified piece may be confused with other instruction models. Accordingly, the quality employee has to verify if every component to assembly has near its process instructions.
This product quality method avoids fatal errors on the finished components, but it is ensured if and only if the Lean Manufacturing theory is applied in the correct way at the workstations. Assembly errors or damages cannot happen if cleanliness and order are maintained at the workplace area.
Furthermore checking the worker is the last assembly instructions verification expected at the VRM assembly plant. The worker in the workstation has the only job to assembly the components following the given and updated process instruction. Hence, if the worker does not know the product’s technical details he/she may commit simple assembly errors if none teaches him/her some important assembly suggestions. Therefore it is necessary to continuously checks what done by workers, in order to ensure the best standard possible.
These assembly arrangements are very useful to guarantee the final high level product quality, so the finished components have high reliability and durability. The described arrangements were analyzed in the workplace.

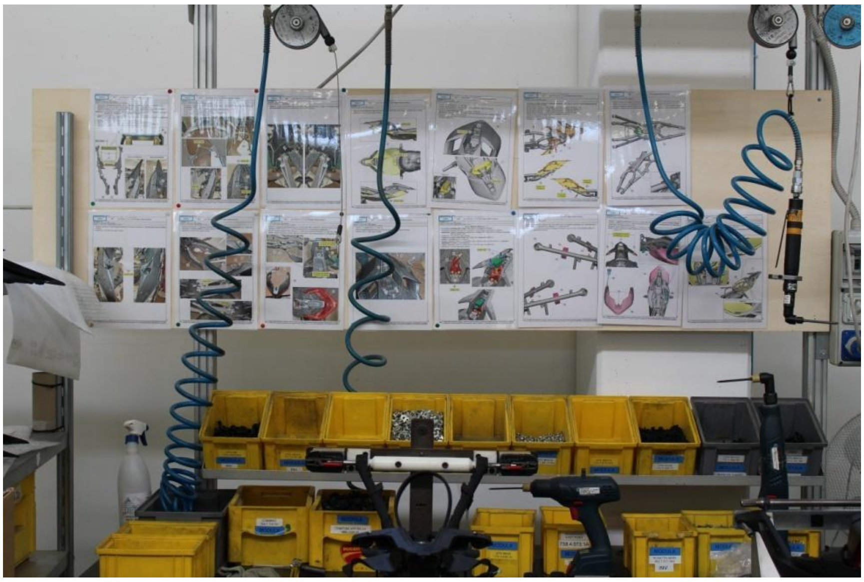


Figure 4.7: A workstation with the assembly instructions

4.3 LEAN MANUFACTURING VERIFICATION

Considering what described until this point, the workstation order verification is a fundamental priority. It is not possible to have high product quality without following the Lean Manufacturing 5s rules and tooling verification.
The product quality can be considered not only the assembly product quality but also the resource and waste product quality. The key point is combining tooling verification and Lean Manufacturing rules. In this way, high product quality will be achieved without wasting resources and hence, better production capability with less costs.
The application of the Lean Manufacturing rules can be considered as a verification product quality system, because the perceived components quality improves, avoiding waste and giving order and cleanliness at the workstations.
The fundamental aim of the Lean Manufacturing checking is to find what does not create value to the product and to eliminate it quickly. In fact what does not create product value is considered a waste.
The VRM assembly plant risks to accumulate waste of time and materials due to workplace disorder, if the Lean Manufacturing method is not applied in the correct way. It is important to apply some arrangements, in the assembly department, to avoid the loss of precious resources; without, diverting the attention from the final product quality.

First precious Lean Manufacturing suggestion to follow is to store the tooling material used during the work cycle time when the worker finished using it. The tooling and the pieces have to be stored in special containers, or in dedicated and easy to reach shelves, or in the carts, in order for the components to be moved away from the workstations in the assembly plant.
Second important Lean Manufacturing suggestion is to vacate and not block the passage in the accumulation points.
These two Lean solutions are important to avoid process errors on the products and they are important to reduce as much as possible the material and time waste.
A misplaced tooling material in the workstation can create disorder; disorder can create unsafe situations for the worker. The unsafe situations can be dangerous and can cause waste of time to solve them.
The workstations must be kept in order and efficient, ensuring cleanliness and control inside and around them; in order to avoid production obstacles that retard the product work cycle times. The respect of the Lean Manufacturing verification rules in the workplace is fundamental and necessary for the final product quality. Indeed the work disorganization and the wasted time do not add value to the finished products, hence, they are not paid by the VRM customers. Accordingly, what does not create product value has to be paid by VRM company, and needs to be eliminated to generate positive profits in the income statement.
A further important verification device can be the suggestions given by the workers. It is important to consider that a worker knows very well the characteristics of the products that he/she assemblies; hence, it is necessary to listen to the considerations and work improvements that the worker can give to decrease the work cycle times during the workstation tooling. Indeed the tooling is something that the customer does not perceive in the product quality; in fact, it does not add value to the product and it is not counted in the component work cycle time. The customer does not pay the tooling time, because the tooling is considered as a loss of time.
Each workers' suggestion can be helpful for the entire assembly plant, both for the amount of finished components, and for the final VRM assembly plant income statement.
The tooling of the fixing plate for the motorbike chassis assembly is an example. In the past the tooling was made by a normal manual screwdriver; but thanks to a worker's suggestion, a modification on the electric screwdriver utilized only for the components assembly was done. In this way the tooling of the fixing plate is now made with the electric screwdriver, drastically reducing the required time, avoiding wasting precious and unpaid time, because it cannot be inserted in the product work cycle time. The saved work time can be utilized for verifications useful to increase the product quality.

In brief, the application of the Lean Manufacturing method in the workplace is order and cleanliness verification.
It is very important to keep in mind that wasted time caused by the work disorganization is not paid by the customer. Therefore, it is fundamental to constantly apply work verification in order to increase product quality.
All this enables the VRM assembly plant to obtain a positive income statement, although this hypothesis will be verified only at the end of the present study.
All the presented considerations were collected directly at the workplace.

Figure 4.8: A clean and tidy workstation

4.4 PRODUCT QUALITY STANDARDIZATION

In the VRM assembly plant only partial components are assembled. Ducati then completes the assembly, producing the actual, complete motorcycle.
Ducati company sends the motorbike projects to VRM's technical office. VRM has to conduct a feasibility study according to the Ducati request. VRM project managers have to know the VRM production capacity and to understand if a new product will be possible to be processed and assembled in the VRM plants. The project managers have also to understand if a new product production will give profits to the own company. After these considerations are confirmed and accepted, the VRM technicians can send to Ducati the production product approval process. In this way a new component will be introduced in the VRM company production cycle.

This should be considered only as a brief overview of the product production approval by VRM company of Ducati's technical projects.
After having understood how the communication for the production of products occurs between VRM and Ducati; it important to underline how VRM engages in improving its product quality applying a product standardization.
The Ducati projects sent to VRM technical office are necessary for VRM plants to understand how the products have to be processed or assembled. VRM tries to modify Ducati's designs to improve the product quality; but cannot modify them in a substantial way, because the clint's standards have to be respected.
The product standardization is the main project modifications that VRM is used to apply on the Ducati plans, to improve the entire product quality.
The product standardization is studied by the VRM engineers and applied in the VRM assembly plant to simplify and standardize the little components used in the assembly. Product standardization is helpful to reduce piece codes in the bill of materials and the amount of used little components in the assembly plant and accordingly, it can be used to adapt the same pieces to different motorbikes.
All the pieces such as screws, bolts, o-rings, nuts, cable ties and etc. are defined as little components present in the automated warehouse.
The product quality standardization is fundamental for the assembly simplification, to reduce the amount of total pieces, and in general of different components between different motorbike models, aiming at reducing the possible assembly errors. Consequently, it is possible to reduce the organization plant costs, diminish material waste, decrease time and resources required and have less codes in the VRM assembly buffer, whilst increasing quality.
What has been described until now are standardization and simplification suggestions that VRM workers notice and actuate in the assembly department during the daily process, but the more detailed suggestions require deep technical modifications in the Ducati projects. Therefore, VRM technical office and the Ducati one constantly exchange precious information to improve the final product quality.
It is necessary to underline that the product quality standardization principal aim is to improve the product quality trying to standardize the component assembly process and the pieces necessary for the production.
This Lean Manufacturing solution is a further important step that could be helpful to reach the main goal of this study, i.e. save money and time. In fact the product standardization process brings to save time and money in the work, avoiding to waste fundamental resources in terms of number of

workers, space in the buffer, work cycle times, product codes management and possible errors that can cause sudden production stops. The described waste resources, that instead can be saved and decreased with the product quality standardization, are seen as costs.

The principal paragraph aim is to improve the product quality, reducing the overall product costs, in order that the profit in the final VRM assembly department income statement would be positive.

The just described Lean Manufacturing system is studied and applied in the workplace.

Figure 4.9: Little components standardization

References:

John Bicheno, Alberto Portioli Staudacher, “Metodologie e Tecniche per la Lean”, 2009, pp.90-94.

CHAPTER 5: VRM PRODUCTION QUALITY

This chapter will take into account the analysis of the VRM assembly plant production quality focalizing on the workstation production quality.

It is important to underline how the workstation production is organized and how the workstations are balanced.

Each workstation is organized as a little production line, while some workstations are organized together to make a bigger production line, called "Subgroup", as explained in the first chapters.

The single workstation or the sum of them have a "Multi Model" production type. The workstations can assembly different products, but with set-up processes between the assembly of a component and the next one.

It is important that the workstations work respecting the production deadlines and in synchronization inside the subgroups. Therefore, it is fundamental to balance the workstations: it is simply a balancing of the production lines. In this way the assembly plant respects the Lean Manufacturing 5s rules avoiding waste of resources and production delays improving and increasing the production quality.

It is necessary to explain some fundamental steps for the workstations balancing.

Starting with the "Takt Time" setting, which tries to level the relationship between working hours and customers production ask, in order that the assembly department will not have wastes or lack of request finished products.

Then the worker balancing has to be found, seen that it is not possible to have employees that work at one hundred percent and others that work at fifty percent. This is to avoid workstation stops or components queues.

Third, it is necessary to stabilize and maintain the product work cycle times during the production, in order to know if the customer demand will be satisfied despite the high component assembly variability.

A further balancing step to improve the production quality is wastes removal, hence, the need to stabilize the most good process procedures, trying to discover what gives value to the product and what does not. The worker movements, the workstation ergonomic characteristics, the signposting, the encumbrances and the no repetitive tasks are taken into account to avoid creating possible wastes losing important assembly resources.

The most important balancing solution in the production lines is “One Piece Flow”, that is the ideal production flow: difficult to reach but it must be the main Lean Manufacturing production objective.
A final detail to underline is the current company trend. Most Italian companies think that the Lean Manufacturing application signifies to transform manual production to an automated one, but it is fundamental to specify some important aspects. Indeed automation of the production lines has to be carefully considered.
Automated assembly could improve the production quality of “dull, dirty, dangerous” and “hot, heavy, hazardous” processes, but the it does not solve the problem of what manual workers can do. In fact, robots do not research the waste and do not try to improve the production quality as employees can do. Furthermore, the workers have a job flexibility that machines cannot have and they always try to improve their work with adjustments or adopting new solutions, while robot cycles merely follow the imposed cycles. [1]
Automated production can thus marginally improve the assembly quality.
The Lean Manufacturing quality approaches teach that a compromise between manual and automated production has to be found.
The just described production quality solutions are useful in order for the assembly quality to increase, giving to the customers a better quality perception and satisfaction, reaching profits for the company.
In the next paragraphs some assembly quality aspects and solutions that VRM assembly plant adopts for a better quality production will be examined.
Thanks to these solutions it will be possible to obtain a better workplace quality with workers less tired, without pains and job problems. In this way the production errors and wastes will be reduced in the assembly department, the workers work in a better way and the overall assembly process can proceed in a better way without problems and stops.
Accordingly, the assembly total production numbers increase, with less assembly errors and resource waste; allowing high quality finished components to exit the plant, guaranteeing customer satisfaction.
Hence, the study and application of new Lean Manufacturing production quality methods contribute to the main thesis goal. Indeed, the production quality improvements help to increase the income statement, creating higher profits for the VRM assembly plant.

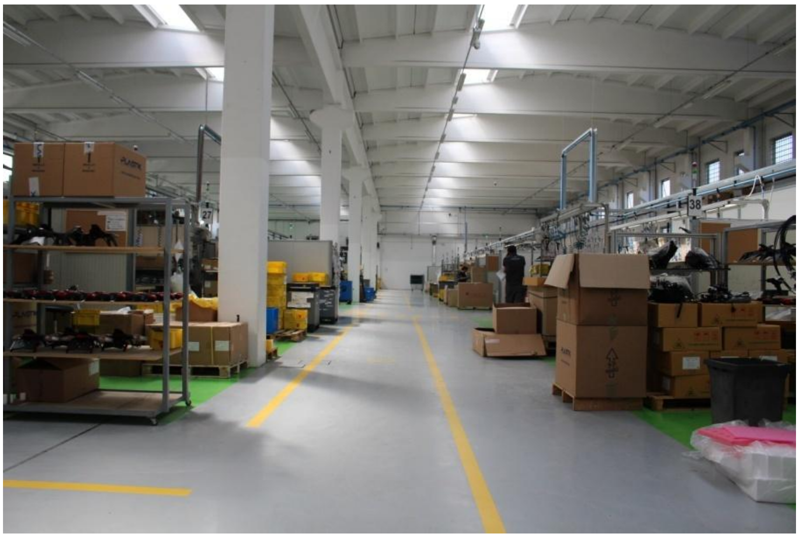


Figure 5.1: VRM assembly plant production quality

5.1 POKAYOKE APPLICATION

In this paragraph the first Lean Manufacturing device applied on the production quality in the VRM assembly plant will be discussed.

First of all, the term "Pokayoke" must be defined. It is a Japanese word used in the Lean Manufacturing theory when a system or an object is used in the production to avoid assembly errors, i.e. anti-error and error prevention.

An error prevention device has to be simple and cheap. The main characteristic of the Pokayoke devices is simplicity to use, seen they execute the complete automated assembly inspection, in order that the worker memory and action cannot be used. This does not imply that the worker can work without paying attention during the assembly, but that the Pokayoke systems stop the assembly process, giving signals about the committed errors or possible product defects.

In the VRM assembly plant the anti-error systems could be a simple mechanical impediment, that avoids a wrong component assembly, or an electronic sensor that understands the possible error or the anomaly and does not allow the start of the automated machine for the manufacture, or a ordered sequence of steps; a series of counters that verify if the correct number of parts is assembled; etc.

The Pokayoke objective is the device design that prevents possible assembly errors; thus, avoiding that these errors subsequently become product defects, causing the customer dissatisfaction.

The "Contact", the "Fixed Value" and the "Motion Step" are the three main prevention error device typologies.

