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PERSONNEL NEEDS ESTIMATION: SIMULTANEOUS TWO-MODEL PRODUCTION IN FINAL REVISION SHOP AT VOLKSWAGEN NAVARRA

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ABSTRACT: Volkswagen Navarra has traditionally manufactured one model at a time. However, in 2019, to the assembly of VW270, to-be-launched in July 2017, a second variant will be incorporated, VW216. Consequently, the company will start applying a simultaneous two-model production for the first time in its history. This new strategy encounters many challenges for which Volkswagen Navarra needs to prepare in advance. Personnel needs is one of them. For this purpose, both general and industry-specific variables have been studied to develop a template for Final Revision Shop, the last phase in a vehicle's production procedure. Moreover, heuristics has been incorporated in the design of a stepwise logical methodology to systemize the design of hiring calendars. Despite the complexity inherent to the incorporation of real life specifications in an operational model, both proposed methods are simple and straightforward attempting to make a direct impact on its subsequent extension and future applications.

KEYWORDS: Volkswagen, Final Revision Shop, Personnel Needs, Production, Automobile Industry, Navarra, Productivity, Heuristic, Hiring Scheduling.

ABREVIATIONS:

- ABS – Autonomous Brake System
- DLQ – Direkt Läufer Quote (quote of directly accepted cars)
- ECU – Electronic Control Units
- EOBD – European on Board Diagnoses
- IO – In Ordnung (OK)
- KW – Kaufwoche (week of sale, use as a time unit)
- LEP – Last Electric Proofs.
- NIO – Nicht In Ordnung (not OK)
- PDI – Pre-Delivery Indicator
- Q - Quality
- SOP – Start of Production
- SUV – Sport Utility Vehicle
- ZP – Zeit Punkt (time point, stage of production process completed)

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1. INTRODUCTION

Volkswagen Navarra is one of the more than 120 plants that Volkswagen's Group own all around the world. Located in Landaben's Industrial State, in Pamplona, this enterprise has been producing Polos steadily since 1984. The extraordinary career the company exhibited throughout the years with an exquisite detail attentiveness, has entitled it as the World Leader Polo Producer. Due to this category, Volkswagen Navarra is placed as the referent for this model's production for all manufacturing facilities internationally, whose representatives visit Pamplona's plant in order to optimize their assembly processes back home.

Moreover, production values enhance the previously mentioned entitlement. With a daily volume of 1,435 Polos, the Spanish company manufactured 296,800 vehicles in 2016 supposing almost 40% of the model's total world production. Volkswagen Navarra currently produces just a single variant, Polo VW250, and it is preparing the forthcoming launch of Polo VW270 next summer, July 2017. Although the introduction of a new model variant always encounters certain obstacles because of the novelties incorporated in terms of materials, techniques or procedures employed, there are no dramatic modifications.

In 2019, however, the Navarre Company will produce, for the first time in its history, two models simultaneously: Polo VW270 and Polo VW216. The acquisition of this second variant to Volkswagen Navarra was described by Francisco Javier García Sanz, the World Vice-President of Volkswagen Group as: "a ratification of the Group's compromise with Spain which is and will be a key country in the company's strategy" (García, F. 2016).

The production of two vehicle variants at the same time encounters numerous challenges such as physical routes, parts adjustment discrepancies, training requirements, or facilities modifications, among others. Nevertheless, Volkswagen Navarra will not be the first car maker enterprise in applying such a strategy. There are currently various Volkswagen Group plants in other countries which already manufacture two or more models simultaneously.

In order to approach the coexistence in production of more than a single variant, different manners can be identified. On the one hand, SEAT in Barcelona, which produces Seat León, Seat Ibiza, and Audi Q3, is characterized by employing separate industrial lines for each model. On the other hand, Volkswagen plant in Bratislava, making VW Touareg, VW Polo, and Audi Q7, utilizes the same manufacturing facilities for all variants. The reasons behind the preference of Volkswagen Navarra for the single-line production over the specialized facility system, relies on the productivity, flexibility, cost efficiency and training widespread gains it entails (Lipúzcoa, C., 2016). Holding in-group referent enterprises which can provide information and empirical knowledge, the potential drawbacks and the production coordination involved are diminished.

Besides, Landaben's plant holds an advantage over the just inferred companies because its two models belong to the same family, Polo. Therefore, the differences among vehicles are much smaller which may contribute to the personnel's adaptation to the new variant. Polo VW270, coming this summer, is a premium "supermini" urban vehicle with a great interior quality, quite on the road and long-distance refinement. It exhibits considerable size variations from currently manufactured Polo VW250 (Annexe 1) being the just-about-to-be-launched variant smaller (-7mm), longer (+81mm) and wider (+69mm).

Meanwhile, the new model coming in 2019, VW216, is still a metropolitan variant from segment B with similar physical measurements to VW270 (Table 1), but defined as a mini Sport Utility Vehicle (SUV). The discrepancies between models encompass, above all, mobile components adjustment, electric innovations and interiors' finish.

Table 1. Model Dimensions and Differences (in millimeters). Source: Self Elaboration.

TIME FRAME	**Current**	**Summer**		**Summer**	**2019**	
MODEL	VW250	VW270	Δ	VW270	VW216	Δ
Front Wheel Bearing	1463	1525	62	1525	1532	7
Rear Wheel Bearing	1456	1505	49	1505	1509	4
Total Width	1682	1751	69	1751	1756	5
Body Width	1682	1740	58	1740	1756	16
Wheel Bearing Distance	2470	2564	94	2564	2565	1

Considering facilities' required modifications, and the variations in the vehicles' adjustments, interiors, and physiognomy, there is a high probability of additional personnel requirements. Not only because it will take longer for employees to adapt to the new car characteristics and its repair works, but also because of the coordination of the simultaneous two-model production.

Bearing in mind the increasing competitiveness of the sector, it is essential to consider any detail in the refinement of both the plant and the production process in order to avoid as many unexpected events as possible. Therefore, the ahead of time estimation of personnel needs will allow the company to early prepare, for instance, training schedules and tools disposition so as to have everything as controlled as possible. It is important to highlight that any unconsidered measure may result in substantial monetary costs and an unpleasant working environment.

Although, this new strategy will impact the company and its production process as a whole, the main focus of this project is the estimation of employee demands at Final Revision Shop, the last warehouse of the car making process. In particular, the workforce requirements of rework groups in this shop considering the increment of repairs that may occurred as a result of combining the initial launch of a new model, VW270, with the coordination of simultaneous two-model production, VW216, for the first time.

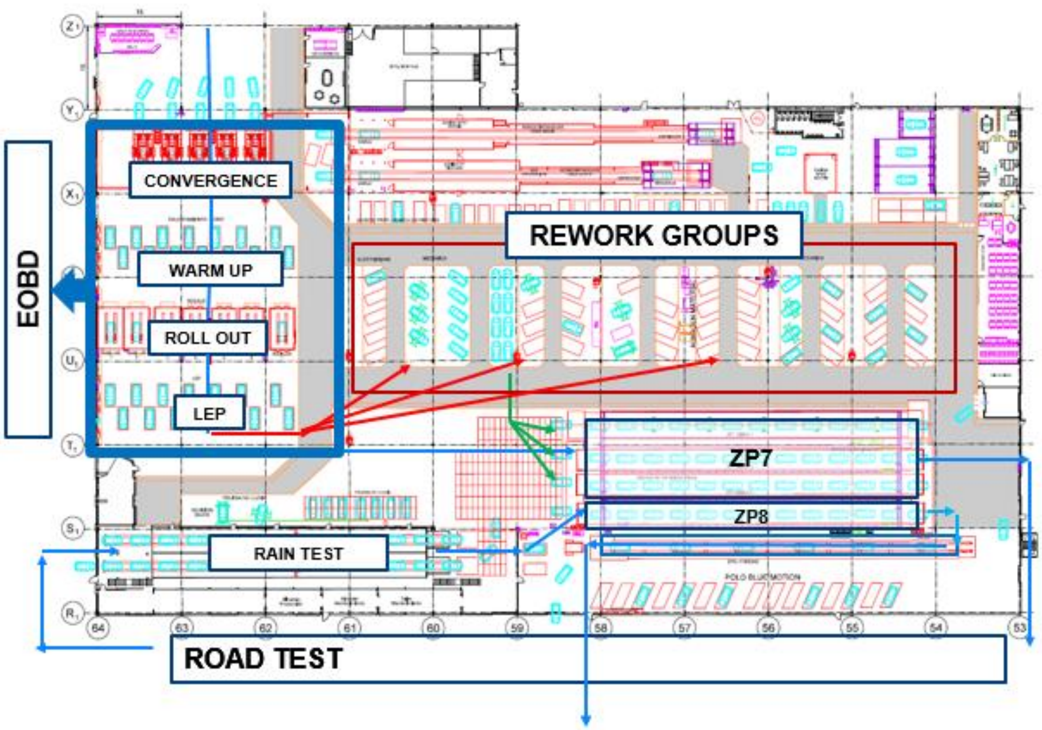
In the remaining body of this paper, so as to fully comprehend the considerations contemplated throughout the performed computations, an in-detail description of the Final Revision process is provided. Secondly, the employed inputs' data are explained along with their source and relevance for the estimation. Then, the findings of the analysis are summarized and interpreted. To conclude, the implications of the conducted analysis are identified along with the exposition of suggestions for future research gates.

2. FINAL REVISION SHOP

Being physically located as the last section of the production process (Annexe 2), Final Revision Shop is in charge of guaranteeing the superior quality of every single car leaving Volkswagen Navarra. A vehicle's manufacturing process begins at Press Shop where parts are stamped and then welded in Body Shop. Once the bodywork has been done, the car skeleton is painted. Later, the assembly process takes place in two different shops. On the one hand, Motor Shop is entrusted with the montage of the powertrain set and doors. On the other hand, in the Assembly Shop bodywork and powertrain are fit together and the additional car parts such as cockpit, seats, etc. are assembled.

In order to accomplish its main exposed objective, apart from the ultimate torques and proofs, Final Revision Shop includes a specific section for each rework group: electric, mechanic, paint shop, body shop, and garnishing. Actually, this warehouse functions as a subfactory itself since it owns, more or less, a representation of all stages of the production process. In this final stage of the production process, the vehicle follows an established journey which is divided in different stages according to the proofs conducted or reworks required (Figure 1).

Figure 1. Final Revision Shop Layout. Source: Final Revision Shop, Volkswagen Navarra



After leaving the Assembly Shop, the car is driven to Final Revision Shop Entrance. The first phase the vehicle encounters while entering this warehouse is Convergence. An employee connects a FUMO (functional monitoring device) to the car's electronic system and places it over the trench (Annexe 3 - Figure 2). Once the car is detected, the inclinometer is attached and the machine starts to function.

Then, the automobile's "Baptism" takes place. At this stage, for the first time, a chassis number is attributed to the car's body. With this mechanism, the European On Board Diagnostics (EOBD) process begins which is basically a proof of all electronic control units (ECU). Whereas underneath, workers regulate the steering bar; at the upper part, employees adjust headlamps and the autonomous cruise control (ACC) system manually. Once finished, the inclinometer is pulled out and the car passes to the warm up phase (Annexe 3 - Figure 3).

During this phase, other electronic tests are conducted along with the manual verification of direction, air conditioning, aerators, pedals, etc. Then the vehicle is directed towards cabins where the roll-out takes place (Annexe 3 - Figure 4). It is a driving test in which gears, both brake pedals, the autonomous brake system (ABS) and the handbrake are examined. The cabin opens and the vehicle is moved to post-cabins or LEP (Letzte Elektrik Probe) phases. It is important to highlight that this one is the process automobiles follow if all examinations end up with status IO (in Ordnung, OK in German). Otherwise, cars would be diverted to rework groups under NIO status (Nicht in Ordnung, not OK in German).

When LEP tests are concluded, vehicles are driven to line ZP7 (Zeit Punkt, time point in German), where small repairs and quality verifications are performed. The physical disposition of the line begins with adjusters who, as its name suggests, are in charge of the final adjustment of mobile components such as doors and hatchback. Then, representatives of the quality department perform a preliminary checking. After them, there are specialists from the various rework groups so that, in case any tiny defect is detected, its reparation can be done on the line.

Any time a car leaves the established route, production time increases and, as a result, productivity decreases. Therefore, the presence of those employees on the line enhances productiveness maintenance since they prevent a certain amount of cars to leave the route. At the end, another group of quality department workers make sure there are no more defects and the first Q (Quality) sticker is pasted on the front glass (Annexe 3 - Figure 5).

In Final Revision Shop, productivity is measured with an indicator called Direkt Läufer Quote (DLQ). It is defined as the ratio of directly accepted cars over total produced. In other words, the percentage of vehicles that did not leave the established route after that specific production stage over the total which already accomplish it. The current objective is fixed at 85%, for every production station. However, as it will be seen later, the value varies depending on the life-cycle stage of a precise model.

Logically, at the initial production phase, employees are not familiar with the vehicle particularities and then, the agreed goal is lower. Over time, the aim threshold increases due to experience gains and training. Hereafter, the road test is performed (Annexe 3 - Figure 6) which is characterized by diverse obstacles such as slipways, unequal mounds and curves.

Throughout the driving proof, not only functional features such as direction or shock absorbers are examined, also perceived noises. These workers leave the vehicle at the entrance of the rain tunnel (Annexe 3 - Figure 7). Footprints present on the chain propel the car through the tunnel where abundant water is poured over it. This test is performed under extreme conditions in order to check there is no possibility of water ingress at any situation.

Finally, considering everything was OK, the last checking and small repairs are performed on line ZP8, following the same procedure as in ZP7. At the end, if everything is OK, the second Q is pasted on the front glass and the vehicle is considered sold and driven to the parking lot (Annexe 3 - Figure 8). From there, cars are loaded to the corresponding mode of transport, train or truck, and send it to their final destination. At any stage of the process, if a defect arises, cars are diverted to the specific rework groups which appear on the middle of the layout previously exposed (Annexe 3 - Figure 9).

3. CONTEMPLATED INPUTS

In this section, all considered inputs data are explained so as to robust the decision making process conducted to compute Final Revision's personnel needs. Initially, the study framework is described, followed by considered factors' classification and their subsequent description.

It is noteworthy to notice that the complexity of the process is directly related with the abundance of contemplations made. Besides, the inherent technical specificities of the automobile industry may be quite complex and challenging to comprehend. That is why a detailed an exhaustive description of all terms is facilitated along with their particular source and, if necessary, process followed to calculate them.

3.1 Study Framework

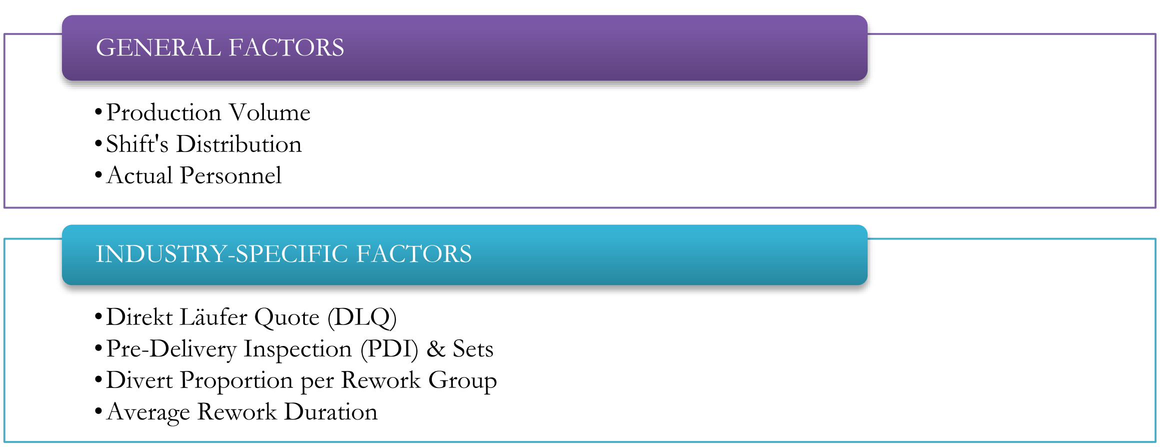
To begin with, it is essential to determine the time frame of the analysis. The period for which personnel needs is computed, covers almost the whole year 2019, from the first week of January (KW1) to the second week of December (KW50). During San Fermín (KW28), local festivities, the company remains closed and therefore, there is no production. Presented data follows the established time units' system on Volkswagen Navarra where daily and weekly' values are employed. The selection of this specific period is supported by VW216's launch calendar that determines the initial stage at which both cars production processes coincide. Moreover, the emphasis on variables' evolution over time, is considered not only interesting, as a sign of continuous improvement present in any Volkswagen enterprise; but also relevant for comparison in future personnel needs estimation.

