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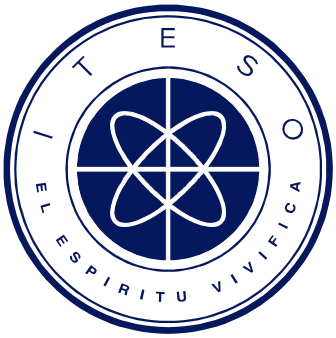
Departamento de Procesos Tecnológicos e Industriales

MAESTRÍA EN INGENIERÍA Y GESTIÓN DE LA CALIDAD



SOFTWARE DEVELOPMENT PROCESS IMPROVEMENT

Tesis que para obtener el grado de

MAESTRO EN INGENIERÍA Y GESTIÓN DE LA CALIDAD

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Elija un elemento.: MTRO. Francisco Ernesto Navarrete Báez

San Pedro Tlaquepaque, Jalisco. Mayo de 2018.

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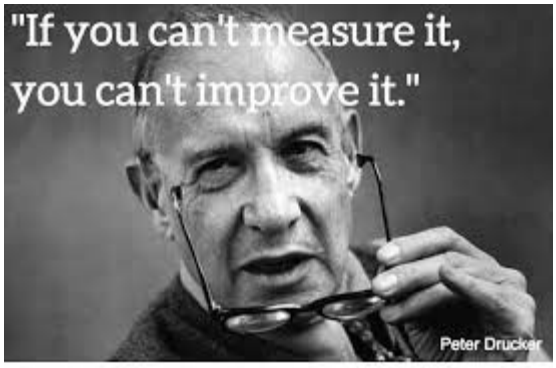


1.2. Continental Automotive overview.

Founded as Continental-Caoutchouc- und Gutta-Percha Compagnie in 1871, Continental-Aktiengesellschaft (AG), headquartered in Hanover, Germany, is now the parent company of the Continental Corporation. The Continental Corporation comprises 510 companies, including non-controlled companies, in addition to the parent company Continental AG. The Continental team is made up of 220,137 employees at a total of 427 locations in 56 countries.

Our customers come from the automotive industry, various key industrial sectors (e.g. railway engineering, machine and equipment engineering, and mining) and the end-user market. We supply them with high-quality innovative or established products, systems, and services around the world.

The Continental Corporation is divided into the **Automotive Group** and the **Rubber Group**, which in the year under review comprise a total of five divisions with 29 business units. A division or business unit is classified according to products, product groups, and services or according to regions.

Figure 1 Continental Key Facts

Within the automotive group there are several products and solutions for passenger cars as shown below, the product we will be reviewing in this project belongs to the information management type of products, specifically the instrument clusters.

Solutions for Passenger Cars

Autonomous Mobility	**Safety**	**Vehicle Networking**	**Information Management**	**Rubber & Plastics Solutions**

Continental works with a wide portfolio of customers, from Asian OEMs to North American OEMs, from petrol-based vehicles to electric and hybrid vehicles, no customer is more important than other. The information management products include but are not limited to Cockpit High Performance Computers, Display Solutions, Head up Displays, Radios, Haptic Controls, Interior cameras and of course, Multimedia Systems. With the use of Continental´s state of the art technology, and in some cases trough joint ventures, great minds create the user experience (UX) of the future.

But, what is in reality this Instrument Cluster product? let´s dig into it!;

“In order to ensure that driving is equally safe and comfortable, a clear presentation of the information relevant at any given point in time and in the current driving situation is indispensable” (Continental, s.f.)

This previous statement is what designing an Instrument Cluster is all about, considerations such a resin color and durability, LED intensity and contrast, microcontroller based hardware, high performance displays, fail safe software architecture and in general a system that works under any condition, is what makes a reliable Instrument Cluster the perfect choice for a successful user experience. The simplest mistake on current calculation, dimension error or a missing bit configuration, could become a fatal distraction to the driver and companions, this is the reason why these products (and all designed by Continental) go through a series of intensive and demanding verification and validation plans.

There are 2 types of Instrument Clusters, the traditional tacho and speedo mechanical pointer based, and the hybrid type, which uses flat displays and traditional analogue pointers and dials, which gives a three dimensional look to the product making it very user friendly and a delight to the interior harmony of the vehicle.

At the end, the 2 types of Instrument Clusters maintain the driver informed at all time in a comprehensively and reliable way by providing information from basic fuel tank level to navigation or lane assist support. Instrument Clusters are used in practically any vehicle of any type that has the need to show information to the user.