Starting with "Contact", it can be classified as an anti-error device which enters in contact with the components to assemble. The Pokayoke contact system has a physical conformation that mechanically prevents possible assembly errors. For example, the contact prevent error device is a component assembly support with which the worker can immediately and automatically understand if he/she has positioned the piece on the wrong side, as shown in the next image.
The "Fixed Value" prevention error method is a design typology that allows to notice if a piece for the entire finished components has been lost or omitted.
Finally, the "Motion Step" Pokayoke system is an anti-error device which automatically ensures that a correct number of assembly steps are surely conducted in the production process. For example, in the VRM assembly plant, a checklist system is used. It is a sequence of switches which do not work if they are not pressed in the correct order, as indicated in the assembly instructions. These switches are fundamental because they activate the tools necessary for each product assembly step. The explained anti-error device can be seen in the next image.
In the VRM assembly department the Pokayoke systems adopted to improve the production quality belong to the "Contact" and "Motion Step" typology, as the examples described before.
It is important to underline that the Lean Manufacturing anti-error methods are adequately adopted and well adapt for the VRM assembly department thanks to its production organization, in fact VRM assembly plant organization is based on the "Multi Model" and "Just In Time" production. Accordingly, despite of the big product variance, a lot of possible errors can be eliminated.
The continuous utilization of the anti-error devices brings to repetitive production actions, a possible defect of the Pokayoke system, because the assembly process variance cannot be taken into account by the worker, losing, in this way, the new Lean Manufacturing solutions that may allow for improvements in the VRM production quality. [2]
Therefore, it is necessary to underline the usefulness of the Pokayoke system utilization in the VRM assembly plant. The Lean Manufacturing anti-error devices are fundamental to reduce the assembly errors, in this way the time, resource and, production wastes are reduced, whilst increasing the safety in the workstations.
All these aspects are necessary to improve the global production quality of the VRM assembly department, ensuring that the customer will never receive wrongly assembled components or products with production defects.
All the considered Pokayoke solutions have been studied in the workplace.

Figure 5.2: A "Motion Step" Pokayoke system

Figure 5.3: Some "Contact" Pokayoke devices

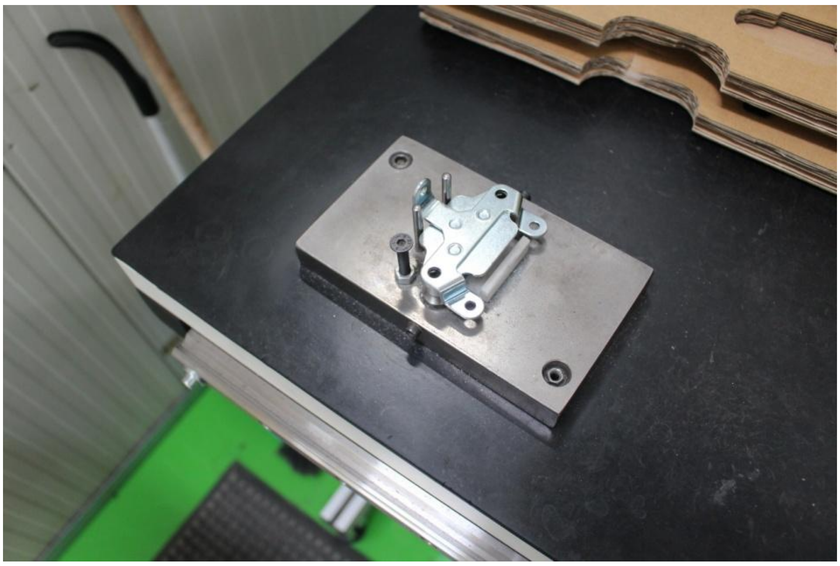


Figure 5.4: An example of Pokayoke instrument

5.2 ASSEMBLY PLANT MAINTENANCE

In this paragraph an explanation on how the VRM company organizes the maintenance of its assembly plant is provided.

The assembly department service is considered like an efficiency, as discussed in the third chapter, with the following formula:

$$K_2 = UT/UT+DT \quad (5.1)$$

DT is the down time, or mean time to repair, i.e. the average time that the machine or the workstation needs to return efficient and operative. Therefore, it is fundamental to reduce as much as possible the DT, in order for the efficiency K_2 to remain with an high value and thus, the overall production is not slowed down or stopped for too long.

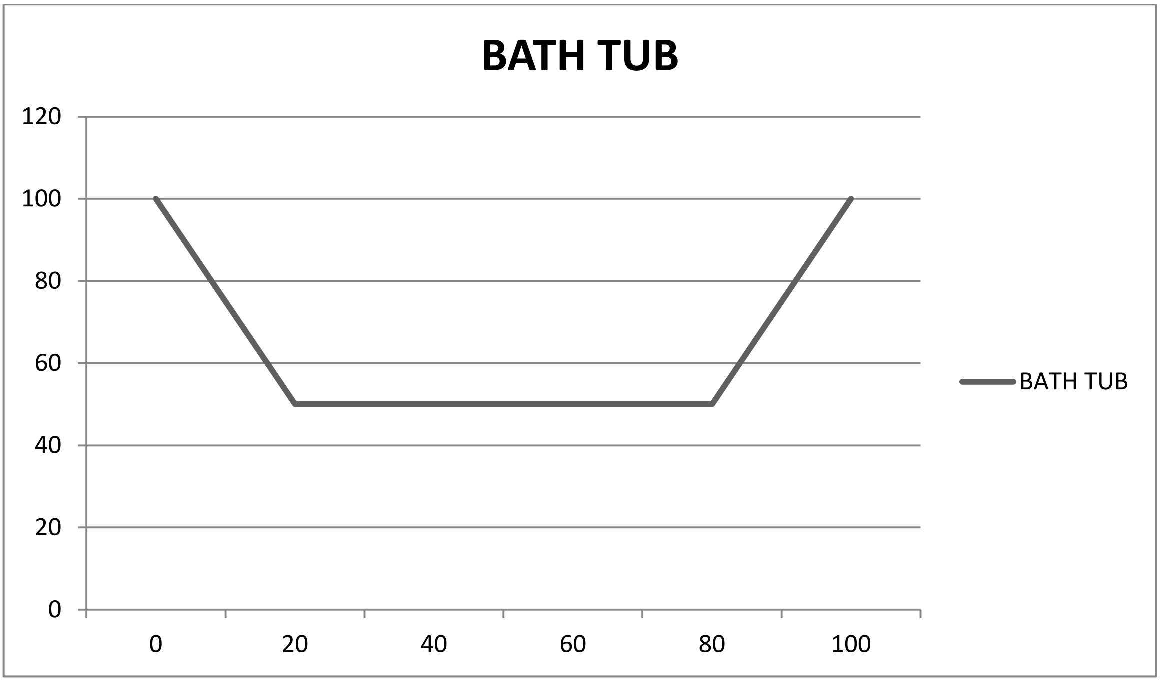
It is important to always take into account the coefficient K_2 , because if K_2 is not considered in the VRM assembly plant the production deadlines will not be respected and the finished assembled component amount will be less than expected; thus not pleasing the client.

Hence, it is necessary to manage in correct way the efficiency K_2 .

The VRM assembly department organization service has to be approached with a Lean Manufacturing method to ensure tidyness and cleanliness in the workstations, avoiding resource waste and sudden production stops, which may bring to dangerous assembly delays.

The plant maintenance derives from a careful study of the service theory. It is important to consider the “Bathtub Graph”, showed in the following image.

It illustrates the working tool failure modes. In this case the tools are those utilized in the VRM assembly department workstations.



Graph 5.1: Bath Tub graph

It is necessary to explain what the “Bathtub Graph” illustrates. In the axis of ordinates the average failure rate is represented, instead the time is represented in the axis of abscissas. The average failure rate is found through the following formula:

$$\text{Lambda} = 1/\text{MTTF} \tag{5.2}$$

MTTF is the mean time to failure. It signifies the average time between failures, that is the average time where the machines are available or the time necessary for the next failure. The MTTF can also be called UP, up time, as it can be seen before. Instead, Lambda indicates how many failures happen in one hour.

It is necessary to say that all the functions just considered are addicted to the time, as can be noticed from the graph.

In the graph only numbers and not the names of three categories of failures appear, because with the numbers allow to show the average failure rate, in the ordinate axis, as a percentage and in the abscissa axis the time is represented by numbers as a percentage of a tool life.

The Bathtub graph is divided in three zones, the zones describe the three categories of failures.

The first failure category is the “Infant Mortality” failure, it goes from zero to twenty percent more or less of the tool cycle life and it has a high failure probability as shown by the Bathtub graph. The

tool has a high failure rate in its first cycle life because it is new, hence an high defectiveness rate is more probable during the tests and the break-in; but the average failure rate decreases with the tool utilization, until arriving at the second failure category.
The second failure category is called "Constant" failures, it describes sixty percent of the tool cycle life and it is the central part of the graph. It can noticed that the failure rate remains constant during this period. The Constant failure zone is also called "Random" failure zone, because the failures can happen suddenly, or the failure can be avoided thanks to programmed maintenance.
The third failure zone is called "Wear Out" failures. It is collocated on the last part of the Bathtub graph. The last graph zone indicates the tool state wear, the working instrument is at the end of its cycle life, it has to be replaced or the wear out tool part has to be repaired. If a heavy maintenance is not done, the tool will start more frequently to break, increasing the average failure rate, as the graph shows.
Therefore, it is necessary to actuate a service policy that ensures the continuous working process in the VRM assembly plant, without sudden process stops, in order that the 45 workstations are able to assembly the expected pieces with the running tools; thus, avoiding production delays and guaranteeing a high production quality level. Accordingly, it is useful to follow the Bathtub graph to know if a tool necessities a preventive maintenance or it can work until failure.
After having analyzed the average failure rate during the tool cycle life, the failure mode and effect analysis have to be considered.
The failure mode and effect analysis is an important Lean Manufacturing method that has to be applied on the production process; in this way is possible improve the assembly plant production quality. The "FMEA", i.e. the acronym of failure mode and effect analysis, is a Lean instrument that enters in the maintenance of the assembly department tools, necessary for the production process. This solution tries to totally eliminate the sudden failures, utilizing a prevention failure policy. For example, workers assigned to the maintenance do a programmed service, or in certain periods they do overtime maintenance, or the plant is well organized with the necessary spare parts, in this way the mean time to repair can be reduced.
Therefore, the mean time to failure increases, thanks to these solutions; indeed the up time extends, increasing the tool cycle lives and, hence, the coefficient K_2 enhances, and, accordingly the number of finished components could be respected, or even it may increase, ensuring a probable overproduction request from the customers during the year.
The "FMEA" fundamental passages are summarized in the following list:

- Fix the failure modes, trying to find how many ways a tool can failure;

- Create a list of the all possible causes for each failure mode;
- List all the possible effects for every failure modes, the dangerous effects have to be carefully taken into account for safety reasons;
- Define a failure probability, the effect severity and the possibility to observe a probable next failure through some prevention controls and checking, for each combination of failure modes, failure effects and failure causes.

Therefore, actuating the list passages, they help to decrease the failure probability and the failure frequency. [3]
Accordingly, a right and accurate maintenance and the application of the failure mode and effect analysis in the VRM assembly allow for production quality improvements, thanks to the respect of the expected production numbers, the decrease of resource waste, avoiding sudden production stops, safety improvement in the workplace, cost reductions in the assembly plant, warranty cost reduction, better product ensurance and enhanced production quality image to the customers, plus technical development of the assembly department know-how.
It is important to see and describe how the VRM assembly plant applies the explained Lean Manufacturing service solutions.
VRM maintains the integrity of the working instruments as a maintenance policy in the assembly plant. Indeed VRM, following the Bathtub graph, does a tool service on the instruments that necessity a substitution of the wear-out parts and instead, for other tools the maintenance is actuated when a failure happens.
VRM does not apply a prevention service policy following the probability rules, but after the maintenance for component wear-out and tool failure, it puts on an overtime prevention maintenance and a checking of the all workstation tools and assembly plant working instruments. This special service follows the "FMEA" theory rules, during August, when the company is closed. In this way it is possible to verify the tools' availability and functionality and it is possible to substitute the wear-out or broken pieces without creating production stops, disorders in the workstations and disturbance to the workers; hence, the maintenance is executed within the expected time and resources spending, avoiding production problems.
The creation of an efficient technical assistance inside the assembly is a further important maintenance solution that VRM implements to enhance the assembly department production quality.
VRM has created a dedicated team of workers as mechanics, their task is to maintain the tools available to process and assembly the products, actuating when it is necessary a maintenance of the

wear-out pieces and substituting the failure pieces with new parts. The mechanic team has also the task of spare parts organization, in order for the plant to not remain without the necessary replacements.
The creation of the maintenance team inside the VRM department has the aim of avoiding sudden production stops and to speed up the replacement of broken tools when an unexpected failure happens, thus, trying to stop the assembly process as seldom as possible.
The VRM assembly plant could require an external assistance for its service in the case of severe failures.
Therefore, it is important to apply the Lean Manufacturing maintenance solutions in the VRM assembly plant, a fundamental contribution to the improvements of the production quality.
In this way no production delays are caused, no time is wasted for maintenance, but the time and resources are accurately spared for a complete dedication to the production quality, in order for the customers to perceive the qualitative commitment.
Accordingly, the high assembly production quality has to be rewarded by an increase of the assembly plant income statement. Finally trying to obtain a positive profit.
The described Lean Manufacturing service system is studied and applied in the VRM workplace.

Figure 5.5: A workstation on maintenance

5.3 ASSEMBLY LEAD TIME

It is important to consider the department "Lead Time" to improve another step of the VRM assembly plant production quality.

The "Lead Time" is the crossing time of a component from the beginning with the raw product to the end of the assembly process with the finished product.
The "Lead Time" is fundamental because it gives an overview of the production process, comparing the production activities that give value to the product with the processes to those who do not, hence, the customer does not pay. Therefore, the process activities without added value inside the VRM assembly department should be eliminated or reduced as much as possible.
The "Lead Time" is the summary of the all processes that transform an initial raw component to a finished one, giving the product all the quality characteristics required by the customers.
The processes that contribute to the sum of the "Lead time" times can be for example: waits, movements, tooling, working queues, processing, quality checks, stock.
Only the processing adds value to the assembled product, therefore the other production passages are a waste of time and resources even if necessary for the entire process and assembly plant.
The objective is to keep the "Lead Time" low, in order that the time wastes can be kept under control.
The Value Rate is an index that explains if a plant works with low time wastes, dedicating more attention to the product manufacture, or if a plant works with a lot of time wastes in the no added value processes.
The Value Rate can be calculated with the following formula:

$$To / Ttot \tag{5.3}$$

To is the processing time, instead, Tot is the Lead Time that includes all the process steps.
The Value Rate should be kept near to one, in order for the Lead Time, Ttot, to be low and similar to the processing time, To; thus, the no added value time processes are very low. Instead if the Value Rate is very low it signifies that the plant loses a lot of time in process waste.
An effective Lean Manufacturing solution to avoid assembly wastes, whilst improving the production quality giving more added value to the product and reducing the times of the not added value items.
The VRM assembly department approach is to keep the Lead time at the maximum of two days.
The VRM assembly department Lead Time depends to the assembly work cycle times but mostly to the delivery ability, to the buffer capacity and to the tooling and handlings velocity.
The two days Lead Time organization is due to the delivery planning and to the buffer capacity. Therefore, the production is anticipated of two days, in order for the finished products made for the customer to be delivered in time save sudden problems.