In addition, the study subject must be delimited. The procedure automobiles accomplish at Final Revision Shop, as exposed on section 2, can be segmented in two subdivisions: production process which describes the established route a vehicle follows if no defect is detected; and rework groups representing the space physically located in the middle of the industrial facility which is in charge of repairing any raised shortcoming. Although the simultaneous two-model production may affect both subdivisions in terms of coordination, organization, physical disposition and personnel, the stronger impact is assumed by rework groups. Therefore, these project calculations in first place target this process branch.

The inclination for rework groups is sustained by the sizeable increase in defects' number and repairs duration, as part of the course of any launch process, along with the errors coming from the accommodation of two simultaneous models manufacture. Besides, adjustments, techniques, and technological new model differences of VW216 with respect to the usually produced Polo, VW270, and its predecessors, also impact negatively on the augmentation of reworks and their average duration.

So as to provide an accurate and comprehensive estimation of repair personnel needs, numerous variables are contemplated. Those factors explanation is structured from more general to industry-specific in order to take into account all required information without leaving anything aside. Besides, to build up a study framework as complete and straightforward as possible, a physical representation of this scheme is exposed below (Figure 10).

Figure 10. Variables Scheme. Source: Self-Elaboration.



3.2 General Factors

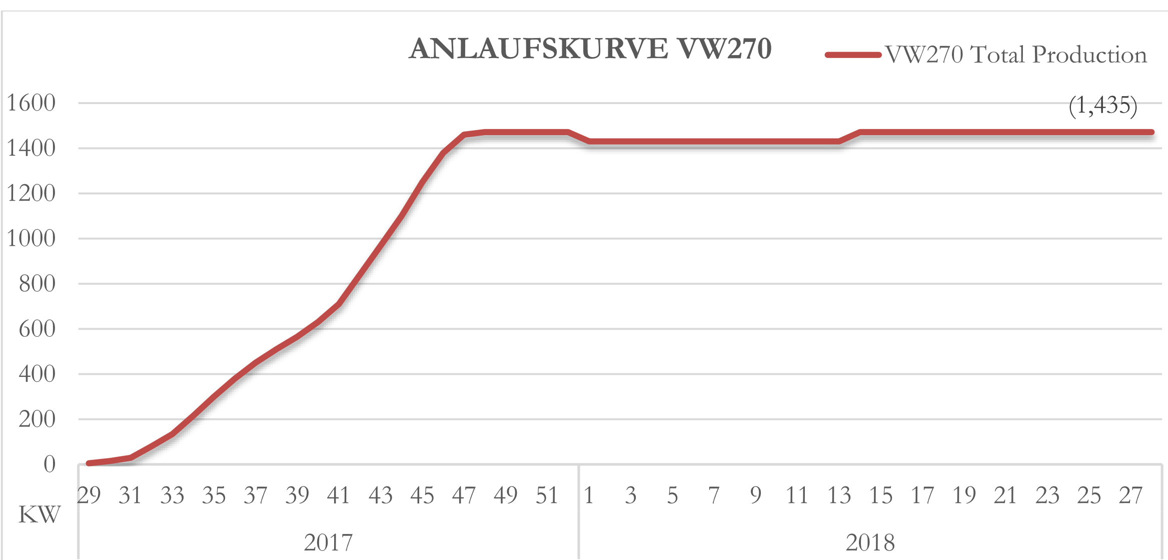
In estimating personnel requirements, the problem needs to support the organizational objectives and reflect the size and complexity of the company, or, as in this particular case, a certain enterprise's section. There are three main variables which capture these aspects: production volume, shift's distribution and actual personnel.

3.2.1 Production Volume

Future employee demand depends on forthcoming production planning. Volkswagen Navarra, as an enterprise of the Volkswagen Consortium, receives the manufacture program from the group headquarters located in Wolfsburg, Germany. Data exhibited on this section were facilitated by the Technic Product Area in Volkswagen Navarra.

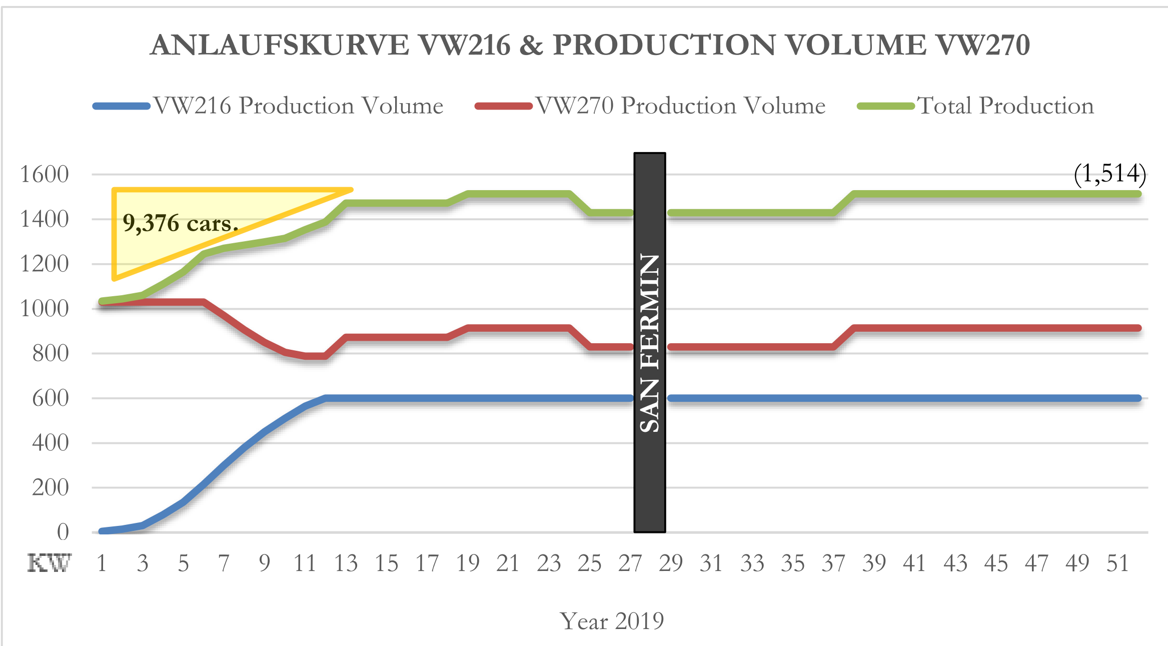
During launch periods, this schedule acquires greater importance because it describes the progressive increase in weekly cars production once SOP (Start of Production) phase begins. This assembly calendar is summarized in a standard document known as Anlaufskurve (launch curve in German). Usually, manufactured vehicles start from a small amount and increase over time. Hence, the graphical representation of the production planning is a single line with an increasing tendency during the first weeks and a constant pattern once it reaches the average daily volume (Figure 11 is provided as an example of usual historical shape).

Figure 11. Anlaufskurve VW270. Source: Self-Elaboration.



However, considering the special conditions under which this analysis takes place with the introduction of a second model for the first time in the plants history, the assembly program changes. To begin with, there is not just a single line but two (Figure 12). On the one hand, VW216 units' production increases over time until it stabilizes in an average daily production of 600 cars. On the other hand, VW270 manufacturing units decrease to adjust to facilities and time constraints up to an average volume of around 900 automobiles. In other words, Volkswagen Navarra will produce 60% of the new version of its traditionally manufactured model, VW270; and 40% of the Polo novelty, VW216. Nevertheless, this distribution will be finally determined by the demand evolution of the two models in consumer's market.

Figure 12. Anlaufskurve VW216 & Production Volume of VW270. Source: Self-Elaboration.



Technic Product Area estimated that, due to the initial coordination of simultaneous production, a total of 9,376 vehicles will be lost (yellow shadowed area). If today's daily average production of 1,435 is compared with Figure 12, it can be seen from total production line, how it will take up to KW13 to reach the same level. Besides, total manufacturing units go slight above, up to 1,514 vehicles, representing a potential productivity gain. In physical terms, production will increase by an average of around 80 units per day.

3.2.2 Shifts' Distribution

Volkswagen Navarra, as many other enterprises from the automobile sector, employs shift work to meet production demands. That is to say, the company works 24 hours a day compromising three eight-hour shifts. However, this distribution was not always like that. Actually, Landaben's plant implanted the three-shift working schedule in 1989. The general trend in shifts attribution follows the alternate work schedule which reinforces a better coverage of established personnel spots. Nevertheless, there are also some special cases such as women with reduced working hours who can choose the shift that better suits their situation.

Each shift has its own pauses distribution which must be subtracted from total manufacturing time provided that, during pauses, lines stop. Morning shifts hold 4 pauses which sum up to 40 minutes, as a result the actual working time is reduced to 440 minutes. During night shifts, regarding it can be considered a risk factor for some health problem in certain individuals (Knutsson, 2003), there are 5 pauses which make 50 rest minutes. Hence, the production minutes add up to 430 minutes. As for these two working schedules, employees share pauses timetable.

However, afternoon shifts have a different pauses distribution. Final Revision goes right after Assembly Shop and so they are strongly dependent on their activity. If they do not stop, no one does. For this purpose and, in order to provide workers with their required breaks, a system called pauses displacement was introduced. *Pauses displacement* is defined as a break system in which employees are divided in groups that are later assigned to sequential rest periods. As a result, each worker enjoys its pauses, although they do not stop at the same time, and production does not stop.

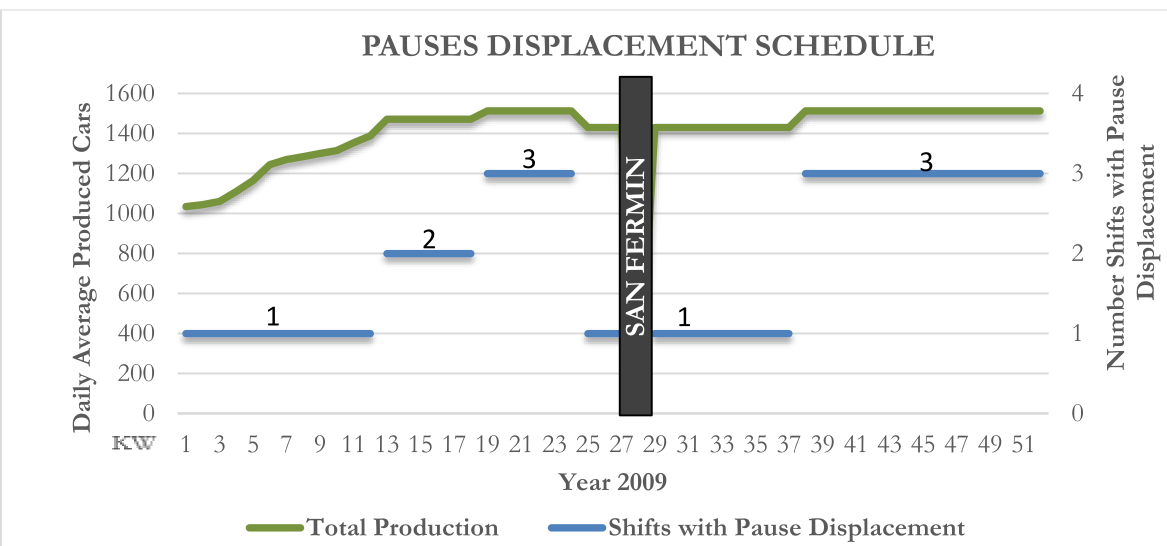
As it was previously addressed, total manufacturing volume may increase for the simultaneous two-model production in 2019. One of the possible ideas to succeed in adapting to that increment is shifts' homogenization in terms of available working time per employee by the progressive standardization of pauses displacement. Although agreements between the Executive Representatives of Volkswagen Navarra and Trade Unions are achieved just a couple of weeks before the actual beginning of the agreed period, negotiations start far before. Regarding pauses duration may be maintained in each shift and the potential productivity gains obtained from this practice, it is considered as a probable solution.

For purpose of this study, the extension of pauses displacement is assumed. Besides, a progressive implementation schedule is proposed through the definition of segments denominated as 1, 2 or 3 according to the number of shifts applying pauses displacement (Figure 13), and taking into account the manufacturing volume exposed by total production line.

During the initial launch weeks and until current production levels are reached (KW13), no changes are introduced in pauses distribution, meaning that just the afternoon shift experiences pauses' displacement. Then, a second one is introduced such that the morning and afternoon shift production stay constant without interruptions (KW14-KW18). Considering the health implications this working system implies, it is understandable to leave the night shift as the last one in the extension procedure.

The complete implementation will be applied from KW19 to KW24 and from KW38 until the end of the year, being the periods with the greatest production volume as shown in Figure 13. During July and August, regarding climate circumstances and the stop of production when warehouses reach a temperature over 28ºC, the current schedule of just a single pauses' displacement shift is contemplated.

Figure 13. Pauses Displacement Implementation Schedule. Source: Self-Elaboration.



Pauses' displacement implementation has a direct impact on working times and productivity. Precisely, depending on the number of shifts applying this strategy the average minutes devoted to production may change. Although variations from one method to the other are not such if we consider daily figures, when taking into account the yearly total minutes gained from the implementation of pauses' displacement, the productivity increments are noteworthy. The applied computations consist on simply subtracting period in which lines are stopped, in other words, rest sessions without pause displacement; from total duty length of 480 minutes. Then, the mean of the three shifts working time schedule is computed for each specific situation.

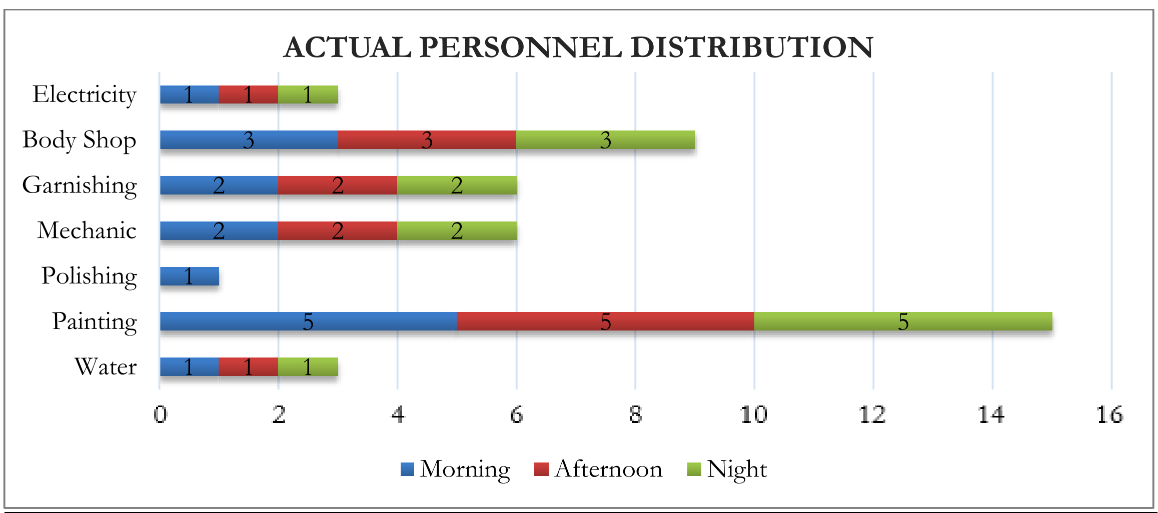
Table 2. Average Working Minutes per Worker depending on the Number of Shifts applying Pause Displacement. Source: Self-Elaboration.