Instrument Clusters

Hybrid Instrument Cluster

Some Instrument Cluster Background:

- 1902 Eddy current speedometer, magnetic-mechanical

- Mid 1930s first Instrument Cluster in the market
- First solid-state instrument cluster was introduced in the Aston Martin Lagonda in 1976

1.3. Auto industry overview.

The auto industry is one of the most if not the most challenging industry on the market, it certainly is the world's premier manufacturing sector. It´s complexity covers all industry span; manufacturing and development, supply chain and distribution, marketing and retail, vehicle

technologies and regulatory trends, suppliers empowerment and social responsibility, and crucially, labour practices and the people who build cars and its parts. (Nieuwenthius, 2015).

Millions of cars are sold every year around the world, from basic cheap versions to the most expensive and luxurious vehicles, the statistic below represents the number of cars sold worldwide from 1990 through 2017, it also presents a forecast for 2018, and approximately 81.6 million automobiles are expected to be sold by the end 2018. (Portal, n.d.)

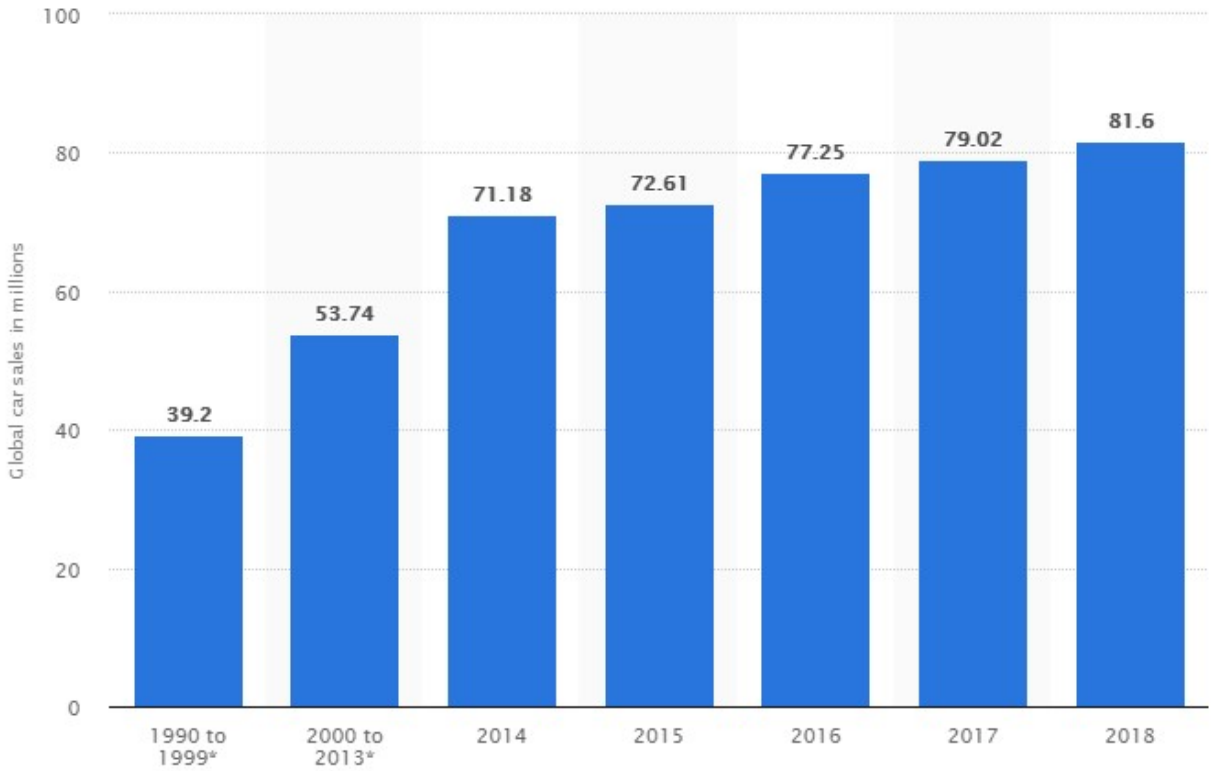


Figure 2 Cars sold from 1990 to 2018 (Statista, 2018)

From the previous global sales the year 2017 behaved as follows per region, noticing that sales in North America declined being the U.S., Mexico and Puerto Rico the cause of the decline and having Canada as the country with growth from this region. It is also shown evident that China keeps being the market with the highest sales.