The production anticipation has the mean of assembly the components two days before the expected finished components delivery to the customer, in order for the assembly plant to proceed with its Lead Time.

The two days VRM assembly plant Lead Time is based on the process organization, unloading of raw materials, loading of raw materials in the buffer, unloading of the components to be processed from the buffer, components assembly, loading of the finished products in the buffer or immediately delivery to Ducati. It needs also to take into account in the VRM Lead Time all the material movements inside the VRM assembly plant.

Obviously the two days Lead Time can be reduced to the only assembly cycle time, if a production urgency is required by the customer. In this case the material to be assembled has to be ready in the buffer to be immediately processed and the finished products have to be delivered without waits; therefore a big resource effort has to be necessary. Hence, in this case the two days Lead Time becomes as soon as possible Lead Time.

In general, the VRM production is organized in the “FIFO” method. The “FIFO” method bases the assembly planning on the first material enters in the plant, it is the first finished piece that exits from the assembly department. In this way material queues and waits can be avoided, a lot of material movements can be reduced and the buffer can be kept in small sizes.

The VRM Lead Time organization is fundamental to respect the product delivery deadlines and to permit that the assembly plant works with its best efficiency.

In this way the production quality improves ensuring high quality standards, thus, satisfying the customer quality needs.

Therefore, the VRM Lead Time Lean Manufacturing solution can bring some benefits to the assembly plant, that will be demonstrated in the final income statement.

The reported Lean Manufacturing application systems to the assembly plant Lead Time are studied and applied in the VRM workplace.

Figure 5.6: An example of distance to cover inside the plant

5.4 SMED APPLICATION

Currently the VRM assembly plant is undergoing changes in the production system.
The assembly system in fact has on one hand a decrease in production lots while on the other hand is increasing the production lot variability. This means that the amount of equal products for each production lot diminishing, but the mount of different components to be assembled is increasing.
Obviously, the production lot contraction and variability increase cause confusion, disorder, time and resource waste, decrease of the production quality and amount of finished components.
The workstation tooling is the main problem and it decreases the efficiency K_4.
The tooling time is simply the time spent to change the tools necessary for the components assembly from a typology of product to another one in the workstations.
In fact the VRM assembly department workstations need more set-ups, because the product variability is increased. Each workstation has to assembly more piece typologies, but the same number of components for each production lot.
The workstations waste a lot of time on tooling, instead of assembling, because each production lot needs a different set-up.
Accordingly, the time wasted on the tooling brings to the decrease of the efficiency K_4 . In this way the production quality decreases, the production deadlines will be difficult to be respected, the number of finished products falls and hence, the customer will be annoyed.
It is important to underline that the tooling time does not give added value to the finished products.

The solution to the tooling problems can be found in the Lean Manufacturing theory with the "SMED".
"SMED" means of "Single Minute Exchange Of Die", and it is a Lean Manufacturing method to reduce the set-up time.
Following some steps to try to reduce the tooling times will be described in order to avoid creating production inconveniences and quality problems.
According to the "SMED" theory, it is important to identify, classify and divide the "internal activities" from the "external activities".
The internal activities are the tooling to conduct on the machines and the workstations that are stopped. Instead, the external activities are the set-ups that can be performed whilst the machines and workstations are running.
The "SMED" method suggests to convert the internal activities into external activities, in order for the set-ups to be made without creating production stops.
It is important to pay attention to the internal activities that cannot be converted into external ones, because while it is fundamental to speed up the internal activities, so the speeding up can give a contribution to the overall tooling time reduction.
Furthermore, it is important to minimize the external activities time because they require the work of some workers and could require too much time to prepare the instruments necessary for the set-up. Therefore, it would be useful to automate the tooling.
It is also important to consider some Lean Manufacturing suggestions to improve the tooling time, hence, trying to reduce it.
It is possible to reduce the set-up time only by timing and recording the tooling activities. Indeed, the set-up time in the plants has been reduced only thanks to the timing and without complex operations.
Then it is necessary to remember that the equation:

$$\text{SET-UP TIME X NUMBER OF LOTS = CONSTANT} \tag{5.4}$$

Therefore, if the department is able to reduce the tooling time, it will be possible to increase the number of finished components. But it is forbidden to reduce the number of finished products to gain some extra time to ensure a correct set-up.
The use of carts, where the tooling instruments are positioned, can simplify and speed up the set-up way, because they can be easily moved through the wheels to the workstations that necessity the

tooling, because they avoid workers physical efforts and they contain a lot of tooling instruments that avoid workers travels repetitions along the plant.
It is fundamental to have a well-organized production and handling of Kanban papers, as said in the second chapter, in order to know what exactly the workstations have to assembly and thus, the set-up tools are already prearranged in the workstations by the workers.
The careful maintenance of workstation instruments is fundamental to avoid severe production errors and production delays, but it is also fundamental to guarantee the working of the job tools, in order that the workstations will not need overtime set-ups that slow down the production.
Attention should be paid to the assembly department bottle necks, finding an optimal tooling time sequence, in order for the set-ups in the bottle necks to not extend and cause stops in the production flow.
Furthermore, controlled and careful production and product quality procedures have to be done, in order for a lot of resources and material waste to be avoided during production. Accordingly, the workstations do not need repetitive tooling, increasing the set-up time and thus, wasting a lot of precious time for the manufacture.
A further Lean Manufacturing detail to underline is the use of the “Little Machines”.
In the VRM assembly plant the term “Little Machines” is intended as the assembly instruments in the workstations.
The “Little Machines” concept is one of the most important theories of the Lean Manufacturing, useful for the “SMED” but also for other Lean facilitators that help the plant production flow organization.
The use of more and little working instruments, instead of few, big and expensive machines in the assembly department, allows to have more production flexibility, while keeping an eye on the production variability, to simplify the assembly organization through the Kanban papers, to reduce the movements of a big size lots to little ones, easier to move, to reduce the production problems in the case of failure or maintenance, to better organize the bottle necks, having more possibility to turn the workers, to automate the assembly department, helping the enhancing of the production flow and to decrease the assembly plant costs thanks to their lower management costs.
Finally, the implementation of little machines helps to decrease the set-up times, having an easier tooling systems, in this way the SMED improves and the working efficiencies increases, because the tools are always in operation with less stops due to the tooling itself, for different components to assembly or sudden problems.
In this way, the cash flow is sure to improve and creating a positive income statement.
The VRM assembly plant applies the “SMED” Lean Manufacturing theory saturating the tooling.

The tooling saturation means that the set-up has to be done only when it is strictly necessary. It needs to set the workstations with all the tools necessary for the assembly of more than only one piece, indeed it is a multiproduct tooling.
The saturation tooling is organized regarding both the available space and the working cycle times.
This means that the available space is organized with movable carts, multiple shelves, colored boxes, drawers and set working instruments, in order that the workstations are always plenty of organized material fundamental for the products assembly and thus, the assembly is simplified, speeded and well-ordered. Instead the working cycle times improves thanks to less stops necessary for the tooling, trying to never stop the production flow.
In this way the VRM "SMED" solutions for the production in the assembly workstations reduces the stops due to the set-ups, it increases the number of finished components and it enhances the production quality thanks to the tidy and cleanliness in the workstations. [4]
Summarizing the "SMED" method applied in the VRM assembly plant gives some advantages to the production quality:

- Increase of the machineries utilization ratio;
- Decrease of the finished products and raw materials stocks;
- Quicker answer to the trade demand;
- Increase of the production flow;
- Decrease of the costs, working cycle times and tooling time;
- Increase of the product and production quality;
- Decrease of the workers number;
- Less sudden production stops and not so frequent maintenance.

The application of the "SMED" Lean Manufacturing solution helps to reach a final positive income statement, granting good profits.
The just described Lean Manufacturing application systems to the assembly plant set-up activities were studied and applied in the VRM workplace.

Figure 5.7: A workstation tooling

5.5 ASSEMBLY PLANT ERGONOMICS

The paragraph deals with the ergonomic principles for the correct physical well-being of the workers.

The correct physical well-being of workers guarantees workplace safety and avoids physical damages. Therefore, the ergonomic studies all the methods and solutions to ensure work safety and well-being for workers, thus, avoiding dangerous situations and permanent physical pain.

The ergonomics regards both the product and the production process, hence, it is a fundamental part of the product quality and production quality of the VRM assembly plant.

It is important to describe the ergonomics solutions adopted by the VRM assembly department to ensure a correct working wellness.

The worker has to work with a regular rhythm; this means that the number of physical movements and the time during which the worker makes an effort must to be regularized, because there is a correlation to be respected between force exerted and the muscle contraction duration. A regular work rhythm avoids physical damages and promotes blood circulation.

The workers are organized to work standing at the VRM assembly plant workstations, and not to sit. This improves movements and posture, avoiding severe back damages. But workers cannot sit or stand for all the eight working hours, because this could create physical problems.

Therefore, it is important that the employees can move or have breaks; this i.e. standard working rhythm.

The possibility to regularize the workplace height is another fundamental tool for the workers well-being in the assembly department. Indeed, the weight of the components to move or lift has to be in the range of 15-25 kg depending on the workplace height, in accordance to labour laws.
The ergonomics has to be a standardized job, in order that possible safety errors or possible workers physical damages can be avoided.
It is necessary to put the job instruments in ordered positions and in dedicated shelves and boxes, keeping the workstations tidy and cleanliness, in this way obstacles in the workplace are avoided.
A further standardized ergonomics is the position of the finished components and boxes with pieces to process around the workstations. Indeed, the products and boxes cannot be positioned around the workstations and on the ground, behind the workers, because they would create a hindrance, where the workers can stumble, thus, possibly causing severe physical damages.
It is fundamental to know the best packaging-way, since they have to move big and heavy boxes full of components. This allows, the boxes to be easily moved and positioned, in order to avoid dangers or damages to muscles, back and feet.
The signposting on the ground through colored lines is important to understand the encumbrance of the workstations, the place where the pallets can be put, the lanes where the material handlers can run and where the workers can walk. In this way possible dangerous hindrance can be eliminated.
A further ergonomics instrument is the lighting. The VRM company has installed a led lighting system in the assembly department and at every workstations. Accordingly, the workplace is better illuminated. Therefore, the work is safer: the dangerous obstacles are in more evidence, the workers see better what they are doing and get less tired.
The noise has also to be taken into account because it can create severe damages to the workers' hearing. [5]
Finally, it is important to underline that with the application of the Lean Manufacturing ergonomic solutions the workers work in better conditions. In this way the workers fell better in the workplace, process more components, assembly the pieces with more attention, thus, increase the production quality.
Ergonomic tools overall improve the working feeling in the VRM assembly plant and the improve production quality; hence, help to guarantee a positive income statement with a good VRM assembly plant profit.
The just illustrated Lean Manufacturing ergonomics application methods to the assembly plant were studied and applied in the VRM workplace.

Figure 5.8: An ergonomic workstation

References:

[1] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.143-145.

[2] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.207-209.

[3] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.73-74.

[4] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.96-101.

[5] John Bicheno, Alberto Portioli Staudacher, "Metodologie e Tecniche per la Lean", 2009, pp.153-154.

CHAPTER 6: VRM FINANCIAL STATEMENTS

In this last thesis chapter some economic and efficiency aspects of the VRM assembly plant will be explained and analyzed.
These aspects will be useful to demonstrate the main hypothesis of this study.
The chapter will deal with the calculation of the assembly department direct costs, trying to take into account all the direct costs necessary to produce a finished motorbike.
Then the chapter will thus consider the billing, calculating the money that Ducati has to pay for the delivery of the requested amount of finished assembled products.
After, it will be important to consider the assembly plant efficiency aspect, demonstrating if the calculated workers' manpower is enough to assembly the expected components or if it is oversized and hence, there is a waste of resources.
Furthermore it will be necessary to compare Ducati's billing and the VRM direct costs, showing if an economic balance is respected.
Finally, an income statement will be drawn up, aiming at showing which are the costs and which the incomes of the VRM assembly department, highlighting if the assembly plant has had profits or losses in the first semester of the year 2019.

6.1 VRM ASSEMBLY PLANT DIRECT COSTS

It is important to define what is intended by direct costs.
Direct costs are all the costs directly interested in the production, i.e. those necessary to assembly the components and add value to the finished product.
The workers manpower is the principal direct cost considered for the finished assembled components and also a fundamental cost to take into account in the final assembly department income statement.
The workers assembly plant manpower is a significant direct cost for the VRM factory, because the employees work for eight or nine hours per day and are approximately sixty-four inside the department.
The right number of present employees depends on the production trend, on the programmed holidays and on illnesses. Therefore, the sixty-four workers are the hired ones for the first semester of the year 2019, but the right number of daily present workers depends on the employees daily plan and on the daily production organization.

Accordingly, the employees have to be paid at the end of each month and thus, as said before, the direct cost for the VRM plant are high.

A further detail to underline is how the number was calculated. The origin of this number was described in chapter 3, in particular the exact number of resources was calculated through specific formulas in paragraph 3.6 “Workstation Sizing”, where the number of workers was calculated based on the requested number of finished components required by Ducati at the beginning of the year, in order to complete the orders within the deadlines.

Instead, the indirect costs are not taken into account, they are what does not add value to the finished product.

The indirect costs can be for example the costs of the assembly plant building, of the working tools and consumables.

In the following table an example of the calculation of one worker manpower costs and hours is presented. There is a calculation based on a single worker example for the month of April and for the total considered semester, from January to June. Obviously the total hours and direct costs calculation has to be done for each month of the considered first current year semester and then for the sum of the total semester; but for length reasons it is not presented here.

WORKER	**WORKING APRIL HOURS**	**GROSS PAY**	**REMUNERATION FEES**	**OVERTIME HOURS**	**OVERTIME PAYEMENT**
Operator 1	154,25	1788,15 euro	608,86 euro	1	12,71 euro
	OVERTIME FEES	**ACCRUALS**	**ACCRUALS FEES**	**TFR**	**TOTAL APRIL**
Operator 1	4.22 euro	553,28 euro	184,03 euro	138,43 euro	3289,68 euro
	HOURLY COST APRIL	**TOTAL SEMESTER COST**	**TOTAL SEMESTER WORK HOURS**	**OVERTIME TOTAL SEM COST**	**PLANT**
Operator 1	21,18 euro	20.085,17 euro	982,5	400,53 euro	Assembly

Table 6.1: An example of Manpower direct costs

The number of the hired employees is seasonal as the motorbikes production during the year and the workers hourly cost is not always equal for all the employees, but it depends on the contractual status.