Calendar Description (KW)	Number of Shifts applying pauses' displacement	TIME AVAILABILITY (mins.)			
		Morning	Afternoon	Night	MEAN
1-13 / 25-37	1	440	480	430	450
14-18	2	480	480	430	463.33
19-24 / 38-50	3	480	480	480	480

3.2.3 Actual Personnel

Another essential factor in determining future workforce needs is how many people are currently employed; in other words, actual personnel. Reworks' staff distribution (Figure 14) was provided by a technic responsible of VW270 at Final Revision Shop (Annexe 4).

Figure 14. Actual Personnel Distribution at each Rework Group at Final Revision Shop with yearly contract. Source: Volkswagen Navarra.



Although most rework groups exhibit a proportional distribution among shifts, there is still a special case, polishing. First of all, Polishing refers to the required refinement of an automobile's surface prospectively to the painting process. The presence of a single worker at this rework group for only one shift has resulted in cars accumulations from one day to the other. Although, a worker from painting usually performed part of the polishing tasks, the situation is not the optimal. As it will be seen later, this idea has been introduced in the computations by applying a conditional Excel formula, which will avoid this unlucky situation

3.3 Industry Specific Factors

The automobile sector includes numerous industry specificities for which additional factors must be added. As exposed before, car makers' efforts focus on continuous improvement and quality enhancement. Moreover, this industry is characterized by fierce competition and a strong focus on technology, being actually considered one of the most innovative and futuristic sectors.

Volkswagen learned the hard way how a single mistake can ruin a strong brand image through the diesel scandal. However, thanks to their marketing campaigns and consistent numbers supporting their slogans, the Group has succeeded in gaining back their clients' confidence. One of the factors which pushed Volkswagen to their preceding predominant position was quality. As a matter of fact, the German company's recover was such that, in 2016, it managed to overpass Toyota as Nº 1 World Car Producer with the greatest number of cars sold (Topham, 2017).

The key element which sustains all Polos' production process, the brand's reputation and the continuity of Landaben's plant over the years, is its personnel. Workers are the essential component responsible for the manufacturing quality standards since they are the ones applying Volkswagen's philosophy of "Love for the detail" to vehicles' assembly procedure. Therefore, all industry-specific variables around them are clearly connected with quality's assurance and control.

3.3.1 Direkt Läufer Quote (DLQ)

DLQ is the most important ratio in Final Revision Shop, and one of the most relevant aspects of Volkswagen Navarra as a whole since it is analyzed throughout a vehicle's production process, from the beginning to the end. It is a quality measure which describes the proportion of directly accepted vehicles. In other words, it provides a percentage of non-rejected cars over the total production volume which has already completed a specific section of the manufacturing process.

Seven are the diverse stations which can be differentiated in Final Revision's production procedure: EOBD, ZP7, Road, Rain, ZP8, Sets and PDI.

The acceptance ratio is daily checked by Final Revision's manager and commented during department reunions such that everyone is informed about the previous day's performance. However, due to time constraints, only DLQ results from ZP7 and ZP8 are considered on behalf of their relevant position in the production process. To recapitulate, at those stations quality patterns are verified and certificated with Q stickers, yellow for ZP7 and green for ZP8.

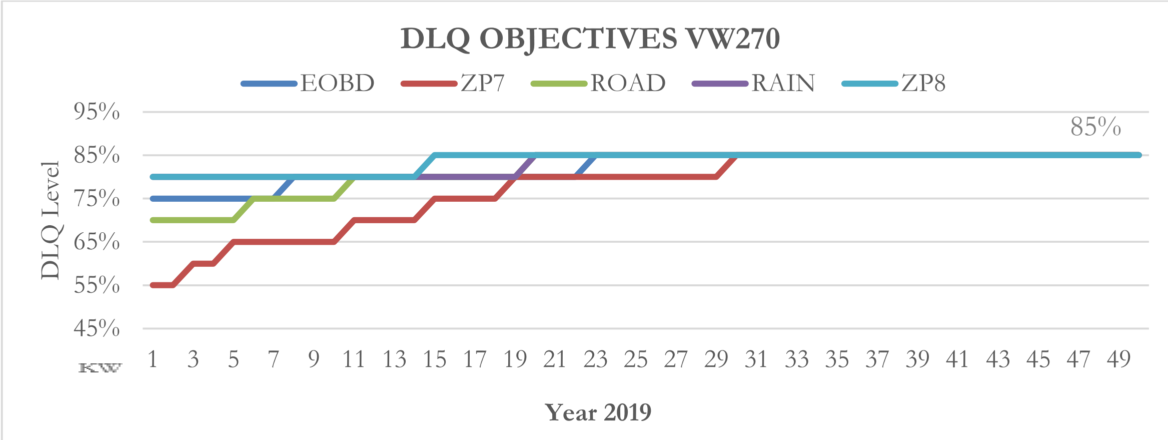
In the course of the initial weeks of any launch period, the acceptance aim is quite low, around 30%. As time passes, workers gain more experience and interiorize the new model's technic novelties. Consequently, DLQ objectives experiment a progressive increment. Today's established acceptance aim for every phase in the course of serie production, is set at 85%, which is a realistic value regarding the probable presence of defects as a result of either human or mechanical causes.

So as to come up with the weekly acceptance objectives for each station, historical data facilitated by Final Revision's manager along with suggestions from employees' personal experience were employed. Although those values have been considered as a starting point, the actual disposition and evolution of the data was obtained as a result of a deductive process conducted for each model individually.

On the one hand, regarding that, by the time the additional personnel is required, Polo VW270, will have been in production for a year and a half, its DLQ's is closer to the 85% targeted aim (Figure 15). Furthermore, the coordination challenges are also contemplated with lower departure values for certain stations such as ZP7, 55%.

Quality analysis is more exhaustive at specific production stages. Precisely, ZP7 and ZP8. Regarding ZP7 is the primary complete checking point of the whole procedure; it seems logical that its DLQ takes longer to reach the desired acceptance aim, than those for the rest production stations. With regard to ZP8's position, which remains at the final quality examination just before sale and, taking into account most shortcomings have already been perceived and repaired in prior phases, it must be one of the first stages in targeting the desired 85%.

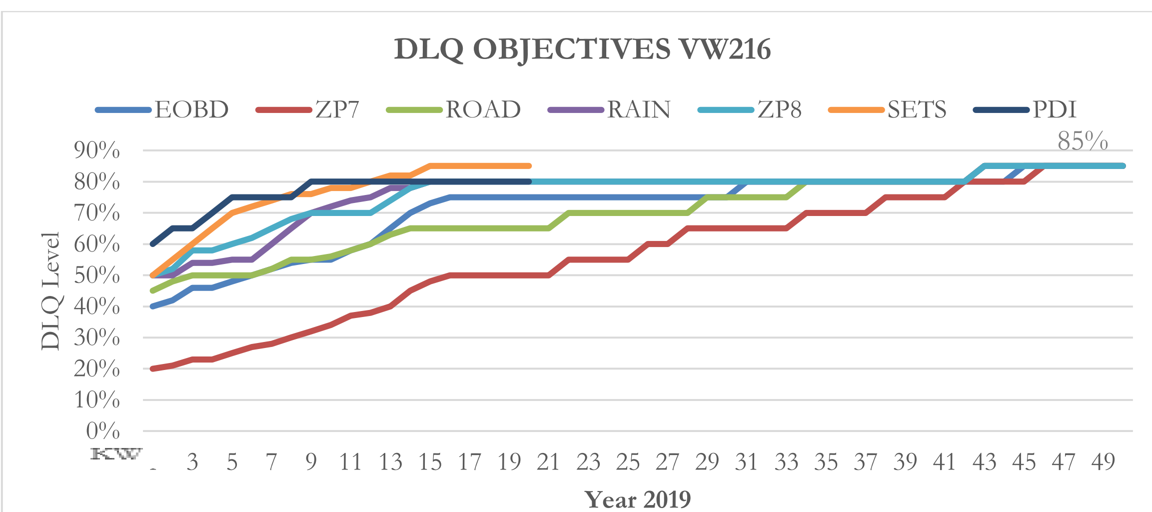
Figure 15. DLQ Objectives for VW270. Source: Self-Elaboration.



Nevertheless, the manufacturing process location does not always have a direct effect on the evolution acceptance ratio. Besides, in spite of being placed before ZP7, EOBD holds a shorter duration for attaining the 85% objective. The reason underlying this behavior is related to its pure mission. Whereas in ZP7 the whole vehicle is inspected, in EOBD the examination focuses mainly on electric and mechanic systems.

On the other hand, VW216's DLQ exhibits a prolonged evolution over time for all stations considering, as it was mentioned before, its sizeable differences with previously produced models (Figure 16). None the less, it is interesting to apprehend how the progression pattern of the acceptance ratio explained for VW270 is also exhibited in the graph below. By order of achieving the 85% goal: first ZP8; then EOBD; and, finally, ZP7.

Figure 16. DLQ Objectives for VW216. Source: Self-Elaboration.



Two new variables, Sets and Pre-Delivery Inspection (PDI), appear on this diagram in comparison with VW270's DLQ evolution. These factors are only relevant for just-launched models because they consist on additional quality auditory procedures. Although, they are explained more in detail in the next section, it can be stated that their accelerated DLQ improvement in few weeks corresponds to, first, their last position in the checking procedure and, second, the special attention employees put on beforehand detected defects so that these shortcoming do not reach those final inspections. Besides, the shorter length of these lines, targeting the period from KW1-KW20, is also determined by their unique presence during the initial weeks of a model's launch.

3.3.2 Pre-Delivery Inspection (PDI) & Sets

The first manufactured units of a new model require an extensive examination of all individual cars leaving the plant. However, the implementation of such an auditory for each vehicle will be incredibly costly and long-lasting. In order to overcome these inefficiencies, two special actions are performed minimizing, meanwhile, time and resources waste. These supplementary measures are Sets and Pre-Delivery Inspection (PDI).

On the one hand, Sets, as its name suggests, describe the grouping of around fifty vehicles with similar characteristics during the initial weeks of production. This aggregation takes place before cars are loaded to the corresponding means of transport and during an average period of five months. From each set, two vehicles are randomly chosen to be subjects of an additional auditory: one is checked by the Proofs Center and the other one by the Finished Car Audit. The defects detected on those automobiles are subsequently examined in every single car of the same Set. In other words, this process can be described as a sampling verification such that two vehicles are targeted as set representatives.

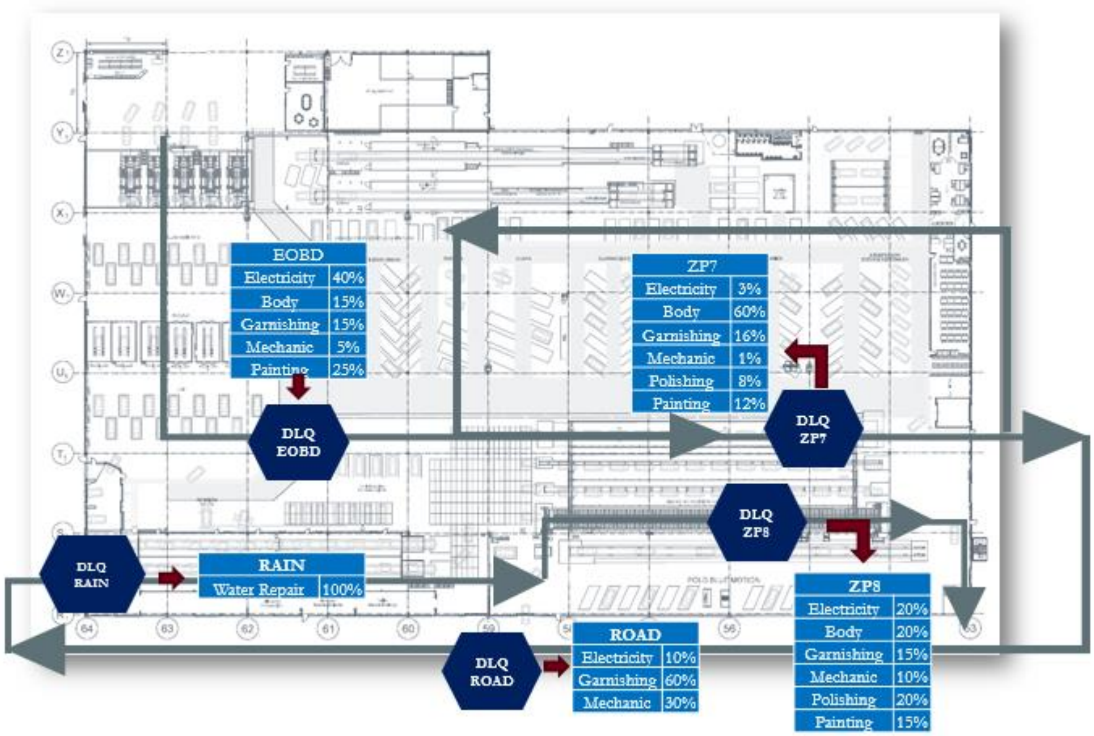
On the other hand, PDI refers to the auxiliary checking accomplished on every single automobile for quality enhancement purposes. It is normally performed after around four weeks of the commencement of a new model's production and it lasts on average two to three months. Its start differs from the previous one, because PDI requires the gathered information about most repetitive defects during Sets examination. Precisely, specialists perform a more exhaustive checking of all vehicles relying on more frequent shortcomings. However, it is important to highlight that not only earlier recognized defects are targeted, but a whole examination of the car is performed.

Logically, these additional audits may affect the rework time per group and, as a result, the personnel needs for each specialty. The schedule for both verification practices has been facilitated by Technic Product Area as for the Anlaufskurve. Finally, as a matter of fact, these two additional stages, as any other production process station, have their own indicators such as DLQ, average repair time per rework group, etc.

3.3.3 Divert Proportion per Rework Group

Apart from the acceptance objective per production station and rework group (85% desirable in each station), it is also interesting to be aware of the divert proportion per repair specialty of non-accepted cars (less than 15% agreeable). That is to say, the percentage distribution of non-accepted vehicles, detected at each phase of the manufacturing process, which are directed to a specific rework group (Figure 17).

Figure 17. Divert Proportion per Rework Group from Production Process Station. Source: Self-Elaboration.



It is noteworthy to mention that the divert allocation is shared by both models and over time, on behalf of the stability of these values, independently on the stage of a vehicle's life cycle.

In Figure 17, a graphical representation of this considered variable is offered. It explains the whole production process conducted in Final Revision Shop by showing the diverted vehicles distribution per station and repair specialty. It is understandable to apprehend, for example, that the majority of detected defects for EOBD belong to electricity regarding its main examination task, the Electronic Control Unit (ECU) checking. Likewise there is a clear predominance of garnishing repair works in the road test, since most noises appear from unfixed car parts such as screws.

The presented percentages of divert distribution in Figure 17 where obtained as a result, once again, of historical data and a personal interview with the technic launch representative from Final Revision Shop on behalf of its experience in preparation of new model's production.

3.3.4 Average Rework Duration

Last but not least, average rework duration in minutes was considered. One of the tasks I performed during my internship was the update of repair time database. For this purpose, I was entitled to download all defects a specific car experienced, separate them by rework specialty and then ask a representative from every group about the average repair duration of all shortcomings. Although, there are always outliers for which a certain rework takes longer by virtue of specific circumstances, it was possible to attribute an average time to every specific defect.