Figure 3 2017 Car sales per region (Demandt, 2018)

Another important sales indicator is that one by fuel type. Alternative fuel vehicles have been increasing sales constantly every year, gasoline vehicles increased 3% and diesel cars sales decrease by 3.7%, below it is shown how the sales behaved by type of fuel.

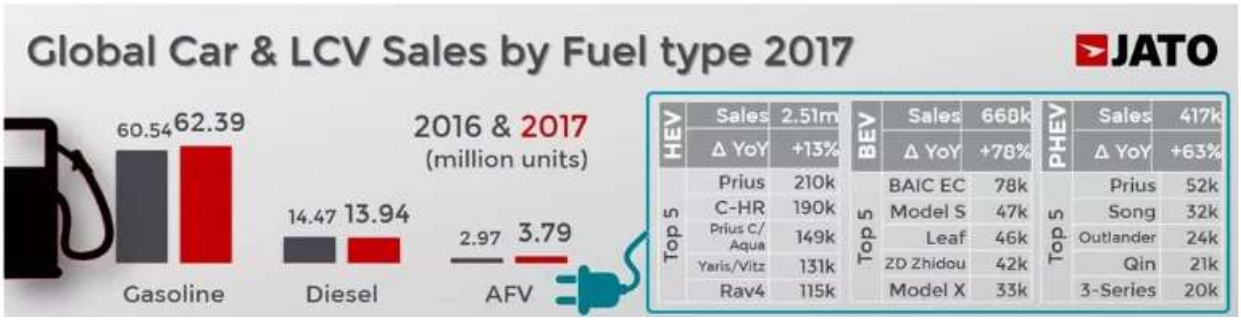


Figure 4 Car sales by type of fuel (Demandt, 2018)

And finally, the sales by brand and model, Toyota remains the leader in sales with an increase of 5% on 2017, while the best-selling vehicle is the F-Series from Ford, this contrast with the fact that Fords actual sales declined in 2017 by 2%, it is noticeable also that the 3 brands with highest sales also have a model each on the most sold vehicles indicator.

On the next page it is shown the sales per brand and model during 2017.

JATO Global Top 25 Brands 2017

	Brand*	Sales	ΔYoY
1	TOYOTA	7,843,423	+5%
2	VOLKSWAGEN	6,639,250	+3%
3	FORD	5,953,122	-2%
4	HONDA	4,967,689	+7%
5	NISSAN	4,834,694	+5%
6	HYUNDAI	3,951,176	-9%
7	CHEVROLET	3,857,388	0%
8	SUZUKI	2,891,415	+11%
9	MERCEDES	2,534,181	+13%
10	KIA	2,511,293	-10%
11	RENAULT	2,275,227	+7%
12	BMW	2,030,331	+5%
13	AUDI	1,847,613	+1%
14	PEUGEOT	1,590,300	0%
15	FIAT	1,503,806	+1%
16	MAZDA	1,495,557	+3%
17	BUICK	1,465,823	-1%
18	JEEP	1,390,130	0%
19	GEELY	1,245,055	+61%
20	SKODA	1,180,672	+5%
21	SUBARU	1,050,390	+5%
22	BAOJUN	1,016,250	+34%
23	CITROEN	999,888	-6%
24	OPEL/VHALL	996,559	-6%
25	WULING	883,663	-21%

*Includes LCV.

JATO Global Top 25 Models 2017

	Model**	Sales	ΔYoY
1	F-SERIES	1,073,285	+9%
2	COROLLA	924,118	-4%
3	GOLF	867,145	-3%
4	X-TRAIL/ROGUE	814,495	+6%
5	CIVIC	800,380	+20%
6	RAV4	770,296	+11%
7	CR-V	749,151	+7%
8	TIGUAN	695,383	+34%
9	HR-V/XR-V/VEZEL	689,798	-4%
10	PASSAT/MAGOTAN	673,471	-4%
11	SILVERADO	656,106	+3%
12	FOCUS	647,521	-10%
13	ESCAPE/KUGA	644,622	+3%
14	RAM PICKUP	614,595	+3%
15	AVANTE/ELANTRA/I35	610,992	-21%
16	CAMRY/AURION	579,113	-4%
17	TUCSON	573,937	-4%
18	BORA/JETTA/SAGITAR/VENTO	552,513	-7%
19	POLO	550,004	-8%
20	HONGGUANG	538,908	-17%
21	SWIFT	521,510	+6%
22	QASHQAI/ROGUE SPORT	515,718	+19%
23	HAVAL/HOVER H6	509,102	-12%
24	ACCORD	506,687	-5%
25	C-CLASS	487,287	+6%