Subsequently it is necessary to show through a table the total costs of the all employees manpower in the VRM assembly department for the months of the first semester of the year 2019. The calculation has to be done by summing the total costs of every workers for each month from January to June.

TOTAL SEMESTER WORKERS COSTS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
907.616,76 euro	108.100,32 euro	155.990,41 euro	175.959,06 euro	161.149,76 euro	168.417,21 euro	138.000 euro

Table 6.2: First semester total VRM assembly plant direct costs

The direct costs trend of the first semester of the current year increases from January to June. The explanation can be found in the production development, in fact the seasonal motorbike production of VRM assembly plant has an assembly peak exactly in the first semester of the year, where the request of finished motorbikes rises before the summer.

Therefore the considered first semester of the year is the most difficult to manage from the production and organization point of view and it is also the most expensive from the material and resources aspect.

Finally, the VRM assembly plant manpower trend graph can be drawn up to better see how the manpower state changes during the first semester of the year 2019.

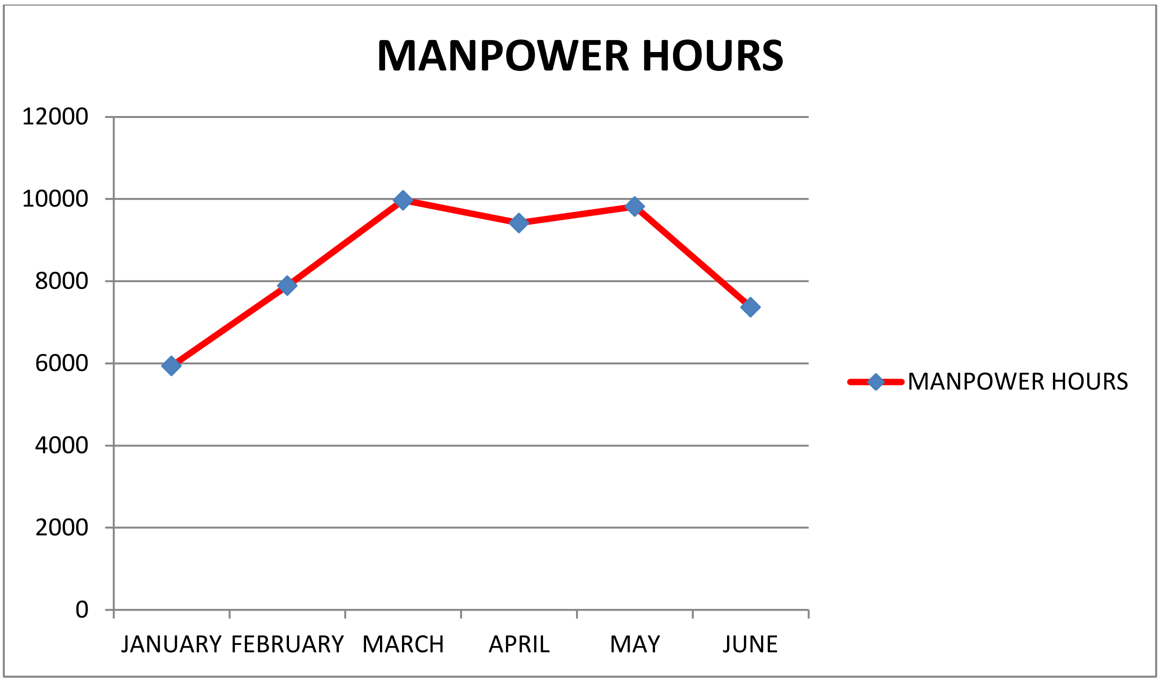
The graph considers all the manpower hours of all employees present in the assembly department for each month from January to June. Making it possible to see the required manpower hours to assembly the expected number of finished products.

From the graph we notice how the manpower hours trend increases from January, levelling from March to May, when the production peak is high, then the manpower hours demand slightly decreases in June, because from June the seasonal motorbikes trend starts to decrease.

The VRM assembly plant needs to be prepared for the variation of the manpower hours demand, in order that to avoid waste of resources.

In fact, it is fundamental to keep in mind that if the manpower hours and the number of workers increase the direct costs will strongly grow.

The personnel management is competence of the VRM human resources office.



Graph 6.1: Semester Manpower hours trend

6.2 VRM ASSEMBLY PLANT BILLING

In this paragraph the mean of billing and some data about the VRM assembly plant sales revenue will be introduced and explained.

The billing is how much the main customer pays for the work performance offered.

In the case of the VRM assembly department, its billing are the sales revenue for the production of the finished assembled components to the customer Ducati.

The billing happens when the requested amount of finished products are delivered to the customer, normally at the end of each production month.

It is important to not confuse billing with earning; in fact, the billing is the payment done by the customer to its supplier for the finished assembled components produced inside the VRM assembly plant, and will be discussed in this paragraph. Instead, the earning is what the supplier, i.e. VRM, earns from the billing removing the costs; but this topic will be discussed in the last chapter paragraph.

In the following table an example of VRM assembly plant billing will be presented.

The data regarding how much Ducati pays VRM for its work performances are top secret. Therefore, only a little example can be shown. The illustrated example is about one motorbike model produced in a generic month of the first considered semester of the current year.

For each single motorbike model all the components that are assembled inside the VRM assembly department are taken into account. Obviously, the billing work has to be done for all the assembled pieces that compose the produced motorbikes from January to June of 2019.
In the appendix A there is a complete list of the assembled products in VRM assembly plant.
The billing is a fundamental topic to be treated because it will be useful to compare the direct costs and to complete the final income statement.
In the table billing example the considered motorbike model is present, as is the amount of finished motorbikes, for each single model, produced in the considered month, the cost of each finished motorbike and the total monthly billing of this single treated motorbike model.
Some important calculation and aspects must though be described and explained.
The number that represents the total amount of finished motorbikes regards the total assembled pieces that compose a single motorbike. As said previously, VRM does not assemble the final motorbike, but only its components.
Therefore, all the assembled pieces for each billed motorbike need to be taken into account. To calculate the costs of each single motorbike. Hence, it is fundamental to know all the products work cycle times of the finished pieces processed in the VRM assembly plant. The products works cycle times have been presented in paragraph 3.2 “Work Cycle Time Timing”, 3.5 “VRM Work Cycle Times”, and illustrated in the tables in the appendix.
In this way, the total costs of the assembled components that compose a single motorbike can be calculated knowing the products work cycle times and the manpower hourly costs.
It is important to describe the fundamental calculations necessary for the billing.
Firstly the workers hourly labour cost has to be taken into account, then, it needs to multiply it for the sum all the work cycle times of the assembled components that compose a single motorbike. In this way it is possible to find the cost of a single motorbike. The considered formula is:

HOURLY LABOR COST X TOTAL WORK CYCLE TIMES = ONE MOTORBIKE COST (6.1)

The formula used to find the billing of the total motorbikes produced for a single model in a generic month is:

ONE MOTORBIKE COST X MONTHLY FINISHED MOTORBIKES = MONTHLY BILLING (6.2)

Obviously to know the total monthly billing it is necessary to do the same job described above for all the motorbike models produced in the considered month; it will be useful for the total VRM assembly department billing.
In the following table a billing example of one single motorbike model assembled in a generic month of the 2019 first semester will be shown.

MOTORBIKE MODEL	**MONTH**	**HOURLY LABOR COST**	**TOTAL CYCLE TIMES**
Ducati Model	Generic	23,50 euro/hour	121 minutes
MOTORBIKE MODEL	**1 MOTORBIKE COST**	**N. MONTHLY MOTORBIKES**	**MONTHLY BILLING**
Ducati Model	47,39 euro/moto	963	45.636,57 euro

Table 6.3: A billing example

It is important to underline that in this case the cost of each motorbike, composed by all the assembled pieces in VRM assembly plant, includes only the assembly department manpower direct costs, as explained in the previous paragraph.
The hourly labour cost means an average hourly manpower cost; it is used to simplify the calculations.
Some data are presented in minutes others in hours, for the calculations it is easy to convert them into the same measure system.
In the calculated and treated VRM assembly plant billing system only the direct costs, i.e. manpower costs, are billed, because the Lean Manufacturing method less influences the indirect costs, that are more or less always fixed.
This calculation billing system, shown in the previous table, will be helpful in the last paragraph of this chapter, where the income statement will be drawn up. In that case the VRM assembly plant billing will be done for the entire first semester of the current year.
The VRM assembly plant billing paid by Ducati factory occurs at the end of each month; in this way the customer pays the supplier the exactly number of finished assembled and delivered components. Therefore, VRM assembly department always has to be in time with the products deliveries, without any delay.
The Lean Manufacturing methods, studied in this thesis, always help to reach these goals.

Figure 6.1: An example of component on assembling

6.3 MANPOWER UTILIZATION COEFFICIENT

In this paragraph, the global manpower utilization coefficient of the VRM assembly plant will be studied.

It is important to know how many workers manpower hours are utilized to assembly the components necessary to build the finished Ducati motorbikes. All the assembly department employees work hours are dedicated to assembly the pieces.

The VRM assembly plant makes the manpower hours plan at the beginning of the year, studying how many workers the department needs to assembly the expected components. Therefore, the VRM plant hires a specific number of employees, knowing how much time is necessary to assembly a product from the work cycle times of the third thesis chapter, in order that the hired workers have to carry out the ordered job without waste of precious time.

The Ducati customer does the same task to know how much time is necessary to assembly and deliver the pieces necessary to build their finished motorbikes. Indeed Ducati observes the products work cycle times, as can be seen from the paragraph 3.1 "Ducati Work Cycle Times" of the third thesis chapter.

In this way Ducati knows the time that it has to pay to VRM to have its required pieces and it does not accept and pay waste of time and what does not add value to the finished product. Accordingly, Ducati pays only the number of required products delivered in its expected time without permitting any delay. The Ducati payment way to VRM can be seen from the previous paragraph.

Therefore, each delay or waste of labour hours of the VRM assembly plant are not taken into account by Ducati, and are merely a responsibility of VRM.
For this reason it is fundamental to study the VRM assembly plant manpower utilization coefficient to find the manpower working efficiency.
The manpower utilization coefficient is useful to see if VRM assembly department has a good job performance without wasting labour hours, respecting to the working hours that Ducati has calculated and pays, in order the assembled pieces are finished and delivered.
It is important to illustrate some formulas necessary for the calculation of the manpower utilization coefficient.
Starting with the calculation of the total hours necessary to assembly the amount of total pieces that compose the Ducati motorbike models for each month of the first semester of the current 2019 year.
To find the total monthly labour hours to assembly all the VRM products, the billing tables must be considered, in this way it is possible to know precisely how many assembled components are assembled for all the Ducati models in each month.
Then, it needs to be multiplied, for each motorbike model, the total amount of finished motorbikes for the all work cycle times of the assembled pieces that compose the considered motorbike model.
In this way, the result will be the total hours necessary to assembly all the components for the total amount of motorbikes that are finished in each treated month.
At the end, it needs only to apply the sum operation, to know the total hours utilized to assembly all the components for every Ducati models.
It is important to underline that the above mentioned hours belong to the Ducati calculated hours, hence they are the billed hours.
To simplify the ideas a calculation and example table follow.
The explained used formula is:

$$\text{TOTAL MOTO HOURS} = \text{TOTAL CYCLE TIMES X N. FINISHED MOTOS} \qquad (6.3)$$

A brief table to summarise what has to be considered:

MOTORBIKE MODEL	**MONTH**	**N. FINISHED MOTO**	**TOTAL CYCLE TIME**	**TOTAL HOURS**
Ducati model	May	807	117 minutes	1574 hours

Table 6.4: An example of hours necessary to complete a motorbike model

Only the total number of hours necessary for a single motorbike model assembled in that month are reported. Hence, the same tables should be created for all the motorbike models assembled by VRM for each month of the first semester of the year 2019, to have the sum of all Ducati models total labour hours.

Instead, the real manpower hours utilized by the VRM assembly plant workers are those counted in the first paragraph of this chapter, in fact they are the assembly department direct costs.

After having all the information necessary, the VRM assembly plant manpower utilization coefficient can be considered.

The manpower utilization coefficient is a simple formula that indicates a labour hour efficiency. In fact, it underlines how many labour hours the VRM assembly department utilizes to assembly the request products, respect to, how many labour hours are considered by Ducati for the billing, for the assembly and delivery of the ordered components.

Higher is the labour efficiency better is the resources utilization, in particular the waste of manpower hours is reduced.

Obviously if the utilization coefficient remains high for the considered first semester, the final income statement will be positive, with also a positive VRM assembly plant profits.

Indeed, an high labour utilization coefficient implies a difference between the VRM manpower direct costs and the manpower hours billing is present. In this way the waste of time and resources is strongly decreased.

Therefore, the VRM manpower utilization coefficient, for each month of the first semester, is a simple formula made by the total labour hours paid by Ducati and billed by VRM for all the assembled motorbike models in the treated month, divided by all the VRM workers manpower hours really used to assembly all the ordered components in each month.

The calculation formula is:

$$\text{MUT} = \text{TOTAL MOTORBIKE HOURS} / \text{REAL WORKER LABOR HOURS} \qquad (6.4)$$

MUT is a simplification of manpower utilization coefficient.

The results deriving from the previous formula can be summarised in a graph, indicating the trend of the manpower utilization coefficient for each month of the first semester of the year 2019.

The values of labour hours efficiency over the seventy percent can be considered acceptable for the VRM assembly plant, in order that the waste of resources can be limited.

It is important to underline that the manpower hourly efficiency has been calculated considering the workers labour hours instead of using the physical number of workers presences in the workplace.

The explanation can be found in the fact that the real used work in the assembly department, during the studied period, is more detailed and precise to calculate the labour utilization coefficient with the utilization of the manpower hours instead of the number of workers.

A further important clarification is the resolution of the variability because the utilization of the labour hours mostly specifies where and how many resources are utilized for the production.