In order to establish the average repair duration per specialty and station, this database and the recommendations from technic managers and rework groups' employees were considered. As it happened with DLQs, rework length decreases over time thanks to experience gains.

The same reasoning as the one exposed in DLQ subsection underlying discrepancies among models was applied. By way of illustration, the average time devoted to VW270 for KW1 is already lower than that of VW216, regarding the new version of the traditional Polo VW270 will have been produced for year and a half by 2019 (Table 3). Besides, as it can be seen, there are no lines devoted to Sets and PDI for VW270 due, as it was addressed before, to the unique existence of these processes for just-launched models.

At the same time, the initial reworks length for VW216 is much higher than the normally established values regarding the novelty of the model in comparison with its predecessors (Table 4). The evolution of rates for both vehicle variants is slower than under single-model conditions as a result of the coordination problematic that is derived from the application of simultaneous production for the first time in Volkswagen Navarra's history.

Table 3. Example of the average time distribution per rework group and production station – VW270. Source: Self-Elaboration.

AVERAGE REPAIR TIME	KW1	Electricity	Body Shop	Garnishing	Mechanic	Polishing	Painting	Water
	EOBD	30	25	25	35	5	60	27
	ZP7	20	20	25	35	5	60	27
	ROAD	20		25	30			
	RAIN							27
	ZP8	15	20	20	30	5	60	27

Table 4. Example of the average time distribution per rework group and production station – VW216. Source: Self-Elaboration.

AVERAGE REPAIR TIME	KW1	Electricity	Body Shop	Garnishing	Mechanic	Polishing	Painting	Water
	EOBD	40	50	40	55	5	75	65
	ZP7	40	30	40	55	5	75	65
	ROAD	50		45	55			
	RAIN							65
	ZP8	40	30	40	55	5	75	65
	SETS	50	40	40	50	5	70	
	PDI	40	20	40	40	5	70	

4. METHODOLOGY

All factors earlier explained are required so as to come up with proper and accurate personnel needs estimation for Final Revision Shop. Additionally, it is important to highlight that the developed mathematical method is characterized by its great flexibility which allows for the incorporation of unexpected events along with its widespread to other industries.

Real life is much more complex than any potentially defined methodology. Although the exposed computations included most of the particularities of this production process section, the year and a half uncertainty period from today's calculations to the actual launch phase, supposes a clear limitation. That is why the excel document presented has been defined in such a way that any unforeseen event can be introduced and most values will instantaneously adapt to it.

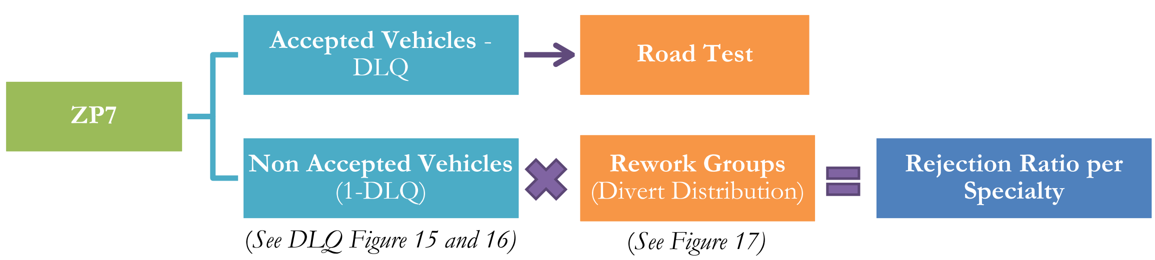
4.1 Personnel Needs Estimation

Before explaining the proposed estimation table which shows the weekly personnel needs for each rework group, a new variable under the name of "Rejection Rate" is defined which results from additional transformations performed on previously mentioned factors. Its computation has been accomplished by combining the information of weekly divert distribution per model, specialty and station, with DLQ objectives [1]. It precisely describes the weekly non-accepted proportion estimation per rework group and production process station.

[1] $$Rejection\ Ratio = (1 - DLQ) * Divert\ Distribution$$

The mathematical set of ordered steps performed to obtain those values appears as follows. First of all, the complementary for the acceptance ratio has been calculated (1-DLQ). It makes sense to contemplate such a variable considering the proportion of vehicles which actually reach rework groups are precisely those that are not included in DLQ. Then, by multiplying the weekly rejected cars estimation per production station by the divert distribution per rework group, the rejection ratio is obtained. In order to clarify this explanation Diagram 1 is provided.

Diagram 1. Rejection Percentage Explanation for ZP7. Source: Self-Elaboration.



The computation exhibited above is performed for every production station and rework group from KW1 to KW50. The resulting values' interpretation express the percentage of rejected vehicles from a certain station that is actually diverted to a specific rework group. It is important to bear in mind that the sum of all rework groups rejection ratios for a certain phase of the production process coincides with total rejection values presented before through DLQ's evolution on Figure 15 for VW270, and Figure 16 for VW216.

As an illustrative example, for VW270 from ZP8, 4% of total automobiles are diverted to the electricity repair section and 2% to mechanic (Table 5). Whereas, for VW216 from the same station and week, 10% of total vehicles are redirected to the electric rework group and 5% to mechanic (Table 6).

Table 5. Rejection Ratio Final Result Example KW1 for VW270. Source: Self-Elaboration.

	KW1	Electricity	Body Shop	Garnishing	Mechanic	Polishing	Painting	Water
REJECTION	EOBD	10%	4%	4%	1%	0%	6%	0%
	ZP7	1%	27%	7%	0%	4%	5%	0%
	ROAD	3%	0%	18%	9%	0%	0%	0%
	RAIN	0%	0%	0%	0%	0%	0%	20%
	ZP8	4%	4%	3%	2%	4%	3%	0%

Table 6. Rejection Ratio Final Results Example KW1 for VW216. Source: Self-Elaboration.

	KW1	Electricity	Body Shop	Garnishing	Mechanic	Polishing	Painting	Water
REJECTION	EOBD	24%	9%	9%	3%	0%	15%	0%
	ZP7	2%	48%	13%	1%	6%	10%	0%
	ROAD	6%	0%	33%	17%	0%	0%	0%
	RAIN	0%	0%	0%	0%	0%	0%	50%
	ZP8	10%	10%	8%	5%	10%	8%	0%
	SETS	3%	13%	15%	3%	8%	10%	0%
	PDI	12%	2%	14%	8%	2%	2%	0%

Personnel needs' calculations have been broken down into three different parts: series, which encompass the production stations from EOBD to ZP8; PDI and Sets. Considering the restricted existence of the two last examination proofs during the initial life-stages of a vehicle, it is understandable to separate their workforce estimations from usual serie production.

The explanation base for the performed computations is serie production, considering it is the only section in which both models are contemplated and, accordingly, the most comprehensive one. For Sets and PDI, more or less the same calculations are performed but taking into account just VW216's values. So as to provide a stepwise and easy-to-comprehend description of the conducted process, the same order as the one exhibited on Table 7 is followed. Nevertheless, peculiarities of PDI and Sets computations are incorporated throughout this table's explanation.

Before being able to obtain weekly personnel requirements per rework group, there are certain values that need to be computed. Initially, the number of expected non-accepted vehicles along with the average rework duration per automobile and repair group for both models.

Table 7. Excel Computations Example: Serie Production for KW1. Source: Self-Elaboration.

		KW1	Electricity	Body Shop	Garnishing	Mechanic	Polishing	Painting	Water	
Summer 2017	VW270	% To-be-repaired	18%	35%	32%	13%	8%	15%	20%	[7.1]
		Produced cars/day	1030	1030	1030	1030	1030	1030	1030	[7.2]
		Repaired Cars/day	189	357	329	130	78	150	206	[7.3]
		Average Repair Time	21	21	23	32	5	60	27	[7.4]
New in 2019	VW216	% To-be-repaired	42%	67%	62%	25%	16%	32%	50%	[7.1]
		Produced cars/day	5	5	5	5	5	5	5	[7.2]
		Repaired Cars/day	2	3	3	1	0	1	2	[7.3]
		Average Repair Time	42	36	41	55	5	75	65	[7.4]
	TOGETHER	Total Time / Group	4053	7605	7690	4215	390	9075	5692	[7.5]
		Needed Personnel	9	17	17	9	1	20	13	[7.6]
		Adjusted Needed Personnel	10	17	18	10	1	21	13	[7.7]
		Actual Needed Personnel	10	17	18	10	3	21	13	[7.8]
		Current Personnel	3	9	6	6	1	15	3	[7.9]
		Additional Personnel	-7	-8	-12	-4	-2	-6	-10	[7.10]

To begin with, once all rejection ratios are computed and there is a clear image of the proportion of non-accepted cars by station and, even more important, by rework group; the total to-be-repaired percentage must be calculated. Although for PDI and Sets the rejection rates are exactly equal to the to-be-repaired vehicles' proportion, the serie value requires a further step to be completed. Regarding serie production includes all manufacturing process stages, the sum of the individual rejection ratios of each phase for each rework group separately is performed. This results in the total proportion of automobiles per repair specialty which need to be repaired throughout the production process, in other words, the to-be-repaired ratio [7.1].

Then, these just-computed ratios are multiplied by the average daily production of that specific model, mentioned before on Figure 12, in order to obtain the expected number of cars which require a rework [7.2]. Considering the attained value refers to complete cars, there must be no decimals. As a result Excel's integer function is applied as follows [7.3]:

[7.3] *"Repaired Cars/day" = INTEGER ("To-be-repaired" *"Produced cars/day")*

Finally, the average repair time is calculated as simply as performing the arithmetic mean of rework minutes per station for a specific rework specialty [7.4]. The employed variables were previously explained on Table 3 and 4. Regarding PDI and Sets, the expected average duration will not be taken as average rework time since they incorporate just a single stage.

[7.4] $$\text{“}Average\ Rework\ Time_{RepairGroup}\text{”} = MEAN_{Repair\ Group}\ (EOBD, ZP7, RAIN, ROAD, ZP8)$$

Once, both the number of repaired vehicles and the average repair time are obtained for both models, total rework time per group is calculated by simply summing the multiplication result of these two values per model [8].

[7.5] $$Total\ Rework\ Time = Repaired\ cars_{VW270} * Average\ Repair\ Time_{VW270} + Repaired\ cars_{VW216} * Average\ Repair\ Time_{VW216}$$

Thereupon, total rework time will determine the number of needed personnel. Depending on the average working time per worker available, the workforce requirements will be one or another. That is why the pauses' displacement implementations schedule beforehand explained in Figure 13 is contemplated. In order to come up with the necessary number of workers, the total rework time required is simply divided by the average working availability per employee shown in Table 2 [7.6].

Furthermore, two adjustment formulas are included so as to, first, take into account people's indivisibility and, second, the previously exposed problem about the presence of a single representative for the polishing repair group in just a single shift.

On the one hand, considering the obtained values describe people and, consequently, all numbers must be integer an additional equation is employed [7.7]. Precisely, adjusted needed personnel is computed as the round function of summing obtained personnel needed and 0.51. This addition is performed to ensure the final value rounds to the next integer independently from decimals.

[7.7] *“Adjusted Needed Personnel”=ROUND (“Needed Personnel” + 0.51; 0)*

On the other hand, a conditional formula is defined such that there are at least three representatives, one per shift, in a specific position. The existence of unequal distribution of workers at the various rework groups per shift is not such a problem, if there is always someone occupying the spot [7.8]. That is to say, if the adjusted needed personnel value for mechanic is 14, then the shift distribution will be 5-5-4, meaning 5 mechanics on the first and second shifts and 4 on the last one. And, although, this unbalance may result in some production differences, it is not considered as a big deal. The complete absence of employees, however, will suppose an issue. The formulation definition implies that if the value is smaller than three, three employees are needed, otherwise the Adjusted Needed Personnel number is selected.

[7.8] *"Actual Needed Personnel" = IF ("Adjusted Needed Personnel"<3; 3; "Adjusted Needed Personnel")*

This expression is not included in PDI and Sets calculations. On behalf of their short duration and required training and experience, either one or two specialists per rework group are hired according to production volumes. Besides, those employees usually operate exclusively during morning shifts and, if needed, they work overtime.

Lastly, taking into account the people who will be required to accomplish the earlier computed repair goals and the current staff per rework group [7.9] (Figure 14), its difference reveals the additional personnel needs [7.10]. Therefore, the present workforce per repair specialty is subtracted from the actual needed personnel in order to obtain the pure additional personnel values. So as to create a more visual manner of identifying directly from the table the rework groups in which there was either surplus or shortage of employees, a conditional colorful format was applied such that excess appears in green and scarcity in red.

It is important to notice that the about-to-be-described procedure is performed for every single week (from KW1 to KW50), and for the three considered manufacturing sections: sets, PDI and serie production. The attained results are summarized separately as shown in Table 8.

Table 8. Example of Obtained Personnel Needs per Production Specialty. Source: Self-Elaboration.

	PERSONNEL NEEDS - SERIE PRODUCTION							
	Electricity	Body Shop	Garnishing	Mechanic	Polishing	Painting	Water	Total
KW1	10	17	18	10	3	21	13	92
KW2	10	18	18	10	3	22	15	96
…	…	…	…	…	…	…	…	…
KW50	7	7	10	4	3	13	12	56

	PERSONNEL NEEDS - SETS							
	Electricity	Body Shop	Garnishing	Mechanic	Polishing	Painting	Water	Total
KW1	0	1	1	1	1	1	0	5
KW2	1	1	1	1	1	1	0	6
…	…	…	…	…	…	…	…	…
KW50	0	0	0	0	0	0	0	0

	PERSONNEL NEEDS - PDI							
	Electricity	Body Shop	Garnishing	Mechanic	Polishing	Painting	Water	Total
KW1	0	0	0	0	0	0	0	0
KW2	0	0	0	0	0	0	0	0
…	…	…	…	…	…	…	…	…
KW50	0	0	0	0	0	0	0	0

4.2 New Hiring System

Workforce planning involves further steps than simply determining future personnel gaps per rework group over a certain time frame. By way of illustration, it can incorporate the development of action plans such as training and hiring calendars.

In this project, a proposal for new contracts' scheduling is provided by applying heuristics as decision making procedure. The choice of such a methodology over mathematical models is mainly supported by the great difficulty of formulating every single particularity that appears on real life situations due to the rich complexity and volatile nature of the surrounding entourage. Besides, the advantages inherent to this relatively simple model, exposed below; the lack of knowledge and the restricted extension limitations of a Final Degree Project also contributed to the selection of the suggested method.

This section begins with an introduction of what is heuristics, its strengths and under which circumstances it leads to better outcomes than other operational methods. Then, the specifications of the proposed problem are presented. Finally, a definition of the logical rules applied is provided, so as to understand the process followed to obtain the resulting hiring calendar.

4.2.1 Heuristics for Decision Making

Heuristics can be defined in numerous manners according to the field of application. In a more general overview, this method is "a procedure developed to solve problems by an intuitive approach in which the structure of the problem can be interpreted and exploited intelligently to obtain a reasonable solution" (Nicholson, 1971).

For this project and regarding it constitutes a decision making methodology, heuristics is more appropriately described as an efficient cognitive processes that "ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods" (Gigerenzer & Gaissmaier, 2011).

Realistic formulations are likely to lead to comprehensive mathematical problems which are almost impossible to solve. The lack of technical knowledge, time or accurate estimations has resulted, among other considerations, in the recent increasingly widespread of heuristic methods for solving decision making problems (Hauser, 2014; Hu, & Wang, 2014; Pendharkar, 2015). Other advantages this straightforward methodology encompasses are: comprehension and application simplicity, speed in finding adequate outcomes, savings in formulation time, and production of multiple solutions (Silver, Vidal, & de Werra, 1980; Ridha, 2015).