** Excludes LCV

Figure 5 2017 sales by brand and model. (Demandt, 2018)

A truly complex business architecture surrounds the auto industry where sometimes it is not so evident how the brands and OEMs are structured, the industry might give the impression that there is a considerable amount of OEMs in the market when in reality one OEM could have 5 or 6 different brands on its portfolio. Figure below is a representation of the most popular OEMs and their respective brands, this diagram shows how easy it is to get confused between the brands. In addition to this complexity on the branding, some OEMs have joint ventures among them where they could share a vehicle assembly location, use of same distribution channels or even being part of close cooperation on specific technology areas. The case of joint ventures in China in unique since as of today the Chinese government is not allowing foreign OEMs to establish their own brand in that Country, foreign OEMs are forced to go in a joint venture with a local OEMs if they desire for their brand to be sold in China.

There are also acquisitions that take place where an OEM group absorbs another OEM, this was the case of the FCA fusion, where at the time of the financial crisis of Chrysler, Fiat increases its ownership to 100%, becoming in 2014 the Fiat Chrysler Automobiles company. This merger allowed for the Jeep brand to build vehicles in Italy and for Alfa Romeo to return to North America market after an absence of 20 years. (Automobiles, n.d.)

Figure 6 Auto Industry OEM Map (Desjardins, 2016)

A big and important part of the auto industry is it´s supplier base, the supplier industry is structured in a hierarchical latter, where 3 main tiers are where the supplier base is distributed, the next figure shows the tier levels and the type of suppliers and products each tier provides. Some of the Tier 1 suppliers are or were part of the OEMs, business units that function independently but at the same time being a part of the OEMs group.

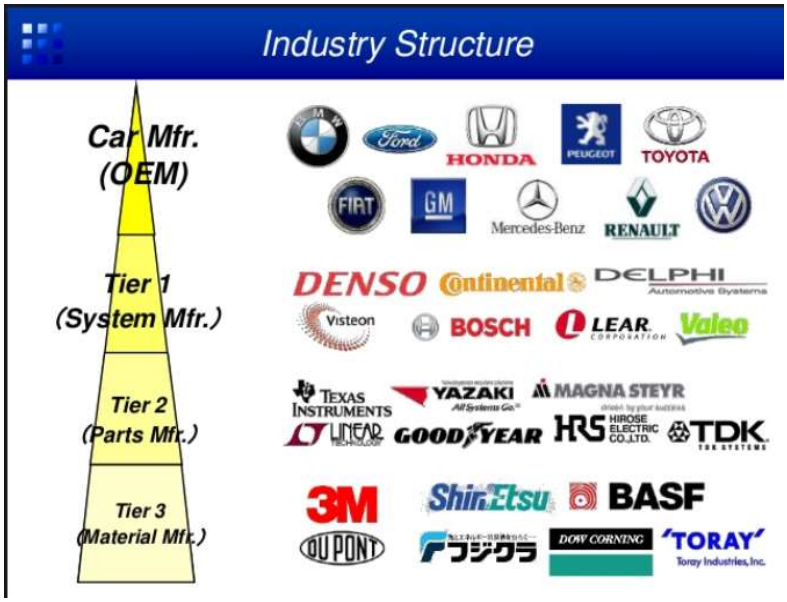


Figure 7 Auto Industry Structure (Suzuki, 2015)

Being a multibillionaire industry, it impacts and gets impacted by several factors globally, political aspects as technological affect positively or negatively the auto industry, at the same time it can destabilize markets and potentially cause countries economic recessions. It has also been the case where environmental or natural disasters have had a big impact on the industry, a clear example was the 2011 Japan earthquake which impacted Tier (1,2 and 3) suppliers and OEMs around the world.

1.4. Base line scenario description

As part of the automotive group, in specific the Interior products division, the CD4 instrument panel clusters (IPC) consists of an integrated system of mechanical, electrical and software architectures. Even though Continental design processes are well established, this IPC platform had the need to deviate from the SW development process known as SMK. Software problems have occurred since the deviation was introduced that have impacted the customer creating

discomfort and affecting the trust from our customer to Continental. This situation has continued for several years now without truly being able to systematically solve it.