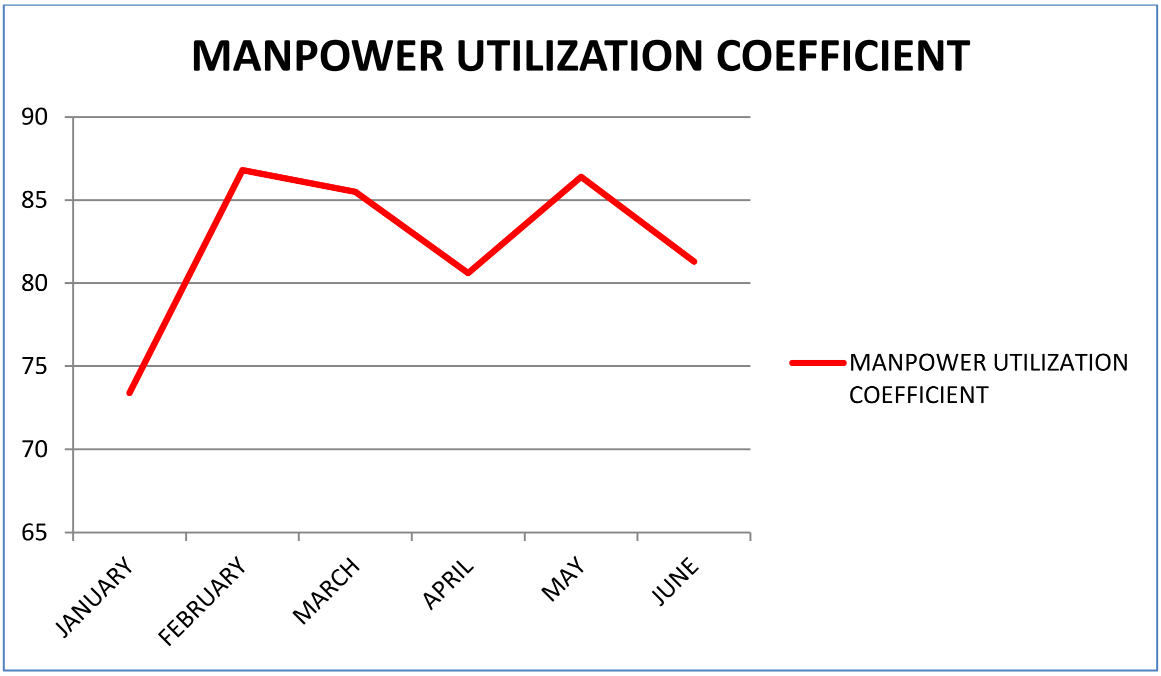
It is fundamental to say that January is the month with the lowest efficiency because there are more than required employees as explained when discussing flexibility and because of work training.

Instead, an higher manpower efficiency can be noticed in the central months of the first semester, during the pick of production, because a more work effort is required to the workers.

It can be noticed that the graph trend starts to decrease from June, because the number of finished assembly components decreases and thus the manpower hours request. Accordingly, it will be opportune to reconsider the overall number of employees in the assembly plant.

The graph shows the labour efficiency is always less than the one hundred percent, that would be the perfection, because it needs to take into account the workers problems and necessities like the breaks, absenteeism, illness and preparation to the job.

Following the manpower utilization coefficient graph is illustrated.



Graph 6.2: Semester Manpower utilization coefficient trend

The just illustrated labour utilization coefficient data applied to the VRM assembly plant are studied and elaborated in the VRM workplace.

6.4 BILLING AND DIRECT COSTS COMPARISON

In this paragraph the comparison between the VRM assembly plant billing and its direct costs will be shown.

Indeed, after having explained, in the previous paragraphs of this chapter, the VRM assembly plant direct costs and the billing of the first semester of the current year; now, it is opportune to illustrate, through only one graph, the trend of the direct costs together with the trend of billing from the month of January to June of the year 2019.

In this way, it is possible to see how much the applied Lean Manufacturing method on the VRM assembly department system is positive for billing or negative for the direct costs.

It is important to remember what has been said in the previous paragraphs about the VRM assembly plant direct costs and its billing.

The direct costs are simply the VRM assembly department workers manpower hourly costs necessary to assembly the pieces that compose the Ducati motorcycles. Therefore this is a necessary cost, because it adds value to the finished products.

Instead, the billing is simply the payment of the finished assembled and delivered components done by the customer Ducati. It needs to say that in the considered billing the indirect costs are neglected.

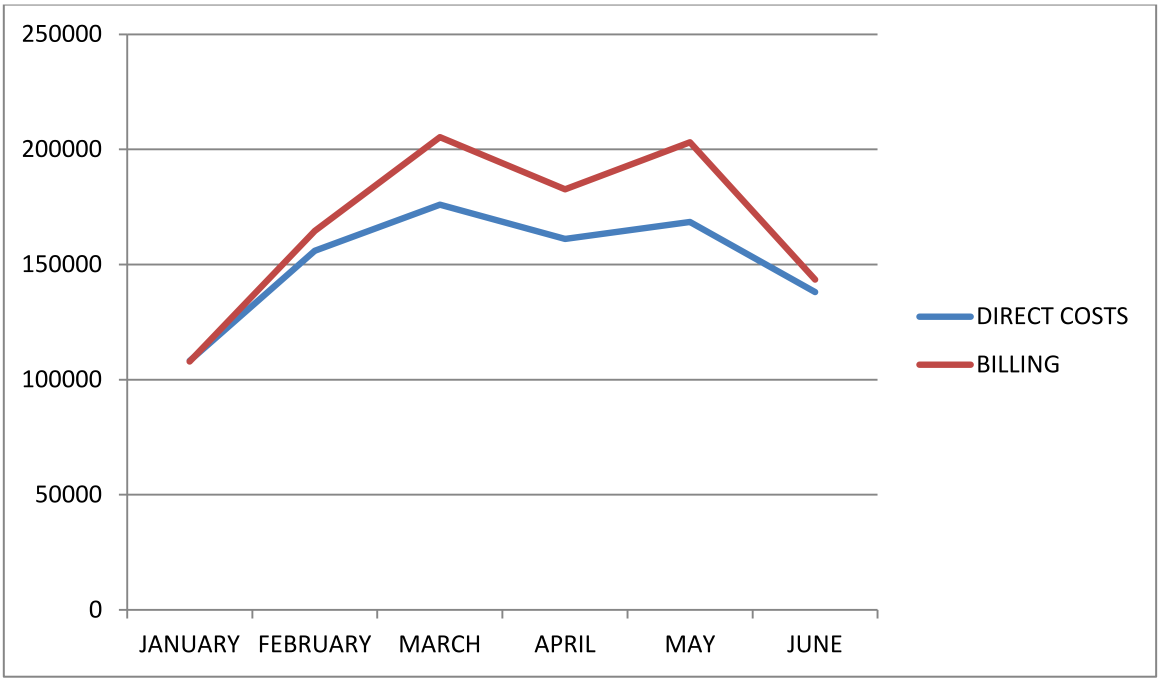
The following graph will have only monetary data regarding the VRM assembly plant billing and labour hourly costs.

The importance of this graph is to see the distance between the two lines, because the more the lines are distant the more the difference between VRM assembly plant direct costs and its billing. The distance could signify a positive earning or a negative loss in term of money during the considered six months. Accordingly, it will be discovered drawing up the graph.

The data present in the graph was elaborated as explained in the previous chapter six paragraphs.

Following a comparison graph, highlighting the difference between costs and billing.

The data are expressed in the Euro.



Graph 6.3: Semester direct costs and billing trends

It is important to underline some fundamental aspects of the drawn up comparison graph.

It is possible to see that the trend of the direct costs is more linear than the billing line trend.

The labour direct costs follow the production trend of the first semester of the 2019, hence, from January it starts to increase deeply until the production pick of the months of March, April, May, as can be seen from the flat part of the blue line; then, from June the line slightly decreases because the drop production request.

The variation of the production trend requires the change of the number of workers present in the VRM assembly plant and thus, the labor hourly cost changes.

Instead, the billing line trend has more or less the same trend of the direct costs, in an upper position respect to the other one, because the billing should be always higher than the costs; in order for the assembly plant to have earnings. The billing line represents the billing of the amount of assembled components that compose the Ducati motorbikes.

It is important to describe the difference between the two lines in the graph. In fact, the line distance is representative of the earnings or loses of the assembly department.

In more detail it can be seen that the billing line is always above the manpower direct costs, except the month of January, where the two lines are very near and they touch each other. This signifies that the VRM assembly plant always has a variable and positive profit in the five months of the considered semester, except the month of January where the result was a slight loss because the two lines cross at one zero gain point.

The explanation of this trend can be found in the semester production trend and required workers manpower. Indeed, in the month of January the VRM plant has to hire more workers than request from the production numbers, because the flexibility.
In this way in January the VRM assembly plant prepares the new workers training them to the pick of production of the next months. Therefore in this case the direct costs are slightly higher than the billing.
In the months of February, March, April and May the two lines are visibly distant, because all the employees work with a high labour utilization coefficient. Accordingly, in these months there will be positive profits with probable earnings.
The depth study of the probable earnings and loses will be done in the income statement present in the next paragraph.
Passing to June, the last month of the considered semester, the two lines start to approach again due to the transitory workers and the decrease of the production trend.
Therefore in the month of June the direct costs increase compared to the billing decrease. Indeed the transitory workers are those hired only for a certain period of the year; hence, in the month of June some workers are dismissed for the transitory contract reason and also because the decrease of the production request; but other new employees have to be hired and trained for the next months as it is done in January.
Accordingly, the workers training decreases the manpower utilization efficiency; in this way the direct costs increase; but the decrease of the production numbers, for seasonal reason, brings to the decrease of the VRM assembly plant billing.
Obviously, the graph shows that the direct costs decrease instead of an increasing because the drop of the production request; hence, the reduction of the workers labour hours, is higher than the direct costs of the new hired and trained employees.
The just done explanation underlines the reason why the two lines are near and the reason why in the month of June the margins of positive profit are very low.
The described comparison data applied to the VRM assembly plant are studied and elaborated in the VRM workplace.

6.5 VRM ASSEMBLY PLANT INCOME STATEMENT

In this final thesis paragraph the summary of the Lean Manufacturing method applied in the VRM assembly plant to draw up this thesis and the final economic results of the considered department will be presented.
It is important to underline that the economic results shown in the following through a graph, are the result of a depth study and application of the Lean Manufacturing theory in the VRM assembly plant.
Indeed the studied and applied Lean Manufacturing passages, as seen and read in the previous paragraphs, contribute in the process of reaching positive results in terms of reducing resource waste, workers wellness, workplace safety, optimal production organization and capacity to reach the VRM goals.
The economic results are the last point this study aims at presenting, in order to demonstrate if the Lean Manufacturing method has had positive economic contributions. Therefore, writing the VRM assembly plant income statement is the main objective of this paragraph.
It is the moment to draw up the income statement and to discover the assembly department profits and losses, after having described the VRM assembly plant labour direct costs, the billing and the manpower utilization efficiency.
The income statement considers first semester of the year 2019.
It is fundamental to explain, through a formula, how the income statement is built.
Starting with the manpower direct costs that are the expenses and with the billing that are the income. Then it is necessary to make the difference between the income and the expenses for each month of the treated first 2019 semester. This calculation permits to find the VRM assembly department earnings and the losses for each month.
The process can be better understood through the following formula:

$$\text{MONTHLY BILLING} - \text{MONTHLY COSTS} = \text{MONTHLY EARNINGS/LOSSES} \quad (6.5)$$

In this way it is possible to find the VRM assembly plant profits or losses data for the next graph.
Obviously, the total income statement can be done with the previous formula but taking the direct costs and billing of all first semester months.
The total income statement is not clearly written because it is a VRM reserved data.

All the founded and illustrated data in the following graph derived from the previous studies of the preceding paragraphs of this chapter.

The following graph indicates the profits and losses, describing the monthly profit and losses trend of the VRM assembly department.

The reference balanced budget point, to understand if the written values are a earning or a loss, is the reference number zero. All data are expressed in Euro.

Graph 6.4: Semester profits and losses trend

Obviously, the results now described can be also deduced from the previous paragraph comparison graph.

The graph trend is more or less similar to the graph of the previous paragraph, and the reasons of this trend are the same.

It can be noticed that in the month of January a slight loss is present, in fact the graph line goes under the reference balanced budget point zero. The loss has been previously explained, seen that the production is not still at high values but the numbers of workers is increased for flexibility and training reasons, hence producing direct investments costs. In this month the labour direct costs are higher than the VRM assembly plant billing. Accordingly, the difference between the two values is a negative number.

Then from February to March the line strongly rises until March and it remains in the highest position during the three central months of the semester that are March, April and May. In the month of April a little drop can be noticed because of the Easter holidays; hence, the production component numbers decrease but the manpower direct costs remain the same. In these three months the assembly department earnings are high; especially in May, the most significant productive month.

Finally, from May to June the line deeply goes down; hence, the profits decrease but they remain positive without any loss of money. The reason of this monthly trend are the transitory workers and the new employees to be trained, furthermore the seasonal production request decreases.

Therefore, summarising it can be said that the VRM assembly plant obtained positive profits for five out of six ones of the considered first semester of the year 2019, with a minor loss during one month.

Accordingly, it can be underlined that the Lean Manufacturing method application in the VRM assembly plant has brought several benefits.

The illustrated income statement data of the VRM assembly plant were studied and elaborated in the VRM workplace.

CONCLUSIONS

A comprehensive Lean Manufacturing application was performed in the VRM assembly plant. Based on the results obtained in the discussed paragraphs, the following conclusions can be drawn up.

Thanks to the constant and dedicated Lean Manufacturing theory application, it is possible to say that the main goals of this thesis have been reached. Following a list of every objectives reached in the VRM assembly department.

- Positive assembly plant income statement with important earnings during the analyzed semester;
- Maximization of the department resources considering the required production number components;
- Minimization of the production costs, bringing to successful economic results;
- Minimization and respect of the delivery times, delivering to the customers the ordered finished products without any delay;
- Reduction of the crossing times and stop production times, improving job efficiencies;
- Reduction and elimination of resource and time waste, avoiding loss of money and improving production;
- Obtaining a production flow with different components typology assembly, improving the production organization and the number of finished products;
- Achieving high product and production quality, increasing the products quality standards.

The Lean Manufacturing method application has thus brought important benefits to the VRM assembly department, from an economic to a production and organization point of view; but the thesis goals achievements have required work commitment, dedication to work and workers efforts.

It is fundamental to constantly apply the Lean Manufacturing theory, because only constant study and application of it will ensure the results.

This is what in the Japanese call the “Kaizen”, i.e. continuous improvement.

All the employees have to give their contribution to maintain the benefits and enhance them, even when the goal is difficult to achieve.

The next goal will be reached with constant and continuous improvement, experimentation, innovation, research and development. [1]

Figure: A finished and assembled motorbike component

References:

[1] John Bicheno, Alberto Portioli Staudacher, “Metodologie e Tecniche per la Lean”, 2009, pp.224.