Organizations seem ideally suited to the application of heuristics because of managers' preference of adequate over optimal solutions for their problems (Guignar, 1992; Hillier, 1990; Lawrence, 2002; Taylor, 2007; Wästelung, Otterbring, Gustafsson, & Shams, 2015; Ridha, 2015), the uncertainty inherent to the business entourage, and the critical importance of time and costs in their daily operations. By way of illustration, most managers in Europe, North America, Japan, Brazil, and India rely on "intuitive" heuristics rather than on this or similar mathematical methods (Parikh, 1994).

Regarding the competitive environment and continuous improvement philosophy that surround Volkswagen's production system, where time, uncertainty and costs are regarded as key factors of any decision making problem, it seems logical to define a heuristic method for hiring scheduling. Besides, the simplicity and logical way of proceeding of such a model may enhance the widespread of the proposed methodology from Final Revision Shop to other manufacturing process stages, and its use in future launch periods.

4.2.2 Hiring Scheduling Specifications

Numerous are the contemplated factors in this project which directly influence the definition of hiring scheduling rules. From Volkswagen Group's influence in decision making and the presence of confronted interests of labor unionists and the executive board, to the pursuit of procedural efficiency at any stage of the manufacturing process, the pure complexity inherent to automobiles' production and the incorporation of innovative advances due to education.

Regarding the previously obtained weekly personnel needs' estimation, there are certain additional factors to be contemplated which involve both side's interests: employee rights, for workers and trade unionists; and costs optimization, for the company. On the one hand, although workforce requirements change over time, it is unethical and illegal to hire someone just for a week and fire him right after. That is why, worker claims come to play in the shape of contract lengths and labor agreements. In particular, in Volkswagen Navarra the duration of temporary covenants range from 3 to 6 months. Consequently, these are the two employed contracts incorporated in this project's analysis in the establishment of new hiring calendars.

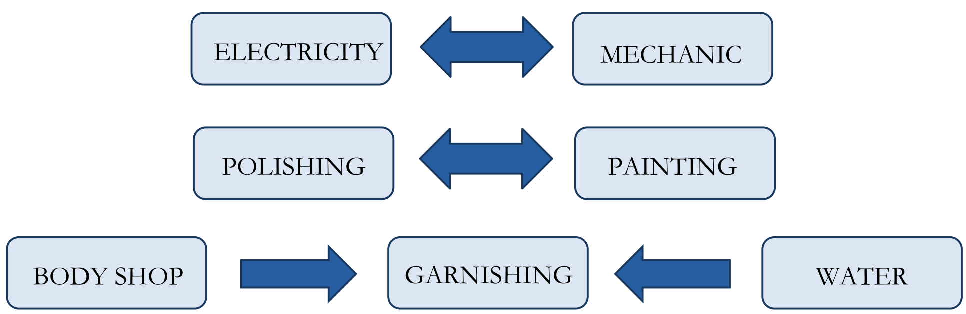
On the other hand, personnel demands are not directly ratified in Pamplona but rather sent to Wolfsburg, Germany. There, the human resources department of the Volkswagen brand decides how many new employees are hired, from the provided analysis. Logically, there is not always an exact coincidence between the approved number and the estimated requirements. As a result, other variables such as training and overtime plans acquire a greater importance. Training, regarding it reinforces workforce flexibility in the sense that a worker hired for a specific position can occupy another one, if necessary, such as the current situation between painters and polishers. And overtime plans, in consequence of the shortage personnel gaps that may exist due to the stated discrepancy between needs and actual hiring.

Moreover, considering the required paperwork that the human resources department needs to prepare for employees' incorporations, a time restriction on hiring dates is introduced. In fact, there are only certain weeks in which new employees can be hired which coincide, more or less, with each month's beginning (KW: 1, 5, 9, 13, 17, 21, 26, 30, 34, 38, 42, 46, 50). The logic of this additional consideration relies on the enhancement of efficiency throughout Volkswagen's production process. In particular, the possibility of forming new employees' packages and, consequently, facilitating the planning of bureaucratic formalities.

Additionally, novel employees are considered as multi-talented such that they hold the required knowledge to successfully complete the tasks attributed to more than a single rework group, when necessary. This condition is attributed to new staff members assuming they are either specialists with preceding career experience or students who just finished their professional training under the tuition of well-prepared experts. Nevertheless, not all technicians can develop the specific tasks of every single rework group. In fact, there are certain rules which need to be applied. The current multi-task patterns were obtained by, first, observing the performed position reorganizations as a result of absenteeism during my internship and, second, asking shift managers for their personal recommendations.

To begin with, due to education improvements, now most electricians are also trained to perform mechanic repair works through a program called electromechanical studies. Secondly, as exposed earlier, painters and polishers are also interchangeable. Thirdly, employees devoted to water repair works are normally garnishing specialists. Nevertheless, not all garnishers have the required training in fixing water entrances. Besides, if necessary, workers specialized in Body Shop can also occupy garnishing positions. In order to provide a clear overview of this multi-task interchangeability, all this information is summarized on Diagram 2 employing arrows to provide a graphical overview of employees' mobility possibilities.

Diagram 2. Multi-talented interchangeability patterns. Source: Self-Elaboration



There may be a possibility that even after all possible adjustments are performed, there are still periods characterized by shortage gaps in personnel demands. This relative problem, which directly reflects the impossibility of reaching the established manufacturing volume, must be compensated in-between weeks and through the establishment of overtime work.

Lastly, in order to design a new hiring's calendar, serie production, PDI and Sets are collectively considered. Initially, personnel needs for these three procedures are summarized in order to have a general overview of employees' weekly demand for each repair group. Then, to identify the actual rework group needs per week, the current staff distribution is subtracted. The resulting data constitute the base of application of the proposed step-by-step process of heuristic algorithms which will result in the hiring calendar definition.

4.2.3 Heuristic Logical Rules

In this section, general strategies applied to heuristics' development are initially explained. Then, a detailed specification of followed steps is combined so as to provide a comprehensive and easy-to-replicate process.

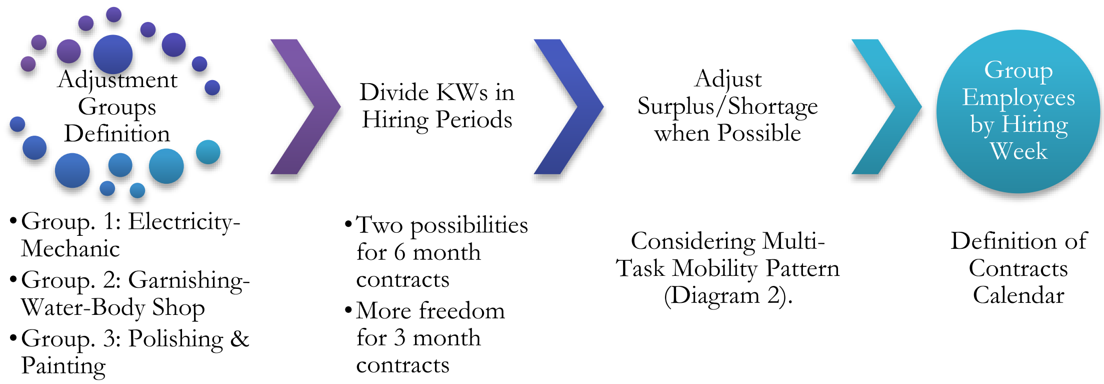
There are four key principles while defining a heuristic method: construction, improvement, component and learning (Gigerenzer & Gaissmaier, 2011; Ridha, 2015). To begin with, this model's construction relies on the data defining the specific instances of the proposed problem. For purpose of this project, the additional weekly employees' demand per rework specialty are considered. Besides, for each solution, a single component is considered at a time; and the result of a previous decision is an input of the next one. That is to say, the hiring of, for instance, six workers under a six months contract, directly impacts both the moment in time and the amount of employees which will be subsequently hired.

With regard to improvement, heuristic methodologies are characterized by continuous refinement by the application of a serie of modifications. Furthermore, this model employs the component strategy for big-sized problems, such as the suggested one with a 50 weeks' time window. This approach consists on the puzzle decomposition into manageable parts and, although sometimes these portions are regarded as independent from one another, for purpose of the proposed study, the decisions performed on one repair specialty directly impacts those belonging to the same multi-task mobility group. In particular, as presented on Diagram 2, three blocks can be distinguished: 1. Electricity-Mechanic, 2. Garnishing-Water-Body Shop and 3. Polishing-Painting.

Finally, the last strategy targets choices sequencing in problem solving. Normally, decision trees are employed in order to track the established decisions' order performed for each obtained outcome. On Diagram 3, the proposed heuristic steps conducted to get the attained solution are summarized as a general overview of performed steps in order to create a theoretical framework for the analysis. Regarding the pursued simplicity and directness of the heuristic procedure in this project, the process scheme can be differentiated in four key steps (Diagram 3).

To begin with, rework specialties are grouped according to their multi-task mobility possibilities in three main categories: Group 1: Electricity and Mechanic; Group 2: Garnishing, Water and Body Shop; and Group 3: Polishing and Painting.

Diagram 3. Decision Making Process. Source: Self-Elaboration.



Then, the year is divided in two separate parts of 6 months (KW1-24; KW26-50) for assigning the minimum necessary number of 6-month contracts. These values are obtained from last personnel weekly needs per rework group for each 24-weeks section. That is to say, the essential needed workforce at the end of each period (ex. KW24, for KW1-24; & KW50, for KW26-50).

Logically, the company wants to minimize as much as possible the existence of personnel surpluses, since costs optimization is one of the main goals of such a competitive industry. Therefore, regarding the available options for temporary covenants, 3-month contracts are favored over 6-month ones, due to the additional flexibility this first type of legal documents impose on hiring calendar planning.

Afterwards, a serie of adjustments is applied in order to introduce the multi-task mobility possibility in the hiring scheduling. The compensation among rework groups results in an increase in efficiency and cost optimization in the hiring process. Lately, contracts are summarized per week, type and specialty to define a proper contracts' calendar.

So as to provide a more visual explanation of the conducted heuristic process, a template for hiring calendar definition is designed for each repair group with certain key variables: contracts, personnel needs, balance and hiring availability (Table 9).

The suggested scheme is based on straightforward principles and repetitive patterns in order to provide the most intuitive results' representation as possible. First of all, yellow cells reflect the moment and amount of new incorporations approved on a certain week. Moreover, the number of reiterations of a certain value determines the agreed contract length, 24 for 6-month contracts and 12 for 3-month ones.

Table 9. Rework Hiring Planning Template Fragment. <u>Source</u>: Self-Elaboration.

	GROUP 1		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
		ELECTRICITY	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6		2
			3	3	3	3	3	3	3	3	3	3	3	3														
							5	5	5	5	5	5	5	5	5	5	5	5										
											2	2	2	2	2	2	2	2	2	2	2	2						
																			2	2	2	2	2	2	2	2	2	2
[9.1]		CONTRATCS	9	9	9	9	14	14	14	14	16	16	16	16	13	13	13	13	10	10	10	10	8	8	8	8	2	4
[9.2]		ADDITIONAL NEEDS	7	8	8	8	10	12	13	14	14	15	15	15	14	12	12	10	10	10	10	10	7	7	6	6	6	6
[9.3]		BALANCE	2	1	1	1	4	1	1	0	2	1	1	1	-1	1	1	3	0	0	0	0	1	1	2	2	-4	-2
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
		MECHANIC	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
			2	2	2	2	2	2	2	2	2	2	2	2														
							2	2	2	2	2	2	2	2	2	2	2	2										
											2	2	2	2	2	2	2	2	2	2	2	2						
[9.1]		CONTRATCS	5	5	5	5	7	7	7	7	9	9	9	9	7	7	7	7	5	5	5	5	3	3	3	3	0	0
[9.2]		ADDITIONAL NEEDS	5	5	5	6	7	7	7	7	8	9	9	9	8	7	7	7	6	6	6	5	3	3	3	3	2	2
[9.3]		BALANCE	0	0	0	-1	0	0	0	-1	0	-1	-1	-1	-2	-1	-1	-1	-2	-2	-1	0	0	0	0	0	-2	-2
[9.4]		ADJUSTMENT	2	1	1	0	4	1	1	-1	2	0	0	0	-3	0	0	2	-2	-2	-1	0	1	1	2	2	-6	-4

Additional information is included to facilitate the contracts distribution over time. Firstly, "Contracts" row is the number of current contracts available per week, attained as the sum of values of a specific column [9.1]. Subsequently, "Additional Needs" consists on a simple reference of a specific group weekly additional specialists' demand.

[9.2] $$\text{"}Additional\ Needs\text{"} = Demand_{Serie} + Demand_{Sets} + Demand_{PDI} - Staff_{Actual}$$

Then, "Balance", defined as the difference between "Additional Needs" (Table 8) and "Contracts", provides further details on the current solution status and supposes an input for consequent decisions [9.3]. In other words, it can be seen as an indicator of the amount and moment in which new contracts must be introduced. Finally, green cells on the top indicate the possibility of hiring, and yellow ones, the beginning of any contract.

The multi-task mobility incorporation results in the inclusion of additional analytical considerations such as the row "Adjustment" [9.4]. This formula, which is differently defined depending on the considered adjustment group, represents a measure of the global combined balance for groups 1 and group 3; but it supposes a sign of Garnishing adjusted balance for group 2. None the less, the variable "Adjustment" takes into account the diverse balance status of each group in addition to the compensation effects, and develops an indicator which constitutes the essential base for next contracts allocation.

As a matter of fact, this row's formulation for groups 1 and group 3 is identical, regarding the mutual interchangeability of workers among rework specialties of the same aggrupation, which consists on the simple sum of each component's balance.

[9.4] $$Adjustment_{Group\ 1} = Balance_{Electricity} + Balance_{Mechanic}$$

However, for group 2 an additional equation is required considering employees from Water and Body Shop can also occupy garnishers working positions; but not the other way around. Therefore, a more complex formula considering this additional difficulty is applied.

It is important to highlight that adjustments among repair groups are applied since the beginning of the process. For example, as exhibited on Table 9, Electricity holds personnel surpluses for KW4, KW10, and KW11, in contrast with Mechanic shortage in the same period. Consequently, regarding the mobility possibility among these two specialists (Diagram 2), instead of hiring additional employees, specialists from this first specialty are diverted to the second one.

The allocation process, as mentioned before, begins with the initial assignment of 6-month contracts. As soon as this preliminary step has been accomplished, the strategic distribution of 3-months contracts begins. In order to optimize the hiring scheduling, "Balance" values are considered first individually and, then, in comparison to other components of the specific group.

First of all, maximum shortages are identified and studied. Secondly, regarding their considerable size and the correspondent numerous problems that they may bring, they need to be tackled as soon as possible. Finally, iterations in-between groups and weeks are performed so as to get the best possible solution.

A key indicator in determining the accuracy of the proposed model is the overall sum of all related surpluses and shortages from the "Adjustment" row. In fact, any attained outcome whose addition value is close to one is considered as an adequate solution. Small resulting personnel deficits attained from differences between needs and demand, are compensated through overtime hours or in-between weeks, but great discrepancies may lead to coordination problems. That is why available and necessary staff is so important.

All these considerations must be contemplated while developing the heuristic approach of the proposed hiring scheduling. Nevertheless, as mentioned before, the application of the improvement strategy which consists on going over the obtained solution repeatedly, results in a final better outcome.

5. FINDINGS & DISCUSSION

5.1 Workforce Requirements' Evolution

The first performed calculations of this project consisted on estimating weekly personnel needs per rework group. The obtained results share the same tendency independently on the repair specialty, with a sharp initial increase in staff requirements during the first eight to ten weeks, followed by a progressive decrease and a subsequent stabilization (Annexe 5 – Figure 18).

Two are the essential factors explaining this appreciated evolution over time. Firstly, the initial increase of production proper of any launch phase. Logically, the increment in vehicles' volume results in a raise of defects' frequency and, consequently, of personnel demands.