APPENDIX

APPENDIX A: Tables of assembled components in the VRM assembly plant workstations

	WORSTATION NUMBER 5
DUCATI MONSTER	SWINGARM
DUCATI SUPERSPORT	SWINGARM 1312 AUSTRALIA

	WORKSTATION NUMBER 6
DUCATI DIAVEL	STGR REAR SWINGARM
DUCATI XDIAVEL	SWINGARM

	WORKSTATION NUMBER 7
DUCATI PANIGALE V4	STGR RADIATOR DUCT 1409

	WORKSTATION NUMBER 8
DUCATI MONSTER	STEERING BASE
DUCATI MONSTER 797	STEERING BASE
DUCATI MULTISTRADA	STEERING BASE 1106
DUCATI HYPERMOTARD	STGR STEERING BASE 092 SP D58
DUCATI DIAVEL	STEERING BASE 1309/1207
DUCATI XDIAVEL	STEERING BASE 1309/1207
DUCATI SUPERSPORT	STEERING BASE 1312

	WORKSTATION NUMBER 9
DUCATI PANIGALE V2	FLYWHEEL
DUCATI PANIGALE V4	FLYWHEEL
DUCATI MONSTER	FLYWHEEL
DUCATI MONSTER 797	FLYWHEEL
DUCATI MULTISTRADA	FLYWHEEL
DUCATI HYPERMOTARD	FLYWHEEL
DUCATI DIAVEL	STGR FLYWHEEL 1208
DUCATI XDIAVEL	FLYWHEEL
DUCATI SUPERSPORT	FLYWHEEL
DUCATI SCRAMBLER 800/400	FLYWHEEL
DUCATI SCRAMBLER 1100	FLYWHEEL

	WORKSTATION NUMBER 10
DUCATI HYPERMOTARD	VOLTAGE REGULATOR SUPPORT
DUCATI DIAVEL	CENTRAL SADDLE BOTTOM COVER
DUCATI DIAVEL	HANDLE RELEASE RING
DUCATI DIAVEL	INERTIAL SHELF STIRRUP
DUCATI XDIAVEL	CENTRAL SADDLE BOTTOM COVER
DUCATI XDIAVEL	PASSENGER SHELF

DUCATI SUPERSPORT	EXHAUST SUPPORT
DUCATI SUPERSPORT	EXHAUST HEAT SHIELD

	WORKSTATION NUMBER 11
DUCATI PANIGALE V2	CHASSIS

	WORKSTATION NUMBER 12
DUCATI PANIGALE V4	FINISHED CHASSIS 1409

	WORKSTATION NUMBER 13
DUCATI MONSTER	WATER RADIATOR

	WORKSTATION NUMBER 14
DUCATI PANIGALE V4	STGR REAR LATERAL EXHAUST HEAT SHIELD
DUCATI PANIGALE V4	STGR 1409 LED HEADLIGHT

	WORKSTATION NUMBER 15
DUCATI DIAVEL	CYLINDER OR
DUCATI DIAVEL	CYLINDER VR
DUCATI XDIAVEL	CYLINDER OR
DUCATI XDIAVEL	CYLINDER VR

	WORKSTATION NUMBER 16
DUCATI MULTISTRADA	STGR LEFT REAR CHASSIS
DUCATI MULTISTRADA	STGR RIGHT REAR CHASSIS
DUCATI MULTISTRADA	REAR RIGHT CHASSIS SYNCRO
DUCATI MULTISTRADA	REAR LEFT CHASSIS SYNCRO
DUCATI MULTISTRADA	EXPANSION VESSEL

	WORKSTATION NUMBER 17
DUCATI PANIGALE V4	STGR RIGHT FOOTREST PLATE 1409
DUCATI MONSTER	REAR RIGHT FOOTREST PLATE
DUCATI MONSTER	REAR LEFT FOOTREST PLATE

	WORKSTATION NUMBER 18
DUCATI HYPERMOTARD	STGR FRONT LEFT FOOTREST PLATE 1509
DUCATI HYPERMOTARD	STGR FRONT RIGHT FOOTREST PLATE 1509

	WORKSTATION NUMBER 19
DUCATI MULTISTRADA	STGR FRONT RIGHT FOOTREST PLATE 1504
DUCATI HYPERMOTARD	STGR LEFT PASSENGER FOOTREST PLATE 1509

DUCATI HYPERMOTARD	STGR RIGHT PASSENGER FOOTREST PLATE 1509
DUCATI MONSTER	FRONT RIGHT FOOTREST PLATE
DUCATI MONSTER	FRONT LEFT FOOTREST PLATE

	WORKSTATION NUMBER 20
DUCATI DIAVEL	STGR RIGHT FOOTREST PLATE 1309/1309S
DUCATI DIAVEL	STGR LEFT FOOTREST PLATE 1309
DUCATI XDIAVEL	FRONT RIGHT FOOTREST
DUCATI XDIAVEL	FRONT LEFT FOOTREST
DUCATI MONSTER	STARTER MOTOR TIMING

	WORKSTATION NUMBER 21
DUCATI MULTISTRADA	GLOVE COMPARTMENT
DUCATI MULTISTRADA	STGR TUBE RIDE CANISTER
DUCATI MULTISTRADA	STARTER MOTOR TIMING
DUCATI MONSTER	LICENSE PLATE

	WORKSTATION NUMBER 22
DUCATI MULTISTRADA	STGR 1504 LICENSE PLATE
DUCATI MULTISTRADA	LICENSE PLATE SYNCRO

	WORKSTATION NUMBER 23
DUCATI MULTISTRADA	STGR HEADLIGHT SUPPORT 1504
DUCATI MULTISTRADA	HEADLIGHT SUPPORT SYNCRO

	WORKSTATION NUMBER 24
DUCATI PANIGALE V2	RIGHT FOOTREST PLATE
DUCATI PANIGALE V2	LEFT FOOTREST PLATE

	WORKSTATION NUMBER 25
DUCATI MONSTER	ELECTRIC COMPONENTS SUPPORT
DUCATI SUPERSPORT	HEADLIGHT

	WORKSTATION NUMBER 26
DUCATI PANIGALE V4	STGR BRAKING SYSTEM ABS 1409
DUCATI MULTISTRADA	STGR BRAKING SYSTEM ABS 1504
DUCATI MULTISTRADA	BRAKING SYSTEM SYNCRO
DUCATI XDIAVEL	ABS SYSTEM
DUCATI SUPERSPORT	BRAKING SYSTEM 1312

	WORKSTATION NUMBER 27
DUCATI MULTISTRADA	STGR STOP SENSOR PLATE
DUCATI MULTISTRADA	STGR HORN 1504
DUCATI DIAVEL	STGR BLACK LEFT LATERAL PLATE
DUCATI DIAVEL	STGR BLACK RIGHT LATERAL PLATE
DUCATI XDIAVEL	LEFT LATERAL PLATE
DUCATI XDIAVEL	RIGHT LATERAL PLATE
DUCATI XDIAVEL	VERTICAL COIL
DUCATI SUPERSPORT	HORN

	WORKSTASTION NUMBER 28
DUCATI MONSTER	ABS PIPES SUPPORT
DUCATI MULTISTRADA	STGR HORIZONTAL HEAD COVER
DUCATI DIAVEL	STGR PIPE RIDE CANISTER
DUCATI XDIAVEL	LOWER CODON CAP
DUCATI XDIAVEL	LOWER CASEBACK CODON
DUCATI XDIAVEL	PIPES RIDE
DUCATI XDIAVEL	CONNECTING ROD
DUCATI MONSTER	CANISTER STIRRUP SUPPORT

	WORKSTATION NUMBER 29
DUCATI MULTISTRADA	STGR CONNECTING ROD WATER RADIATOR 1504
DUCATI SUPERSPORT	WATER RADIATOR
DUCATI SUPERSPORT	MUFFLER SUPPORT

	WORKSTATION NUMBER 30
DUCATI PANIGALE V2	STEERING BASE
DUCATI PANIGALE V4	STGR STEERING BASE D68 1409
DUCATI HYPERMOTARD	STGR CANISTERROKI 1509
DUCATI SUPERSPORT	CANISTER

	WORKSTATION NUMBER 31
DUCATI MULTISTRADA	STGR FRONT LEFT FOOTREST PLATE 1504

	WORKSTATION NUMBER 32
DUCATI PANIGALE V4	STGR LEFT FOOTREST PLATE 1409

	WORKSTATION NUMBER 33
DUCATI PANIGALE V4	FIVE WAYS JUNCTION
DUCATI DIAVEL	STGR LICENSE PLATE ARM USA
DUCATI XDIAVEL	LICENSE PLATE

	WORKSTATION NUMBER 34
DUCATI MULTISTRADA	STGR SECONDARY AIR ACTUATOR
DUCATI MULTISTRADA	STGR HORIZONTAL COIL
DUCATI MULTISTRADA	STGR VERTICAL CENTRAL COIL
DUCATI MULTISTRADA	STGR LATERAL VERTICAL COIL
DUCATI MULTISTRADA	STGR AIRBOX COVER 1504
DUCATI MULTISTRADA	STGR SADDLE TANK SUPPORT 1504

	WORKSTATION NUMBER 35
DUCATI PANIGALE V4	STGR REAR SUSPENSION OUTRIGGER 1409
DUCATI PANIGALE V4	STGR CANISTER ROKI 1409
DUCATI SUPERSPORT	KINEMATIC REGULATION PLEXI

	WORKSTATION NUMBER 36
DUCATI MONSTER	ESPANSION VESSEL
DUCATI MONSTER	CANISTER
DUCATI MONSTER	RIGHT FRONT USA INDICATOR
DUCATI MONSTER	LEFT FRONT USA INDICATOR
DUCATI MONSTER 797	RIGHT FRONT INDICATOR
DUCATI MONSTER 797	LEFT FRONT INDICATOR
DUCATI MULTISTRADA	CANISTER
DUCATI MULTISTRADA	STGR TANK BLOW-BY
DUCATI MULTISTRADA	STGR REAR BRAKE OIL TANK SUPPORT
DUCATI HYPERMOTARD	STGR ESPANSION VESSEL
DUCATI SUPERSPORT	ESPANSION VESSEL

	WORKSTATION NUMBER 37
DUCATI PANIGALE V4	STGR FRONT CHASSIS 1409

	WORKSTATION NUMBER 38
DUCATI MONSTER	REAR CHASSIS USA
DUCATI SUPERSPORT	REAR CHASSIS 1312

	WORKSTATION NUMBER 39
DUCATI HYPERMOTARD	STGR REAR CHASSIS 1509

	WORKSTATION NUMBER 40
DUCATI PANIGALE V2	WATER COOLER

	WORKSTATION NUMBER 41
DUCATI MULTISTRADA	STGR ELECTRIC COMPONENTS SUPPORT 1504
DUCATI MULTISTRADA	KEY VERIFICATION
DUCATI MULTISTRADA	ELECTRIC COMPONENTS SUPPORT SYNCRO
DUCATI MULTISTRADA	KEYS KIT
DUCATI DIAVEL	KIT HANDS FREE 433 MHZ CE VRM USA

	WORKSTATION NUMBER 42
DUCATI PANIGALE V2	TANK STIRRUP
DUCATI PANIGALE V2	REAR CHASSIS
DUCATI PANIGALE V2	VERTICAL EXHAUST HEAT SHIELD
DUCATI PANIGALE V4	STGR REAR CHASSIS 1409

	WORKSTATION NUMBER 43
DUCATI PANIGALE V2	TANK STIRRUP
DUCATI PANIGALE V2	REAR CHASSIS
DUCATI PANIGALE V2	VERTICAL EXHAUST HEAT SHIELD
DUCATI PANIGALE V4	STGR REAR CHASSIS 1409

	WORKSTATION NUMBER 44
DUCATI PANIGALE V2	TANK STIRRUP
DUCATI PANIGALE V2	REAR CHASSIS
DUCATI PANIGALE V2	VERTICAL EXHAUST HEAT SHIELD
DUCATI PANIGALE V4	STGR REAR CHASSIS 1409

	WORKSTATION NUMBER 45
DUCATI PANIGALE V2	TANK STIRRUP
DUCATI PANIGALE V2	REAR CHASSIS
DUCATI PANIGALE V2	VERTICAL EXHAUST HEAT SHIELD
DUCATI PANIGALE V4	STGR REAR CHASSIS 1409

APPENDIX B: Tables of daily production quantities for each month of the 2019

	FEBRUARY 2019																			
DAY	**1**	**4**	**5**	**6**	**7**	**8**	**11**	**12**	**13**	**14**	**15**	**18**	**19**	**20**	**21**	**22**	**25**	**26**	**27**	**28**
DUCATI PANIGALE V2	21	21	21	21	21	21	11	11	11	11	11	11	11	11	11	11	11	11	11	11
DUCATI PANIGALE V4	21	21	21	21	21	21	21	21	32	32	32	32	32	32	32	32	32	32	32	32
DUCATI MONSTER	10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI MONSTER 797	10	10	10	10	10	10	10	10	10	10	10	5	0	0	0	0	0	0	0	0
DUCATI MULTISTRADA	40	40	40	40	40	40	40	40	40	40	40	40	50	50	50	50	50	50	50	50
DUCATI HYPERMOTARD	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
DUCATI DIAVEL	10	20	20	20	20	20	20	20	20	40	40	40	40	40	40	40	40	40	40	40
DUCATI X DIAVEL	10	10	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DUCATI SCRAMBLER 800-400	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI SCRAMBLER 1100	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10
DUCATI SUPERSPORT	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
TOTAL	184	204	204	204	204	204	183	183	194	214	214	209	224	224	224	224	224	224	224	224

	MARCH 2019																				
DAY	**1**	**4**	**5**	**6**	**7**	**8**	**11**	**12**	**13**	**14**	**15**	**18**	**19**	**20**	**21**	**22**	**25**	**26**	**27**	**28**	**29**
DUCATI PANIGALE V2	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
DUCATI PANIGALE V4	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
DUCATI MONSTER	20	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
DUCATI MONSTER 797	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI MULTISTRADA	50	50	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
DUCATI HYPERMOTARD	32	32	32	32	32	32	32	32	32	33	33	33	33	33	33	33	33	32	32	32	32
DUCATI DIAVEL	40	40	40	40	40	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
DUCATI X DIAVEL	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI SCRAMBLER 800-400	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	30	30
DUCATI SCRAMBLER 1100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI SUPERSPO	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

RT																					
TOTAL	224	234	244	244	244	244	244	254	254	265	265	265	265	265	265	265	265	264	264	264	264

	APRIL 2019																		
DAY	**1**	**2**	**3**	**4**	**5**	**8**	**9**	**10**	**11**	**12**	**15**	**16**	**17**	**18**	**19**	**23**	**24**	**29**	**30**
DUCATI PANIGALE V2	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	7	0
DUCATI PANIGALE V4	32	32	32	32	32	32	32	21	21	21	21	21	21	21	21	21	21	21	21
DUCATI MONSTER	30	30	30	30	40	40	40	40	40	40	35	30	30	30	30	35	40	40	40
DUCATI MONSTER 797	10	10	10	10	10	10	10	20	20	20	20	20	20	20	20	10	10	10	10
DUCATI MULTISTRADA	60	60	60	60	60	60	60	60	60	60	70	70	70	70	70	70	70	70	70
DUCATI HYPERMOTARD	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
DUCATI DIAVEL	30	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI X DIAVEL	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI SCRAMBLER 800-400	30	30	30	30	20	20	20	20	20	20	20	20	20	20	20	30	30	30	30
DUCATI SCRAMBLER 1100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI SUPERSPORT	10	10	10	10	10	10	10	10	10	10	10	20	20	20	20	10	10	10	10
TOTAL	264	254	254	254	254	254	254	253	253	253	258	263	263	263	263	258	263	260	253

	JUNE 2019																			
DAY	**3**	**4**	**5**	**6**	**7**	**10**	**11**	**12**	**13**	**14**	**17**	**18**	**19**	**20**	**21**	**24**	**25**	**26**	**27**	**28**
DUCATI PANIGALE V2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DUCATI PANIGALE V4	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
DUCATI MONSTER	30	30	30	30	30	30	30	30	30	30	20	20	20	20	20	20	20	20	20	20
DUCATI MONSTER 797	10	10	10	10	10	10	10	10	10	10	10	10	0	0	0	0	0	0	0	0
DUCATI MULTISTRADA	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	50	50	50	50	50
DUCATI HYPERMOTARD	11	11	11	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
DUCATI DIAVEL	20	20	20	20	20	20	20	20	20	20	10	10	10	10	10	10	10	10	10	10
DUCATI X DIAVEL	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

DUCATI SCRAMBLER 800-400	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
DUCATI SCRAMBLER 1100	0	0	0	0	0	0	0	0	0	0	0	0	5	10	10	10	10	10	10	10
DUCATI SUPERSPORT	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10
TOTAL	202	202	202	212	212	212	212	212	212	212	202	202	197	202	202	182	182	182	182	182

	JULY 2019																						
DAY	**1**	**2**	**3**	**4**	**5**	**8**	**9**	**10**	**11**	**12**	**15**	**16**	**17**	**18**	**19**	**22**	**23**	**24**	**25**	**26**	**29**	**30**	**31**
DUCATI PANIGALE V2	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	0
DUCATI PANIGALE V4	21	21	21	21	21	21	21	21	21	21	20	20	20	20	19	19	19	19	19	19	19	19	21
DUCATI MONSTER	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI MONSTER 797	0	5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	0	0	0	0	0	0
DUCATI MULTISTRADA	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
DUCATI HYPERMOTARD	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
DUCATI DIAVEL	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20	20	20	20	20	20	20
DUCATI X DIAVEL	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	0	0	0	0	0	0	0	0
DUCATI SCRAMBLER 800-400	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI SCRAMBLER 1100	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10
DUCATI SUPERSPORT	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
TOTAL	172	167	172	172	172	172	172	172	172	172	172	172	172	172	172	162	172	172	172	172	172	172	172

	SEPTEMBER 2019																
DAY	**5**	**6**	**9**	**10**	**11**	**12**	**13**	**16**	**17**	**18**	**19**	**20**	**23**	**24**	**25**	**26**	**27**
DUCATI PANIGALE V2	2	3	3	3	3	4	4	4	4	4	5	0	0	0	0	0	0
DUCATI PANIGALE V4	9	8	8	18	18	17	17	17	17	17	16	21	21	21	21	21	21
DUCATI MONSTER	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI MONSTER 797	0	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10
DUCATI MULTISTRADA	20	20	20	20	20	20	20	20	20	20	20	20	20	20	30	30	30
DUCATI HYPERMOTARD	21	21	21	21	21	21	11	11	11	11	11	11	11	11	11	11	11
DUCATI DIAVEL	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI X DIAVEL	0	0	0	5	5	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI SCRAMBLER 800-400	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI SCRAMBLER 1100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI SUPERSPORT	10	10	10	10	10	10	10	10	10	10	10	0	0	0	0	0	0
TOTAL	122	122	122	137	137	142	132	132	132	142	142	132	132	132	142	142	142

	OCTOBER 2019														
DAY	**9**	**10**	**11**	**14**	**15**	**16**	**17**	**18**	**21**	**22**	**23**	**24**	**25**	**28**	**29**
DUCATI PANIGALE V2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DUCATI PANIGALE V4	21	21	21	21	32	32	32	32	32	32	32	32	32	32	32
DUCATI MONSTER	20	20	20	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI MONSTER 797	10	10	10	10	10	10	10	10	0	0	0	0	0	0	0
DUCATI MULTISTRADA	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
DUCATI HYPERMOTARD	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
DUCATI DIAVEL	10	10	10	10	20	20	20	20	20	20	20	20	20	20	10
DUCATI X DIAVEL	10	10	5	0	0	0	0	0	0	0	0	0	0	0	5
DUCATI SCRAMBLER 800-400	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI SCRAMBLER 1100	0	0	0	0	0	0	0	0	10	10	10	10	10	10	10
DUCATI SUPERSPORT	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10
TOTAL	132	132	127	112	132	132	142	142	142	142	142	142	142	142	137

	NOVEMBER 2019													
DAY	**12**	**13**	**14**	**15**	**18**	**19**	**20**	**21**	**22**	**25**	**26**	**27**	**28**	**29**
DUCATI PANIGALE V2	0	0	0	0	6	11	11	11	11	21	21	21	21	21
DUCATI PANIGALE V4	32	32	32	32	21	21	21	21	32	32	32	32	32	32
DUCATI MONSTER	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI MONSTER 797	0	0	0	0	0	0	0	0	10	10	10	10	10	10
DUCATI MULTISTRADA	30	30	30	30	30	30	30	30	30	30	30	30	30	30
DUCATI HYPERMOTARD	11	11	11	11	11	11	11	11	11	11	11	11	11	11
DUCATI DIAVEL	10	10	10	10	10	10	10	10	10	10	10	10	10	10
DUCATI X DIAVEL	10	10	10	10	5	0	0	0	0	0	0	0	0	0
DUCATI SCRAMBLER 800-400	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DUCATI SCRAMBLER 1100	10	10	10	10	10	10	10	10	0	0	0	0	0	0
DUCATI SUPERSPORT	10	10	10	10	10	5	0	0	0	0	0	0	0	0
TOTAL	142	142	142	142	132	127	122	122	133	143	143	143	143	143

	DECEMBER 2019												
DAY	**2**	**3**	**4**	**5**	**6**	**9**	**10**	**11**	**12**	**13**	**16**	**17**	**18**
DUCATI PANIGALE V2	21	21	32	32	32	32	32	32	32	32	32	28	32
DUCATI PANIGALE V4	32	32	32	32	32	32	32	32	32	32	32	28	32
DUCATI MONSTER	10	10	10	10	10	10	10	20	20	20	20	18	20
DUCATI MONSTER 797	10	10	10	10	0	0	0	0	0	0	0	0	0
DUCATI MULTISTRADA	30	30	30	30	30	30	30	30	30	30	30	27	30
DUCATI HYPERMOTARD	11	11	11	11	11	11	11	21	21	21	21	19	21
DUCATI DIAVEL	10	10	10	10	10	10	10	10	10	10	10	9	10
DUCATI X DIAVEL	0	0	0	0	0	0	0	0	0	0	0	0	0
DUCATI SCRAMBLER 800-400	20	20	20	20	20	20	30	20	20	20	20	18	20
DUCATI SCRAMBLER 1100	0	0	0	0	10	10	10	10	10	10	10	9	10
DUCATI SUPERSPORT	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	143	143	154	154	154	154	164	174	174	174	174	152	174

APPENDIX C: Tables of VRM assembly plant work cycle times

	WORKSTATION NUMBER 6	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI DIAVEL	STGR REAR SWINGARM	9.72	10.98
DUCATI XDIAVEL	SWINGARM	6.75	7.63

	WORKSTATION NUMBER 7	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR RADIATOR DUCT 1409	22.00	24.86

	WORKSTATION NUMBER 8	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MONSTER	STEERING BASE	2.50	2.83
DUCATI MONSTER 797	STEERING BASE	2.50	2.83
DUCATI MULTISTRADA	STEERING BASE 1106	2.50	2.83
DUCATI HYPERMOTARD	STGR STEERING BASE 092 SP D58	2.75	3.11
DUCATI DIAVEL	STEERING BASE 1309/1207	2.50	2.83
DUCATI XDIAVEL	STEERING BASE 1309/1207	2.50	2.83
DUCATI SUPERSPORT	STEERING BASE 1312	2.50	2.83

	WORKSTATION NUMBER 9	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	FLYWHEEL	4.25	4.80
DUCATI PANIGALE V4	FLYWHEEL	3.50	3.96
DUCATI MONSTER	FLYWHEEL	4.25	4.80
DUCATI MONSTER 797	FLYWHEEL	5.00	5.65
DUCATI MULTISTRADA	FLYWHEEL	4.50	5.09
DUCATI HYPERMOTARD	FLYWHEEL	5.10	5.76
DUCATI DIAVEL	STGR FLYWHEEL 1208	5.00	5.65
DUCATI XDIAVEL	FLYWHEEL	4.30	4.86
DUCATI SUPERSPORT	FLYWHEEL	5.00	5.65
DUCATI SCRAMBLER 800/400	FLYWHEEL	5.00	5.65
DUCATI SCRAMBLER 1100	FLYWHEEL	4.50	5.09

	WORKSTATION NUMBER 10	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI HYPERMOTARD	VOLTAGE REGULATOR SUPPORT	1.30	1.47
DUCATI DIAVEL	CENTRAL SADDLE BOTTOM COVER	2.83	3.19
DUCATI DIAVEL	HANDLE RELEASE RING	1.92	2.17
DUCATI DIAVEL	INERTIAL SHELF STIRRUP	2.83	3.19
DUCATI XDIAVEL	CENTRAL SADDLE BOTTOM COVER	4.50	5.09
DUCATI XDIAVEL	PASSENGER SHELF	1.75	1.98
DUCATI SUPERSPORT	EXHAUST SUPPORT	1.00	1.13
DUCATI SUPERSPORT	EXHAUST HEAT SHIELD	1.25	1.41

	WORKSTATION NUMBER 11	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	CHASSIS	4.25	4.80

	WORKSTATION NUMBER 12	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR FINISHED CHASSIS 1409	13.50	15.26

	WORKSTATION NUMBER 13	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MONSTER	WATER RADIATOR	8.00	9.04

	WORKSTATION NUMBER 14	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR REAR LATERAL EXHAUST HEAT SHIELD	3.75	4.24
DUCATI PANIGALE V4	STGR 1409 LED HEADLIGHT	3.50	3.96

	WORKSTATION NUMBER 15	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI DIAVEL	CYLINDER OR	2.83	3.20
DUCATI DIAVEL	CYLINDER VR	2.04	2.30
DUCATI XDIAVEL	CYLINDER OR	2.75	3.11
DUCATI XDIAVEL	CYLINDER VR	2.00	2.26

	WORKSTATION NUMBER 16	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR LEFT REAR CHASSIS	2.90	3.28
DUCATI MULTISTRADA	STGR RIGHT REAR CHASSIS	10.10	11.41
DUCATI MULTISTRADA	REAR RIGHT CHASSIS SYNCRO	0.68	0.77
DUCATI MULTISTRADA	REAR LEFT CHASSIS SYNCRO	0.68	0.77
DUCATI MULTISTRADA	EXPANSION VESSEL	1.00	1.13

	WORKSTATION NUMBER 17	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR RIGHT FOOTREST PLATE 1409	6.00	6.78
DUCATI MONSTER	REAR RIGHT FOOREST PLATE	RIL	RIL
DUCATI MONSTER	REAR LEFT FOOTREST PLATE	RIL	RIL

	WORKSTATION NUMBER 18	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI HYPERMOTARD	STGR FRONT LEFT FOOTREST PLATE 1509	3.00	3.39
DUCATI HYPERMOTARD	STGR FRONT RIGHT FOOTREST PLATE 1509	6.75	7.63

	WORKSTATION NUMBER 19	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR FRONT RIGHT FOOTREST PLATE 1504	3.75	4.24
DUCATI HYPERMOTARD	STGR LEFT PASSENGER FOOTREST PLATE 1509	3.00	3.39
DUCATI HYPERMOTARD	STGR RIGHT PASSENGER FOOTREST PLATE 1509	3.00	3.39
DUCATI MONSTER	FRONT RIGHT FOOTREST PLATE	RIL	RIL
DUCATI MONSTER	FRONT LEFT FOOTREST PLATE	RIL	RIL

	WORKSTATION NUMBER 20	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI DIAVEL	STGR RIGHT FOOTREST PLATE 1309/1309S	6.78	7.66
DUCATI DIAVEL	STGR LEFT FOOTREST PLATE 1309	5.09	5.75
DUCATI XDIAVEL	FRONT RIGHT FOOTREST	5.50	6.22
DUCATI XDIAVEL	FRONT LEFT FOOTREST	4.25	4.80

DUCATI MONSTER	STARTER MOTOR TIMING	RIL	RIL

	WORKSTATION NUMBER 21	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	GLOVE COMPARTMENT	2.00	2.26
DUCATI MULTISTRADA	STGR TUBE RIDE CANISTER	4.75	5.37
DUCATI MULTISTRADA	STARTER MOTOR TIMING	0.55	0.62
DUCATI MONSTER	LICENSE PLATE	RIL	RIL

	WORKSTATION NUMBER 22	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR 1504 LICENSE PLATE	9.50	10.74
DUCATI MULTISTRADA	LICENSE PLATE SYNCRO	0.97	1.10

	WORKSTATION NUMBER 23	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR HEADLIGHT SUPPORT 1504	6.00	6.78
DUCATI MULTISTRADA	HEADLIGHT SUPPORT SYNCRO	0.97	1.10

	WORKSTATION NUMBER 24	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	RIGHT FOOTREST PLATE	5.75	6.50
DUCATI PANIGALE V2	LEFT FOOTREST PLATE	9.85	11.13

	WORKSTATION NUMBER 25	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MONSTER	ELECTRIC COMPONENTS SUPPORT	10.75	12.15
DUCATI SUPERSPORT	HEADLIGHT	1.75	1.98

	WORKSTATION NUMBER 26	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR BRAKING SYSTEM ABS 1409	8.00	9.04
DUCATI MULTISTRADA	STGR BRAKING SYSTEM ABS 1504	3.75	4.24
DUCATI MULTISTRADA	BRAKING SYSTEM SYNCRO	RIL	0.55

DUCATI XDIAVEL	ABS SYSTEM	4.00	4.52
DUCATI SUPERSPORT	BRAKING SYSTEM 1312	3.80	4.30

	WORKSTATION NUMBER 27	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR STOP SENSOR PLATE	0.75	0.85
DUCATI MULTISTRADA	STGR HORN 1504	0.25	0.28
DUCATI DIAVEL	STGR BLACK LEFT LATERAL PLATE	2.83	3.19
DUCATI DIAVEL	STGR BLACK RIGHT LATERAL PLATE	3.67	4.15
DUCATI XDIAVEL	LEFT LATERAL PLATE	2.50	2.83
DUCATI XDIAVEL	RIGHT LATERAL PLATE	3.25	3.67
DUCATI XDIAVEL	VERTICAL COIL	1.75	1.98
DUCATI SUPERSPORT	HORN	0.25	0.28