Secondly, the presence of Pre-Delivery Inspection (PDI) and Sets during from KW1-20 and KW4-20 respectively, also influence these numbers in spite of the low weekly requirements for each of these additional auditing procedures, from one to two employees per rework group. On Annexe 5 – Figure 18, the evolution from KW4 to KW5 and from KW20 to KW21 is graphically described by two noticeable steps. The overall initial increase and subsequent decrease in staff needs adds up to 13 and 16 workers respectively, the biggest changes of the studied period which coincide with the beginning of PDI in KW5 and the ending of both PDI and Sets in KW20.

In order to provide a more in-detail analysis of the attained personnel requirements, the three evaluated processes: Series, PDI, and Sets, are separately examined. To begin with, the serie staff needs follow the general trend of the combined analysis (Annexe 5 – Figure 19). Actually, the only noticeable discrepancies in value terms are found during the first twenty weeks regarding that from KW21 on, series production accounts, by itself, for the whole estimation numbers since both PDI and Sets have already finished. By way of illustration, Polishing personnel needs remain exactly the same in serie, making clear that the exposed evolution on general terms is produced due to PDI and Sets influence. Besides, water staff requirements experience no variation at all, considering those repair works are performed before ZP8 and these two additional auditing procedures are conducted later.

With regard to Sets and PDI (Annexe 5 – Figure 20), the first observable discrepancy among these graphs and the previous ones is its duration. Whereas both series and the overall analysis occupy the fifty proposed weeks, Sets and PDI, as exposed earlier, target only the first twenty weeks. Moreover, Sets share the variations' pattern exposed in the general trend, but PDI does not. In fact, its evolution is characterized by a tiny increment from KW5 to KW8 supported by the progressive weekly production increase of the initial weeks, also present in the overall evaluation; and a subsequent stability which is maintained from KW9 to KW20.

In conclusion, the presented methodology has resulted in an easy-to-understand estimation of personnel needs over time and per specialty group which can be useful for preparing the recruitment process beforehand and all additional requirements such as extra rework-specific tools, working clothes or safety instruments such as globes or glasses.

5.2 Contracts' Calendar

In order to add some extra value to the proposed personnel needs estimation for Final Revision Shop in 2019, a heuristic methodology for designing an adequate, powerful and straightforward hiring calendar has been incorporated.

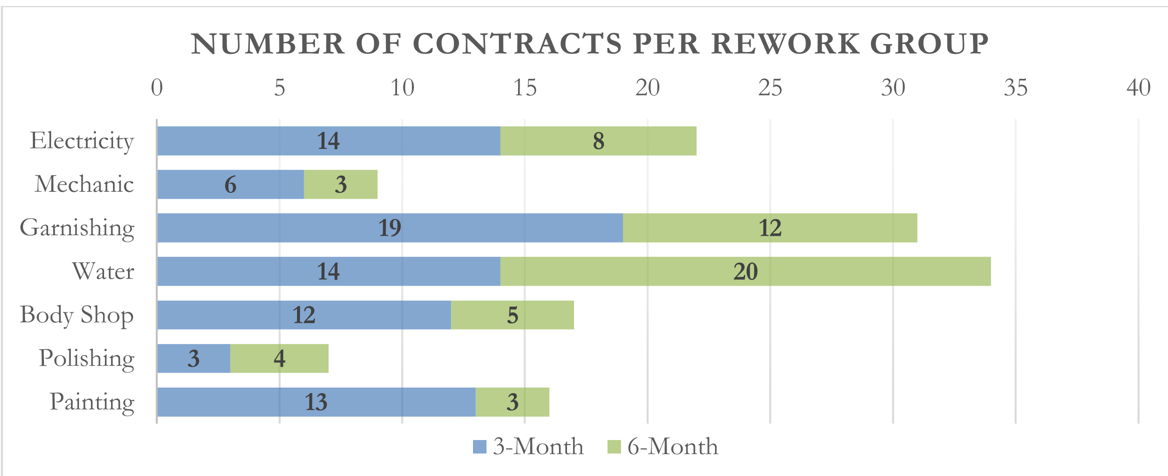
For this second section, the pure additional hiring needs are required (Annexe 6). Therefore, the previously obtained results per production phase: serie, sets and PDI are, first of all, summed to come up with the overall Final Revision Shop demand per week and rework specialty. Then, the actual labor force values from each repair group are subtracted.

There is almost no difference in shape between this new graphical representation and previous ones. The only remarkable discrepancy is the appearance of negative values for additional personnel needs. These numbers indicate the presence of periods when there is an excess in workforce. This situation is not desirable for a company's cost optimization because staff surpluses indicate there is an inadequate allocation of resources. In other words, there are more workers than tasks to perform. That is one of the reasons why the multi-task mobility among repair groups has been introduced, to try to accomplish a resulting hiring calendar as adequate and cost-efficient as possible by minimizing the existent of staff excesses.

After the suggested heuristic methodology was applied to the inputs data of Annexe 6, a proper hiring scheduling was obtained (Annexe 7). The total number of additional temporary employees hired in 2019 raises up to 136, 81 of which correspond to 3-month contracts and 55 to 6-month ones. Although the general tendency represents a preference for shorter covenants over longer ones, as exposed in the introduction; that is not the case for certain specific repair specialties (Figure 21). The supremacy in number of 6-month contracts over 3-month ones for some rework groups rely on their stability over time such as water or mechanic which did not experience sizeable variations.

As a way of illustration, water repair specialists hold a sizeable needs value all over the period with punctual increases; as a result, it is more efficient to sign a fixed number of 6-month contracts and employ 3-month ones only for adjusting. However, that is not the case for other rework groups whose demand is more volatile and, regarding it is more difficult to identify a general trend, 6-month contracts; shorter ones are applied to take advantage of their flexibility in capturing as accurately as possible real fluctuations.

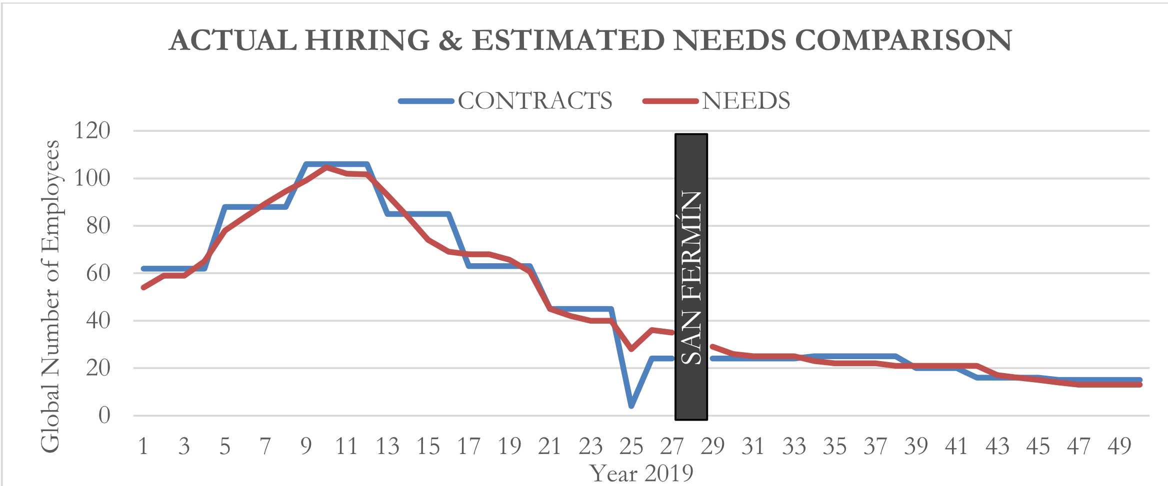
Figure 21. Contracts Distribution per Rework Group. Source: Self-Elaboration.



An easy manner of measuring the accuracy of the proposed heuristic methodology in capturing the complex and integrate nature of real life situations, is to visually compare personnel requirements with the attained outcome. For this purpose, all values were added, independently from specialists groups, for both contracts and additional needs. The comparison consisted on simply analyzing the proximity between the two lines (Figure 22).

From Figure 22, it can be seen how, both lines move relatively close with one another. The main problem of the suggested solution is the existence of considerable gaps. In particular, the sizeable shortage present from KW25-KW30 of around 20 people. However, as it was mentioned before, the presence of two previous surpluses, KW14-KW17 and KW21-KW24, in addition to the use of overtime hours, when necessary, may compensate such a deficit with no problem. Another noticeable aspect is the identical shape of both lines after San Fermín which exhibits an almost identical match between needs and contracts.

Figure 22. Comparison between Hiring and Estimated Needs. Source: Self-Elaboration.



Finally, due to the performed analysis, it is possible to program the hiring moment, the amount per specialty, and type of contracts (Table 10), which may facilitate the beforehand organization planning of Human Resources Department and the in-house structuring of Final Revision Shop. Most labor agreements are expected to be signed during the initial ten weeks as a result of additional personnel needs increments resulting from the escalation of production's volume at the origin of VW216's launch period. Subsequent hiring decisions respond to additional staff requirements or relatively volatile behavior of some rework groups.

Table 10. Proposed Hiring Calendar. Source: Self-Elaboration.

REWORK GROUPS	KW1		KW5	KW9	KW13	KW17	KW21	KW26		KW30	KW34
	3m	6m	3m	3m	3m	3m	3m	3m	6m	3m	3m
Electricity	3	6	5	2	0	2	0	2	0	2	0
Mechanic	2	3	2	2	0	0	0	0	0	0	0
Garnishing	3	10	5	6	0	0	0	2	4	0	1
Water	3	11	7	0	0	2	0	9	0	2	0
Body Shop	5	5	3	4	0	0	0	0	0	0	0
Polishing	1	2	1	0	1	0	0	2	0	0	0
Painting	5	3	3	4	0	0	0	0	1	0	0

To summarize, the application of heuristic method may have not lead to the best optimal solution but it has undoubtedly resulted in a relatively accurate outcome which provides a detailed description of the moment, the number of employees, the specific repair group and the type of contract for each individual worker. In other words, thanks to such a conducted procedure it is possible to ensure a beforehand planning of future needs.

6. CONCLUSION

Volkswagen Navarra will face a complicated situation in 2019 during the coordination of simultaneous two-model production for the first time in its history. As a result, it has started analyzing the probable scenario and initiate the planning of some critical factors. As a way of illustration, most infrastructure and machinery modifications have already been performed.

Nevertheless, the estimations for one of the most important elements of the manufacturing process which accounts for a sizeable percentage of total costs in the automobile industry was unattended. That is the case of personnel needs which constitute an essential component of vehicle's chain production. As a matter of fact, being able to estimate staff demands with time enough to organize an adequate hiring calendar and start a recruitment process, would be incredibly valuable.

During my internship in Final Revision Shop at Volkswagen Navarra, I could foresee the shortcomings and difficulty the estimation of personnel needs encountered. Therefore, I considered it was interesting to try to optimize this computational procedure and to design a systematic approach which could be useful in both future launch periods and other shops in Landaben's manufacturing process.

First of all, the whole set of tests and proofs conducted in this last stage of a vehicle's production procedure was evaluated to identify key informative factors. Besides, more general inputs were also introduced to build up a complete study framework which reflect reality as accurate as possible. Based on all available information and suggestions from employees and technic experts, it was possible to determine a simple method for estimating weekly staff needs per rework group.

Despite the complexity of understanding the whole manufacturing procedure of an auto-maker, the conducted computations were both logical and direct. Moreover, one of the key advantages of this template is the direct relationship of values with one another; such that in case any unexpected event needs to be incorporated in already performed calculations, all values will adjust to the new specificities.

Moreover, I wanted to go one step forward and develop a systematic methodology for defining hiring calendars. For this purpose, heuristics was the selected model relying on its superior results, in comparison to other mathematical proposals, for situations where time, costs and uncertainty are regarded as essential factors. The attained results configure a detailed hiring calendar in which not only the moment and the amount of new incorporations is determined, but also the specific repair specialty and under which type of contract. It is important to highlight, that once again, the developed methodology was based on simple principles and rational thinking, which directly influences its subsequent applications and further extension.

In conclusion, this project has accomplished its main objective, to develop an estimation model and a hiring scheduling procedure which are not only simple, logical and direct, but also powerful and accurate since most particularities of reality have been integrated. As a result, it hopes to contribute in the time reduction and cost savings involved in such a strategic decision and to allow Volkswagen Navarra to focus on keeping innovating to maintain their predominant position in the automobile industry.

7. FUTURE RESEARCH

In this section, two separate aspects regarding existent research gaps from this project are considered. First of all, the extension possibilities of proposed models and, secondly, the comparison of the attained solution with the optimal outcome presumably resulting from mathematical procedures.

To begin with, there are numerous research gaps regarding the applicability of such a heuristic approach. Initially, to other shops present in Volkswagen Navarra's production process. Subsequently, to additional auto producers. Finally, to any company which employs a similar manufacturing procedure taking into account variables such as time, diverse stations, and objective ratios; and that is characterized by a competitive environment where time, cost and uncertainty are essential factors in any decision making problem.

Historically, the optimal outcome would be obtained by designing a mathematical problem which, through the combination of an objective function and a serie of constraints, will lead to the best hiring distribution after a consistent number of iterations. In order to build up such a method, it will be necessary to combine three classic problems: general or portfolio, assignment, and scheduling.

First of all, the original standpoint will be the portfolio or general model which focuses on satisfying a certain demand at the lowest possible cost. In the suggested application, demand is the number of specialists per rework group per week, and the minimization of costs corresponds to hiring just the necessary number of additional personnel. For this purpose, integer variables will be employed. This initial method will suppose the base from which the two additional methods will be based on.

Secondly, the assignment of workers to a specific rework group, only accomplishing one task a week, and the incorporation of workers mobility from one repair station to another will be introduced through the addition of the assignment problem equations. That will be a way in which multi-task knowledge among employees could be incorporated. Finally, it will be necessary to add time continuity. For this purpose, the scheduling model will be added considering the temporary contract lengths possibilities, 3 and 6 months.

The most complicated part of this optimization analysis will undoubtedly be the fusion of the three proposed problems, which was impossible to accomplish due to the specified extension of a Final Degree Project and the lack of knowledge regarding this particular topic. Nevertheless, it could be considered as an interesting and challenging research gap for more experienced and knowledgeable experts.

In this study, as previously commented, heuristic algorithms have been employed in order to succeed in defining a useful and adequate hiring schedule. Usually this type of methodology is later compared with the optimal solution provided by an optimization problem. The difference gap between both procedures' objective functions reflect the accuracy of the performed heuristic methodology. Nevertheless, it is important to highlight that, regarding the importance of time and cost on this decision making problem, the more stochastic proposal may lead to a better solution than the more deterministic one. In other words, the one resulting from mathematical calculations.