	WORKSTASTION NUMBER 28	CYCLE TIME	CYCLE TIME WITH EFICIENCY
DUCATI MONSTER	ABS PIPES SUPPORT	4.25	4.80
DUCATI MONSTER	CANISTER STIRRUP SUPPORT	1.50	1.70
DUCATI MULTISTRADA	STGR HORIZONTAL HEAD COVER	0.50	0.57
DUCATI DIAVEL	STGR PIPE RIDE CANISTER	6.49	7.33
DUCATI XDIAVEL	LOWER CODON CAP	4.70	5.31
DUCATI XDIAVEL	LOWER CASEBACK CODON	1.10	1.24
DUCATI XDIAVEL	PIPES RIDE	5.00	5.65
DUCATI XDIAVEL	CONNECTING ROD	0.75	0.85

	WORKSTATION NUMBER 29	CYCLE TIME	CYCLE TIME WITH EFICIENCY
DUCATI MULTISTRADA	STGR CONNECTING ROD WATER RADIATOR 1504	0.30	0.34
DUCATI SUPERSPORT	WATER RADIATOR	2.75	3.11
DUCATI SUPERSPORT	MUFFLER SUPPORT	0.50	0.57

	WORKSTATION NUMBER 30	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	STEERING BASE	2.75	3.11
DUCATI PANIGALE V4	STGR STEERING BASE D68 1409	2.50	2.83
DUCATI HYPERMOTARD	STGR CANISTER ROKI 1509	13.10	14.80
DUCATI SUPERSPORT	CANISTER	9.0	10.17

	WORKSTATION NUMBER 31	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR FRONT LEFT FOOTREST PLATE 1504	4.80	5.42

	WORKSTATION NUMBER 32	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR LEFT FOOTREST PLATE 1409	10.60	11.98

	WORKSTATION NUMBER 33	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	FIVE WAYS JUNCTION	2.00	2.26
DUCATI DIAVEL	STGR LICENSE PLATE ARM USA	14.75	16.66
DUCATI XDIAVEL	LICENSE PLATE	13.00	14.69

	WORKSTATION NUMBER 34	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR SECONDARY AIR ACTUATOR	1.25	1.41
DUCATI MULTISTRADA	STGR HORIZONTAL COIL	1.00	1.13
DUCATI MULTISTRADA	STGR VERTICAL CENTRAL COIL	1.00	1.13
DUCATI MULTISTRADA	STGR LATERAL VERTICAL COIL	0.25	0.28
DUCATI MULTISTRADA	STGR AIRBOX COVER 1504	0.50	0.57
DUCATI MULTISTRADA	STGR SADDLE TANK SUPPORT 1504	0.75	0.85

	WORKSTATION NUMBER 35	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR REAR SUSPENSION OUTRIGGER 1409	2.00	2.26
DUCATI PANIGALE V4	STGR CANISTER ROKI 1409	3.50	3.96
DUCATI SUPERSPORT	KINEMATIC REGULATION PLEXI	7.04	7.96

	WORKSTATION NUMBER 36	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MONSTER	ESPANSION VESSEL	3.15	3.46
DUCATI MONSTER	CANISTER	4.50	5.09
DUCATI MONSTER	RIGHT FRONT USA INDICATOR	1.70	1.92
DUCATI MONSTER	LEFT FRONT USA INDICATOR	1.70	1.92
DUCATI MONSTER 797	RIGHT FRONT INDICATOR	2.25	2.54
DUCATI MONSTER 797	LEFT FRONT INDICATOR	2.25	2.54
DUCATI MULTISTRADA	CANISTER	2.50	2.83
DUCATI MULTISTRADA	STGR TANK BLOW-BY	0.75	0.85
DUCATI MULTISTRADA	STGR REAR BRAKE OIL TANK SUPPORT	0.50	0.57
DUCATI HYPERMOTARD	STGR ESPANSION VESSEL	9.00	10.17
DUCATI SUPERSPORT	ESPANSION VESSEL	3.50	3.96

	WORKSTATION NUMBER 37	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V4	STGR FRONT CHASSIS 1409	4.50	5.09

	WORKSTATION NUMBER 38	CYCLE TIME	CYLE TIME WITH EFFICIENCY
DUCATI MONSTER	REAR CHASSIS USA	25.00	28.25
DUCATI SUPERSPORT	REAR CHASSIS 1312	20.75	23.45

	WORKSTATION NUMBER 39	CYCLE TIME	CYCLE WITH EFFICIENCY
DUCATI HYPERMOTARD	STGR REAR CHASSIS 1509	65.00	73.45

	WORKSTATION NUMBER 40	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	WATER COOLER	16.50	18.65

	WORKSTATION NUMBER 41	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI MULTISTRADA	STGR ELECTRIC COMPONENTS SUPPORT 1504	21.25	24.01
DUCATI MULTISTRADA	KEY VERIFICATION	1.60	1.81
DUCATI MULTISTRADA	ELECTRIC COMPONENTS	1.27	1.43

	SUPPORT SYNCRO		
DUCATI MULTISTRADA	KEYS KIT	4.75	5.37
DUCATI DIAVEL	KIT HANDS FREE 433 MHZ CE VRM USA	4.41	4.98

	WORKSTATION NUMBER 42	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	TANK STIRRUP	0.40	0.45
DUCATI PANIGALE V2	REAR CHASSIS	16.50	18.65
DUCATI PANIGALE V2	VERTICAL EXHAUST HEAT SHIELD	7.00	7.91
DUCATI PANIGALE V4	STGR REAR CHASSIS 1409	32.90	37.18

	WORKSTATION NUMBER 43	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	TANK STIRRUP	0.40	0.45
DUCATI PANIGALE V2	REAR CHASSIS	16.50	18.65
DUCATI PANIGALE V2	VERTICAL EXHAUST HEAT SHIELD	7.00	7.91
DUCATI PANIGALE V4	STGR REAR CHASSIS 1409	32.90	37.18

	WORKSTATION NUMBER 44	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	TANK STIRRUP	0.40	0.45
DUCATI PANIGALE V2	REAR CHASSIS	16.50	18.65
DUCATI PANIGALE V2	VERTICAL EXHAUST HEAT SHIELD	7.00	7.91
DUCATI PANIGALE V4	STGR REAR CHASSIS 1409	32.90	37.18

	WORKSTATION NUMBER 45	CYCLE TIME	CYCLE TIME WITH EFFICIENCY
DUCATI PANIGALE V2	TANK STIRRUP	0.40	0.45
DUCATI PANIGALE V2	REAR CHASSIS	16.50	18.65
DUCATI PANIGALE V2	VERTICAL EXHAUST HEAT SHIELD	7.00	7.91
DUCATI PANIGALE V4	STGR REAR CHASSIS 1409	32.90	37.18

APPENDIX D: Bottleneck tables

WORKSTATION NUMBER 5																					
MAY 2019																					
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 6																					
MAY 2019																					
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	4.24	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32	4.96	5.68	5.68	5.68	5.68	5.68	5.68	5.68	5.68

WORKSTATION NUMBER 7																					
MAY 2019																					
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 8																					
MAY 2019																					
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 9																					
MAY 2019																					
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 10																					
MAY 2019																					
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	4.24	6	6	6	6	6	6	6	6	6	6	6	6	4.88	5.60	5.60	5.60	5.84	5.84	5.84	5.84	5.84

WORKSTATION NUMBER 11																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

WORKSTATION NUMBER 12																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	6.32	6.32	8	8	8	8	8	8	8	8	8	8	8	8	8	8	6.16	6.16	6.16	6.16	6.16	6.16

WORKSTATION NUMBER 13																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	5.20	5.20	5.20	6.96	6.96	6.96	6.96	6.96	6.96	6.96	6.96	6.96	6.96	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20

WORKSTATION NUMBER 14																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	3.36	3.36	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	3.28	3.28	3.28	3.28	3.28	3.28

WORKSTATION NUMBER 15																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	2.08	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	2.64	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04

WORKSTATION NUMBER 16																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 17																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	2.80	2.80	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	4.08	2.72	2.72	2.72	2.72	2.72	2.72

WORKSTATION NUMBER 18																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	2.24	2.24	2.24	2.24	2.24

WORKSTATION NUMBER 19																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	7.12	7.12	7.12	7.12	7.12

WORKSTATION NUMBER 20																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	5.20	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	6.24	7.36	7.36	7.36	7.36	7.36	7.36	7.36	7.36

WORKSTATION NUMBER 21																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 22																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 23																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 24																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SAURATION RATE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

WORKSTATION NUMBER 25																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATRION RATE	7.36	7.36	7.36	8	8	8	8	8	8	8	8	8	8	7.36	7.36	7.36	7.36	7.68	7.68	7.68	7.68	7.68

WORKSTATION NUMBER 26																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 27																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	4.40	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.12	6.08	6.08	6.08	6.08	6.08	6.08	6.08	6.08

WORKSTATION NUMBER 28																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	7.04	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 29																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.92	1.92	1.92	1.92	1.92

WORKSTATION NUMBER 30																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 31																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28

WORKSTATION NUMBER 32																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	4.96	4.96	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	4.80	4.80	4.80	4.80	4.80	4.80

WORKSTATION NUMBER 33																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	7.36	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 34																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20

WORKSTATION NUMBER 35																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	4.08	4.08	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	4	5.52	5.52	5.52	5.52	5.52

WORKSTATION NUMBER 36																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 37																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	2.08	2.08	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	2.08	2.08	2.08	2.08	2.08	2.08

WORKSTATION NUMBER 38																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 39																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 40																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

WORKSTATION NUMBER 41																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 42																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 43																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 44																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

WORKSTATION NUMBER 45																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
SATURATION RATE	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

APPENDIX E: Tables of workstation sizing

WORKSTATION NUMBER 6																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.53	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.62	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
TOT	55																					

WORKSTATION NUMBER 7																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.28	1.28	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.25	1.25	1.25	1.25	1.25	1.25
TOT	55																					

WORKSTATION NUMBER 8																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.11	1.17	1.17	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.14	1.18	1.18	1.18	1.13	1.13	1.13	1.13	1.13
TOT	55																					

WORKSTATION NUMBER 9																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	2.77	2.91	3.01	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	2.93	2.99	2.99	2.89	2.87	2.87	2.87	2.87	2.87
TOT	55																					

WORKSTATION NUMBER 10																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.53	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.61	0.70	0.70	0.70	0.73	0.73	0.73	0.73	0.73
TOT	55																					

WORKSTATION NUMBER 11																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOT	55																					

WORKSTATION NUMBER 12																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.79	0.79	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	0.77	0.77	0.77	0.77	0.77	0.77
TOT	55																					

WORKSTATION NUMBER 13																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.65	0.65	0.65	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
TOT	55																					

WORKSTATION NUMBER 14																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.42	0.42	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.41	0.41	0.41	0.41	0.41	0.41
TOT	55																					

WORKSTATION NUMBER 15																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.26	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.33	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
TOT	55																					

WORKSTATION NUMBER 16																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91
TOT	55																					

WORKSTATION NUMBER 17																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.35	0.35	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.34	0.34	0.34	0.34	0.34	0.34
TOT	55																					

WORKSTATION NUMBER 18																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.28	0.28	0.28	0.28	0.28
TOT	55																					

WORKSTATION NUMBER 19																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	0.89	0.89	0.89	0.89	0.89
TOT	55																					

WORKSTATION NUMBER 20																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.65	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.78	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
TOT	55																					

WORKSTATION NUMBER 21																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
TOT	55																					

WORKSTATION NUMBER 22																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
TOT	55																					

WORKSTATION NUMBER 23																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
TOT	55																					

WORKSTATION NUMBER 24																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOT	55																					

WORKSTATION NUMBER 25																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.92	0.92	0.92	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	0.92	0.92	0.92	0.92	0.96	0.96	0.96	0.96	0.96
TOT	55																					

WORKSTATION NUMBER 26																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.35	1.35	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.33	1.33	1.41	1.41	1.41	1.41
TOT	55																					

WORKSTATION NUMBER 27																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.55	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.64	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
TOT	55																					

WORKSTATION NUMBER 28																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.88	1.06	1.06	1.17	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.02	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
TOT	55																					

WORKSTATION NUMBER 29																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.24	0.24	0.24	0.24	0.24
TOT	55																					

WORKSTATION NUMBER 30																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.13	1.13	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.12	1.00	1.00	1.00	1.00	1.00
TOT	55																					

WORKSTATION NUMBER 31																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
TOT	55																					

WORKSTATION NUMBER 32																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.62	0.62	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.60	0.60	0.60	0.60	0.60	0.60
TOT	55																					

WORKSTATION NUMBER 33																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.92	1.32	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.15	1.32	1.32	1.26	1.26	1.26	1.26	1.26	1.26
TOT	55																					

WORKSTATION NUMBER 34																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
TOT	55																					

WORKSTATION NUMBER 35																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.51	0.51	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.50	0.69	0.69	0.69	0.69	0.69
TOT	55																					

WORKSTATION NUMBER 36																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	2.33	2.33	2.33	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.33	2.33	2.33	2.33	2.18	2.18	2.18	2.18	2.18
TOT	55																					

WORKSTATION NUMBER 37																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0.26	0.26	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.26	0.26	0.26	0.26	0.26	0.26
TOT	55																					

WORKSTATION NUMBER 38																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	2.59	2.59	2.59	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	2.59	2.59	2.59	2.59	3.15	3.15	3.15	3.15	3.15
TOT	55																					

WORKSTATION NUMBER 39																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69	1.85	1.85	1.85	1.85	1.85
TOT	55																					

WORKSTATION NUMBER 40																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOT	55																					

WORKSTATION NUMBER 41																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	5.71	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71
TOT	55																					

WORKSTATION NUMBER 42																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.91	1.91	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	1.87	1.87	1.87	1.87	1.87	1.87
TOT	55																					

WORKSTATION NUMBER 43																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.91	1.91	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	1.87	1.87	1.87	1.87	1.87	1.87
TOT	55																					

WORKSTATION NUMBER 44																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.91	1.91	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	1.87	1.87	1.87	1.87	1.87	1.87
TOT	55																					

WORKSTATION NUMBER 45																						
MAY 2019																						
DAY	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**13**	**14**	**15**	**16**	**17**	**20**	**21**	**22**	**23**	**24**	**27**	**28**	**29**	**30**	**31**
EXACT RESOURCE	1.91	1.91	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	1.87	1.87	1.87	1.87	1.87	1.87
TOT	55																					

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