8. ACKNOWLEDGEMENTS

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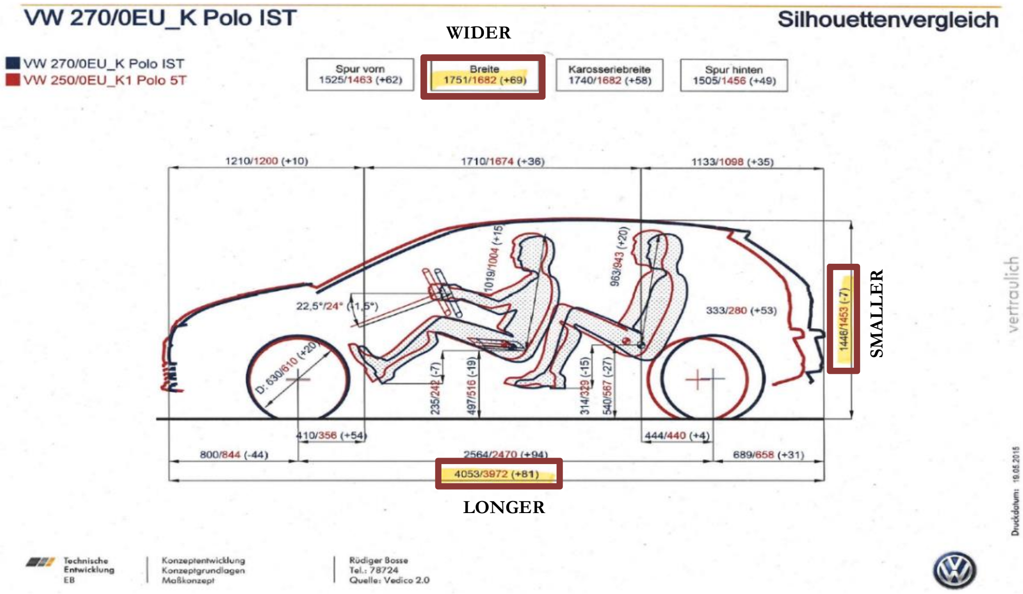
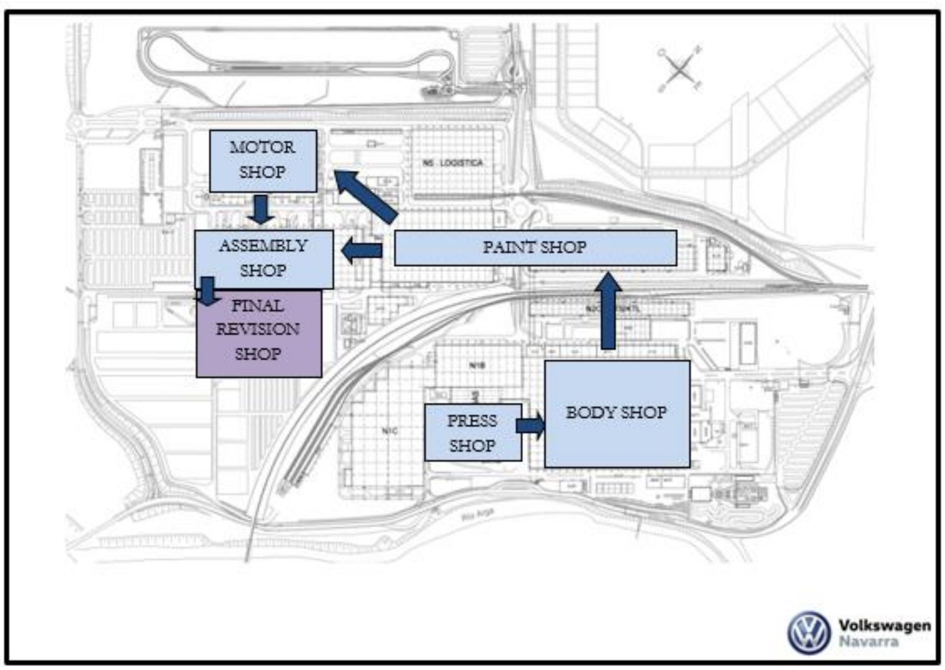
10. ANNEXES

Annexe 1. Physical Comparison between VW250 & VW270. Source: Volkswagen Navarra.



Annexe 2. Volkswagen Navarra. Production Process. Source: Intranet, Volkswagen Navarra.



Annexe 3. Final Revision Shop Instantaneous. Source: Self-Elaboration.

Figure 2. Convergence (up/below view) and FUMO instantaneous.

Upside *Downside* *FUMO*

Figure 3. Warm Up Phase.

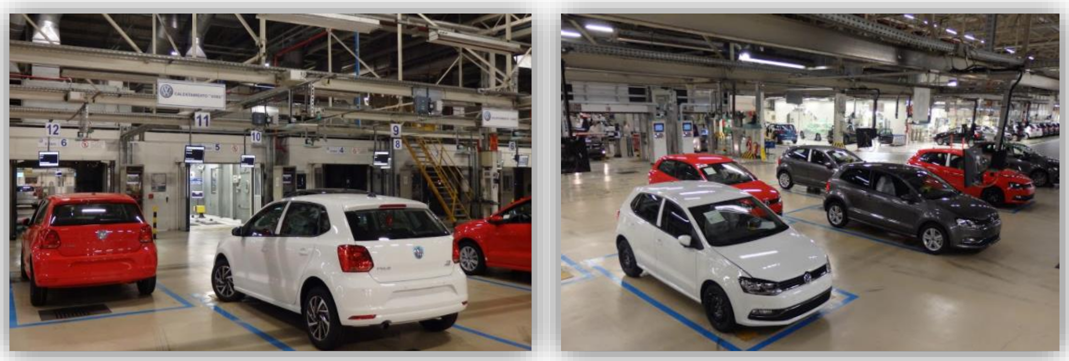


Figure 4. Roll-Out Cabins.

Figure 5. Exit of ZP7, ZP8, and Q stickers.

Figure 6. Road test.

Figure 7. Rain Test.

Figure 8. Parking lot and Truck loading.

Figure 9. Rework Groups.

Rain Repair

Garnishing Repair

Paint Repair

Mechanic Repair

Electric Repair

Body Repair

Annexe 4. Staff Distribution in Final Revision Shop**.** Source: Virginia Valencia, Volkswagen Navarra**.**

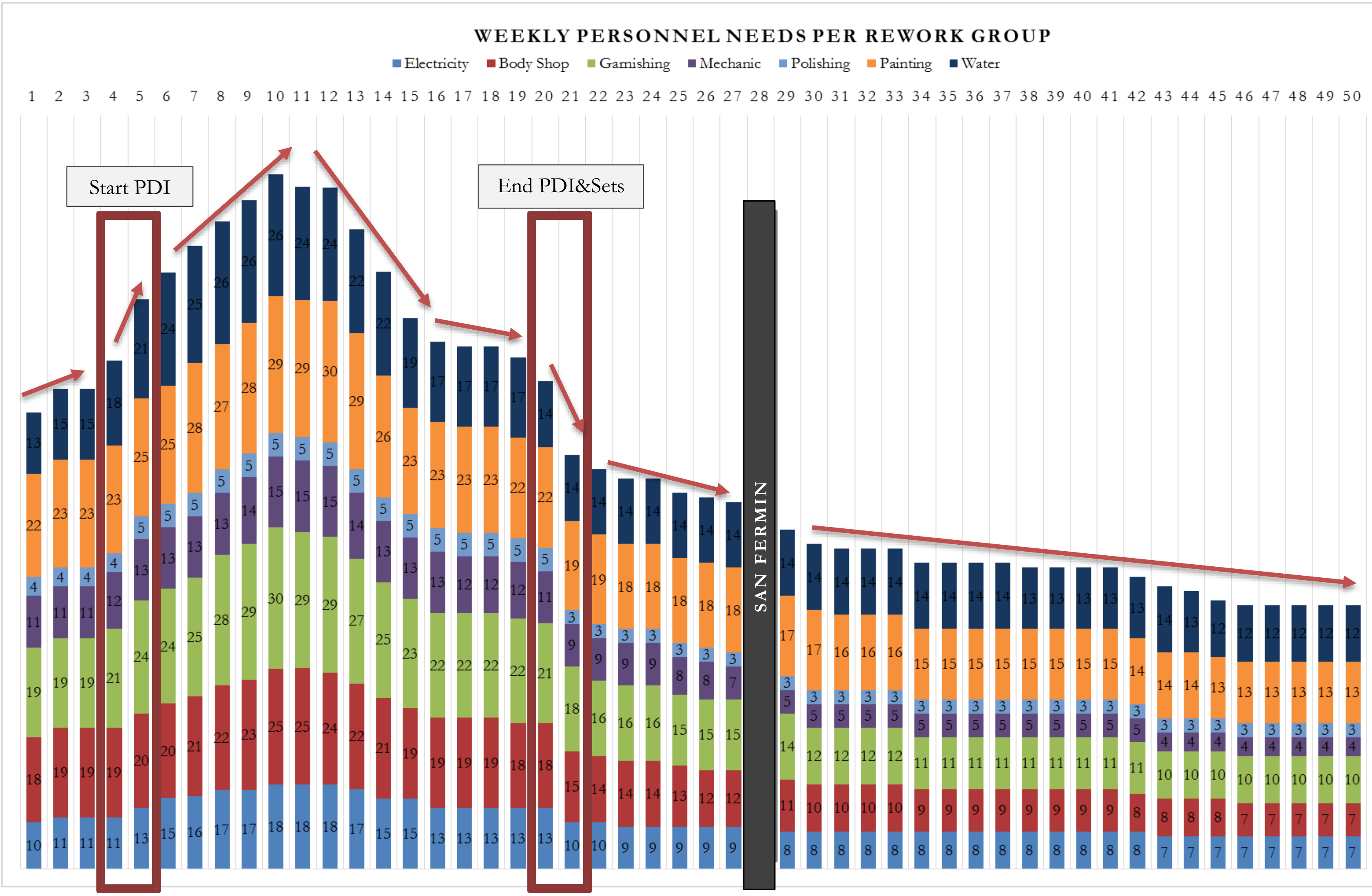
TALLER DE REVISIÓN FINAL

NECESIDADES MOD PARA 1408+43 C/D EN ZP6

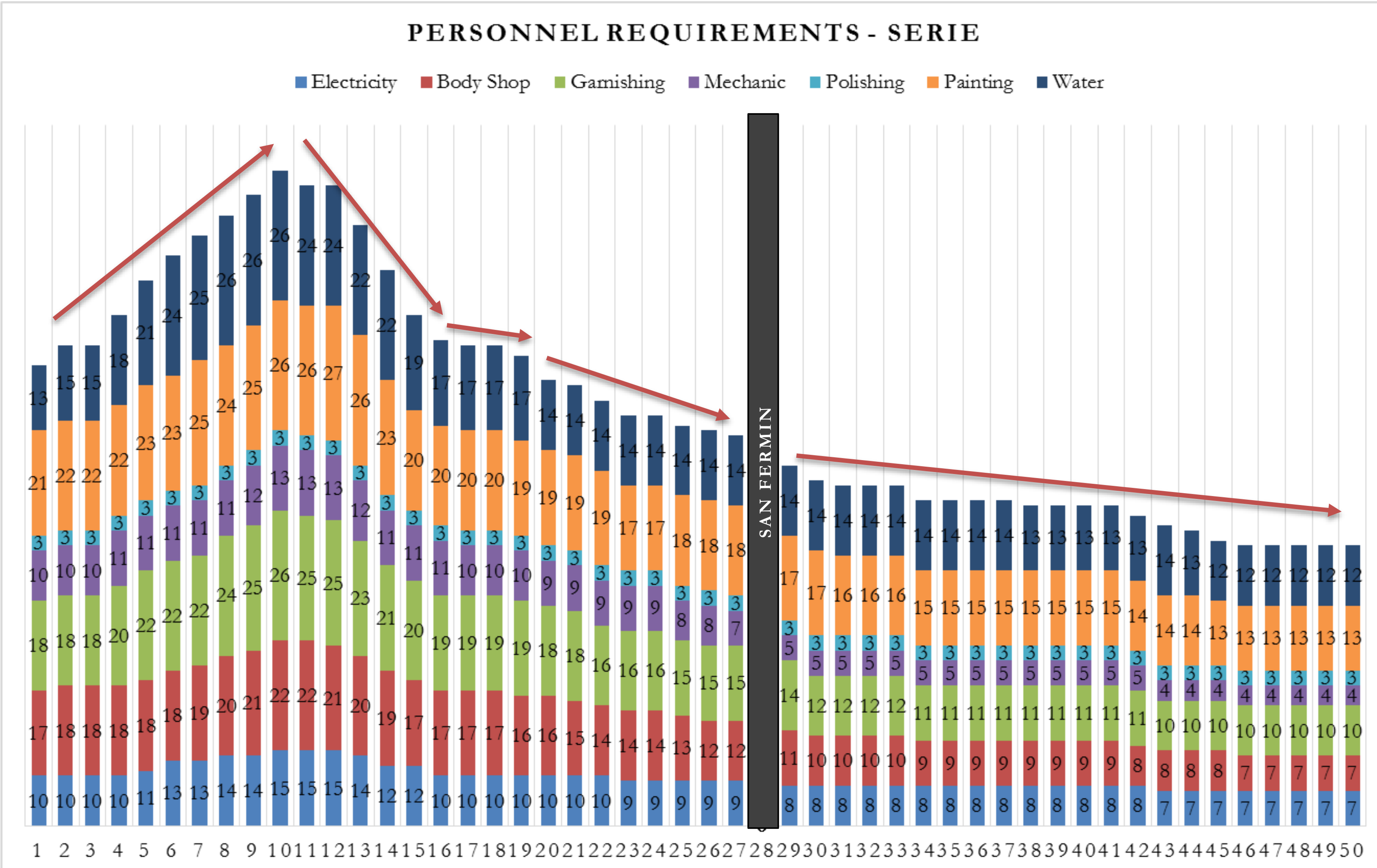
FECHA INTRODUCCIÓN: 18/04/2017

ÁREAS DE TRABAJO		Guarnecido	Revisionista	Conductor instalación	Chapistas	Pulidor	Electrico	Mecánico	Oficial 3ª	MOD TURNO M	MOD TURNO T	MOD TURNO N	MOD DÍA
MONTAJE	AJUSTE ELEMENTOS MÓVILES (PORTÓN)				6					2	2	2	6
	FORMACIÓN AJUSTES				3					1	1	1	3
PRUEBAS	CONVERGENCIA Y ALIN. FAROS		27							9	9	9	27
	PRUEBAS RODILLOS / EOBD	18								6	6	6	18
	C. INSTALACIÓN AREA DE PRUEBAS			3						1	1	1	3
	CONDUCTOR LEP + LLUVIA								12	4	4	4	12
GRUPOS DE REPARACIÓN	REPARACIÓN ESTANQUEIDAD	1								1	0	0	1
	REPARACIÓN ELECTRICA						3			1	1	1	3
	REPARACIÓN MECÁNICA							6		2	2	2	6
	REPARACIÓN GUARNECIDO	6								2	2	2	6
	CAMBIO DE PIEZAS	1								1	0	0	1
	REPARACIÓN CHAPA				9					3	3	3	9
	CONDUCTOR GRUPOS								3	1	1	1	3
	REPARACIÓN PINTURA	3				14				6	6	5	17
ZP7/ZP8	CONDUCTOR ZP7/ZP8								9	3	3	3	9
	AJUSTE ELEMENTO MÓVILES				36					12	12	12	36
	RETOCADOR CHAPA				6					2	2	2	6
	GUARNECIDO	6								2	2	2	6
	PULIDOR					9				3	3	3	9
	COFRE MOTOR ZP8	3								1	1	1	3
	BEATS								1	1	0	0	1
	RECUPERACION CAMPA	1								1	0	0	1
TOTAL / TURNO		39	27	3	60	23	3	6	25	65	61	60	186

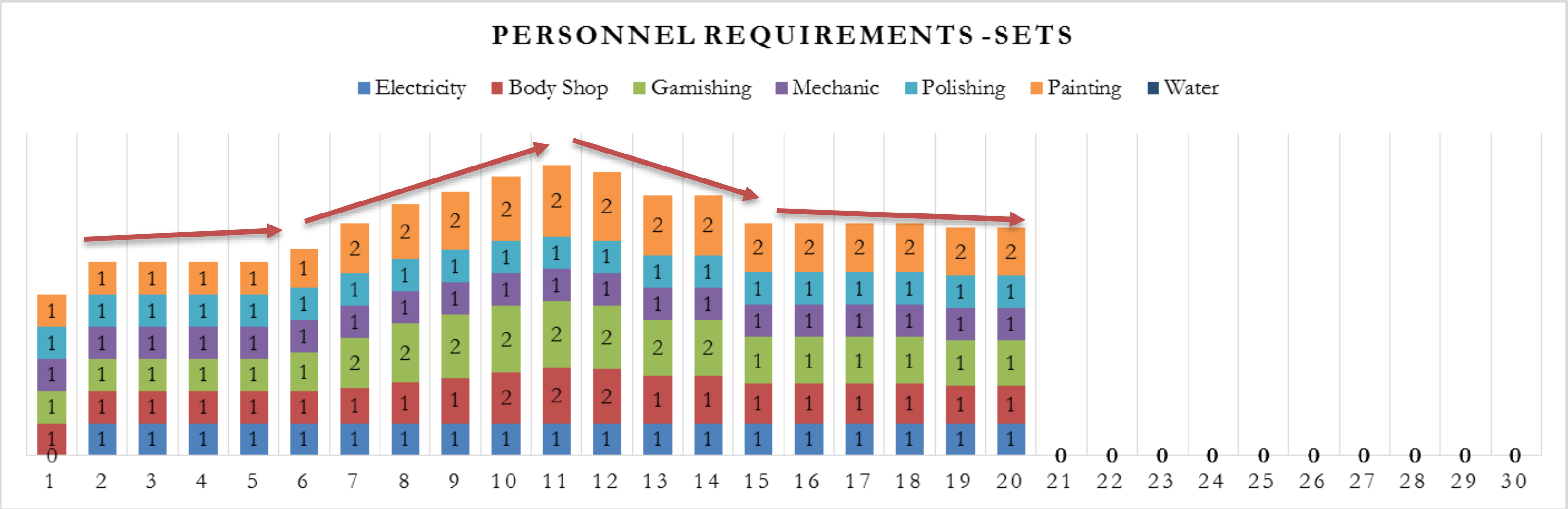
Annexe 5 – Figure 18. Overall Personnel Weekly Demands per Rework Group. <u>Source:</u> Self-Elaboration**.**

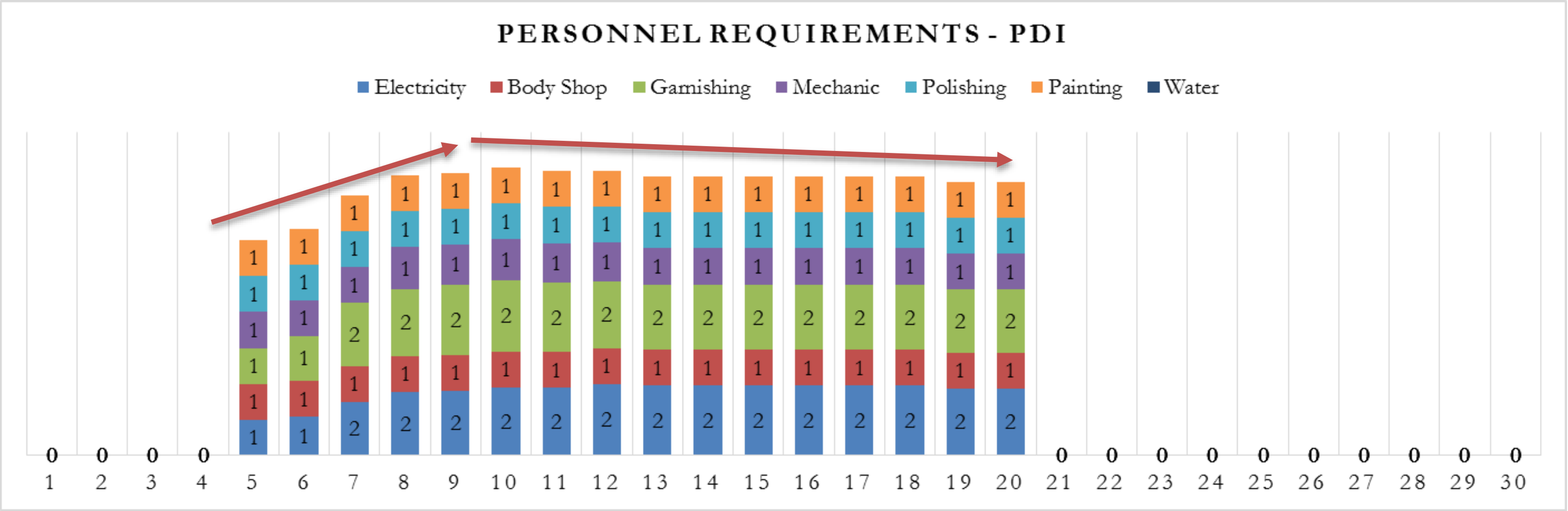


Annexe 5- Figure 19. Serie Personnel Weekly Demands per Rework Group. Source: Self-Elaboration**.**

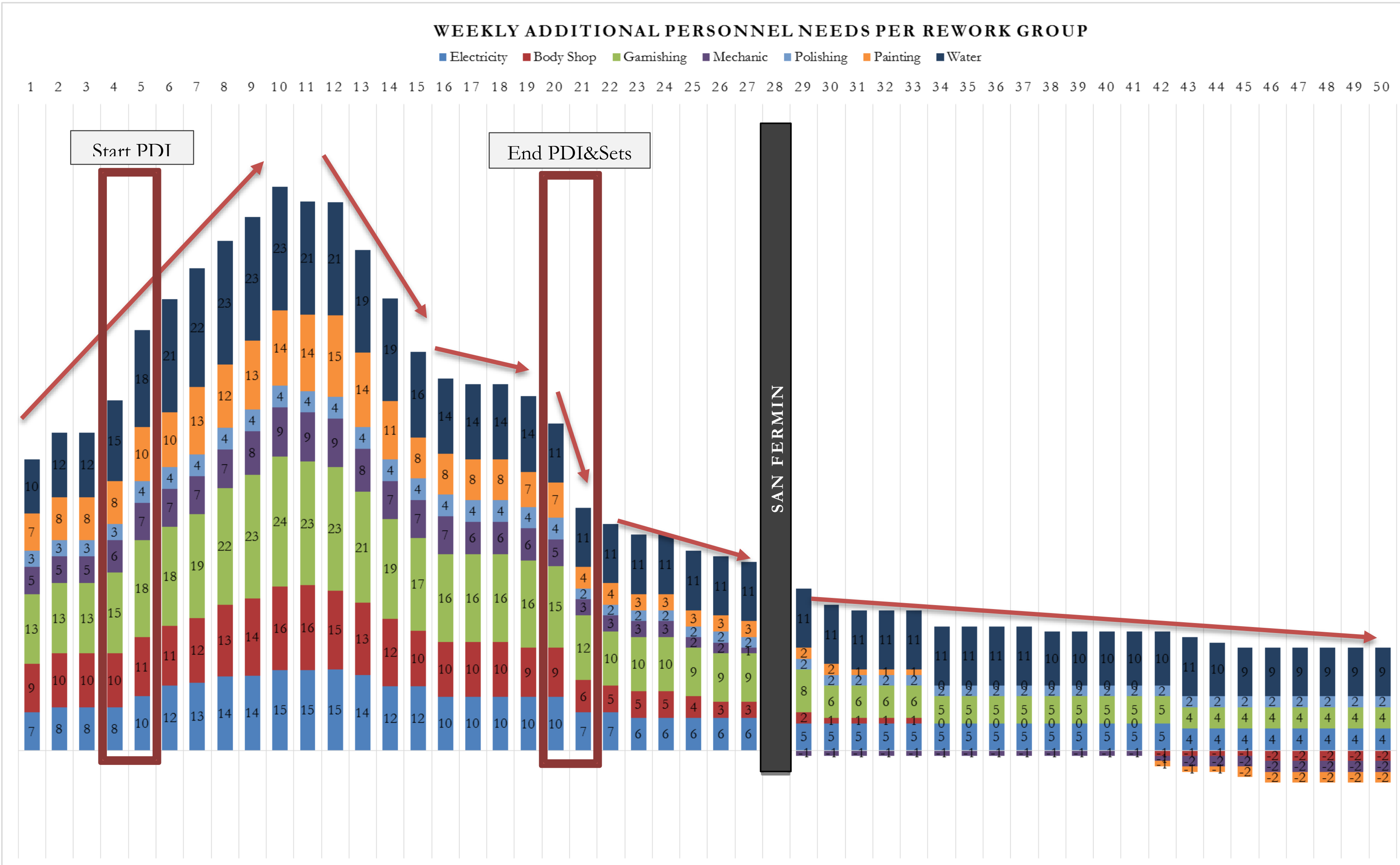


Annexe 5 – Figure 20. Sets and PDI Personnel Weekly Demands per Rework Group. Source: Self-Elaboration





Annexe 6. Additional Personnel Weekly Needs per Rework Group. Source: Self-Elaboration



Annexe 7. Hiring Scheduling Results. <u>Source:</u> Self-Elaboration**.**

GROUP 1 – ELECTRICITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6		2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	3	3	3	3	3	3	3	3	3	3	3	3																		2	2	2	2	2	2	2	2	2	2	2	2										
					5	5	5	5	5	5	5	5	5	5	5	5																																			
									2	2	2	2	2	2	2	2	2	2	2	2																															
																	2	2	2	2	2	2	2	2	2	2	2		2																						
CONTRATCS	9	9	9	9	14	14	14	14	16	16	16	16	13	13	13	13	10	10	10	10	8	8	8	8	2	4	4		4	4	4	4	4	4	4	4	4	4	4	4	4	2	2	2	2	2	2	2	2	2	
ADDITIONAL NEEDS	7	8	8	8	10	12	13	14	14	15	15	15	14	12	12	10	10	10	10	10	7	7	6	6	6	6	6		5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	
BALANCE	2	1	1	1	4	1	1	0	2	1	1	1	-1	1	1	3	0	0	0	0	1	1	2	2	-4	-2	-2		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-3	-2	-2	-2	-2	-2	-2	-2	-2	

GROUP 1 – MECHANIC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3																											
	2	2	2	2	2	2	2	2	2	2	2	2																																							
					2	2	2	2	2	2	2	2	2	2	2	2																																			
									2	2	2	2	2	2	2	2	2	2	2	2																															
CONTRATCS	5	5	5	5	7	7	7	7	9	9	9	9	7	7	7	7	5	5	5	5	3	3	3	3	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
ADDITIONAL NEEDS	5	5	5	6	7	7	7	7	8	9	9	9	8	7	7	7	6	6	6	5	3	3	3	3	2	2	1		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-2	
BALANCE	0	0	0	-1	0	0	0	-1	0	-1	-1	-1	-2	-1	-1	-1	-2	-2	-1	0	0	0	0	0	-2	-2	-1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	
ADJUSTMENT	2	1	1	0	4	1	1	-1	2	0	0	0	-3	0	0	2	-2	-2	-1	0	1	1	2	2	-6	-4	-3		0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0	0	-4

GROUP 2 – GARNISHING	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10		2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	3	3	3	3	3	3	3	3	3	3	3	3														4	4		4	4	4	4	4	4	4	4	4	4													
					5	5	5	5	5	5	5	5	5	5	5	5																		1	1	1	1	1	1	1	1	1	1	1	1						
									6	6	6	6	6	6	6	6	6	6	6	6																															
CONTRATCS	13	13	13	13	18	18	18	18	24	24	24	24	21	21	21	21	16	16	16	16	10	10	10	10	0	6	6		6	6	6	6	6	7	7	7	7	7	3	3	3	3	3	3	3	2	2	2	2	2	
ADDITIONAL NEEDS	13	13	13	15	18	18	19	22	23	24	23	23	21	19	17	16	16	16	16	15	12	10	10	10	0	9	9		8	6	6	6	6	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	
BALANCE	0	0	0	-2	0	-1	-2	-4	1	-1	0	1	0	2	3	4	-1	-1	-1	0	-2	0	0	0	0	-3	-3		-2	0	0	0	0	2	2	2	2	2	-2	-2	-2	-2	-1	-1	-1	-2	-2	-2	-2	-2	

GROUP 2 – WATER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11		9	9		9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	
	3	3	3	3	3	3	3	3	3	3	3	3																		2	2	2	2	2	2	2	2	2	2	2	2										
					7	7	7	7	7	7	7	7	7	7	7	7																																			
																	2	2	2	2	2	2	2	2	2	2	2		2																						
CONTRATCS	14	14	14	14	21	21	21	21	21	21	21	21	18	18	18	18	13	13	13	13	13	13	13	13	2	11	11		11	11	11	11	11	11	11	11	11	11	11	11	11	9	9	9	9	9	9	9	9	9	
ADDITIONAL NEEDS	10	12	12	15	18	21	22	23	23	23	21	21	19	19	16	14	14	14	14	11	11	11	11	11	11	11	11		11	11	11	11	11	11	11	11	11	10	10	10	10	10	11	10	9	9	9	9	9	9	
BALANCE	4	2	2	-1	3	0	-1	-2	-2	-2	0	0	-1	-1	2	4	-1	-1	-1	2	2	2	2	2	-9	0	0		0	0	0	0	0	0	0	0	0	1	1	1	1	-1	-2	-1	0	0	0	0	0	0	5

GROUP 2 – BODY SHOP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5																											
	5	5	5	5	5	5	5	5	5	5	5	5																																							
					3	3	3	3	3	3	3	3	3	3	3	3																																			
									4	4	4	4	4	4	4	4	4	4	4	4																															
CONTRATCS	10	10	10	10	13	13	13	13	17	17	17	17	12	12	12	12	9	9	9	9	5	5	5	5	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
ADDITIONAL NEEDS	9	10	10	10	11	11	12	13	14	16	16	15	13	12	10	10	10	10	9	9	6	5	5	5	4	3	3		2	1	1	1	1	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-2	-2	-2	-2	
BALANCE	1	0	0	0	2	2	0	-1	2	1	1	2	-2	-1	1	1	-2	-2	-1	-1	-1	0	0	0	-4	-3	-3		-2	-1	-1	-1	-1	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	-2
ADJUSTMENT**	0	0	0	-2	0	1	-2	-4	1	0	0	1	0	2	3	4	-1	-1	-1	0	0	0	0	0	0	-3	-3	0	-2	0	0	0	0	2	2	2	2	2	-1	-1	-1	-2	0	0	0	-1	0	0	0	0	-3

GROUP 3 – POLISHING	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	1	1	1	1	1	1	1	1	1	1	1	1																																							
					1	1	1	1	1	1	1	1	1	1	1	1																																			
													1	1	1	1	1	1	1	1	1	1	1	1																											
CONTRATCS	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	0	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
ADDITIONAL NEEDS	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
BALANCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	1	1	1	1	-2	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

GROUP 3 – PAINTING	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3																											
	5	5	5	5	5	5	5	5	5	5	5	5														1	1		1	1	1	1	1	1	1	1	1	1													
					3	3	3	3	3	3	3	3	3	3	3	3																																			
									4	4	4	4	4	4	4	4	4	4	4	4																															
CONTRATCS	8	8	8	8	11	11	11	11	15	15	15	15	10	10	10	10	7	7	7	7	3	3	3	3	0	1	1		1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	
ADDITIONAL NEEDS	7	8	8	8	10	10	13	12	13	14	14	15	14	11	8	8	8	8	7	7	4	4	3	3	3	3	3		2	2	1	1	1	1	0	0	0	0	0	0	0	0	-1	-1	-1	-2	-2	-2	-2	-2	
BALANCE	1	0	0	0	1	0	-2	-1	2	1	0	-1	-4	-1	2	2	-1	-1	0	0	-1	-1	0	0	-3	-2	-2		-1	-1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	2	2	2	2	2	
ADJUSTMENT	1	0	0	0	1	0	-2	-1	2	1	0	-1	-4	-1	2	2	-2	-2	-1	-1	0	0	1	1	-5	-2	-2		-1	-1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	2	2	2	2	2	2

It is important to highlight that, as exposed in the methodology section for hiring scheduling, the "Adjustment" row for group 2 does not provide a direct value for the overall group balance. In fact, it corresponds to the adjusted balance of garnishing. That is why, three different sums are performed for each "Balance" row in order to provide a sign of the model's accuracy.