For illustration purposes it´s shown below an image of the M0 and M1 variant from the CD4 platform IPC and the exploded view of the IPC core. As noted below in the exploded view, the difference between the M0 variant and the M1 variant is practically the display, the M0 cluster uses a monochrome dot matrix display smaller than that on the M1 cluster which uses a TFT color display, the M0 variant also uses a display housing unique to this variant with the whole purpose of using the main light housing as a common component between both variants.

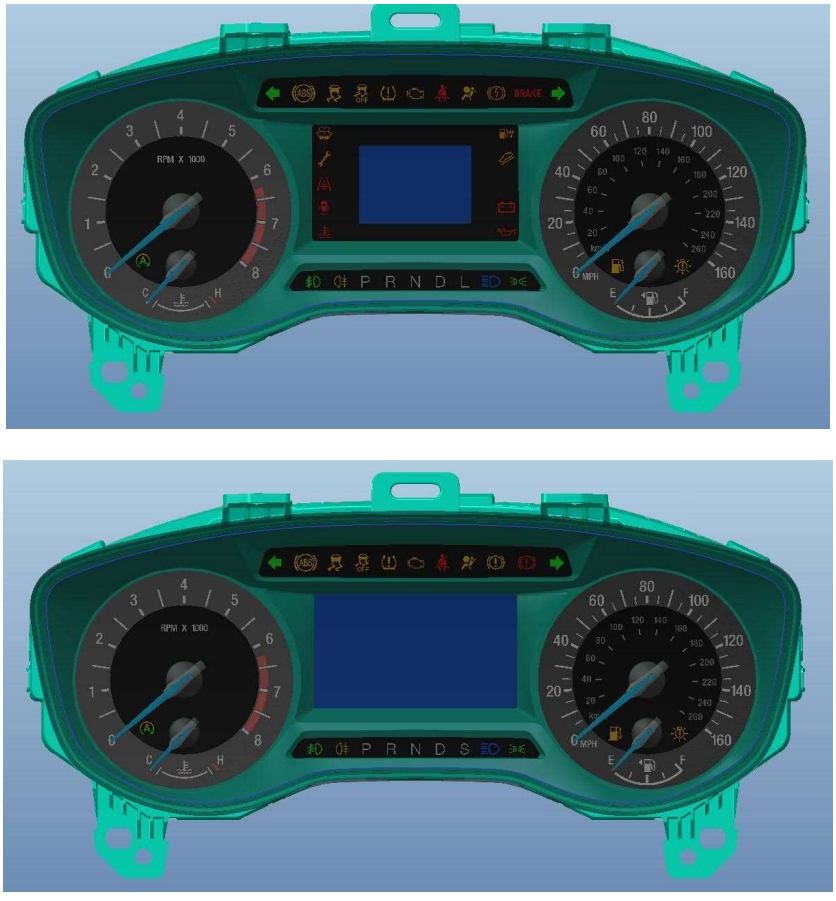


Figure 8 CD4 IPC

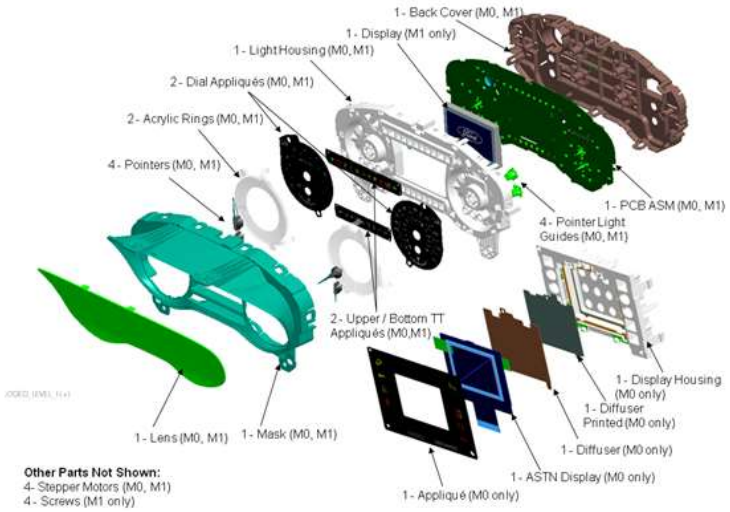
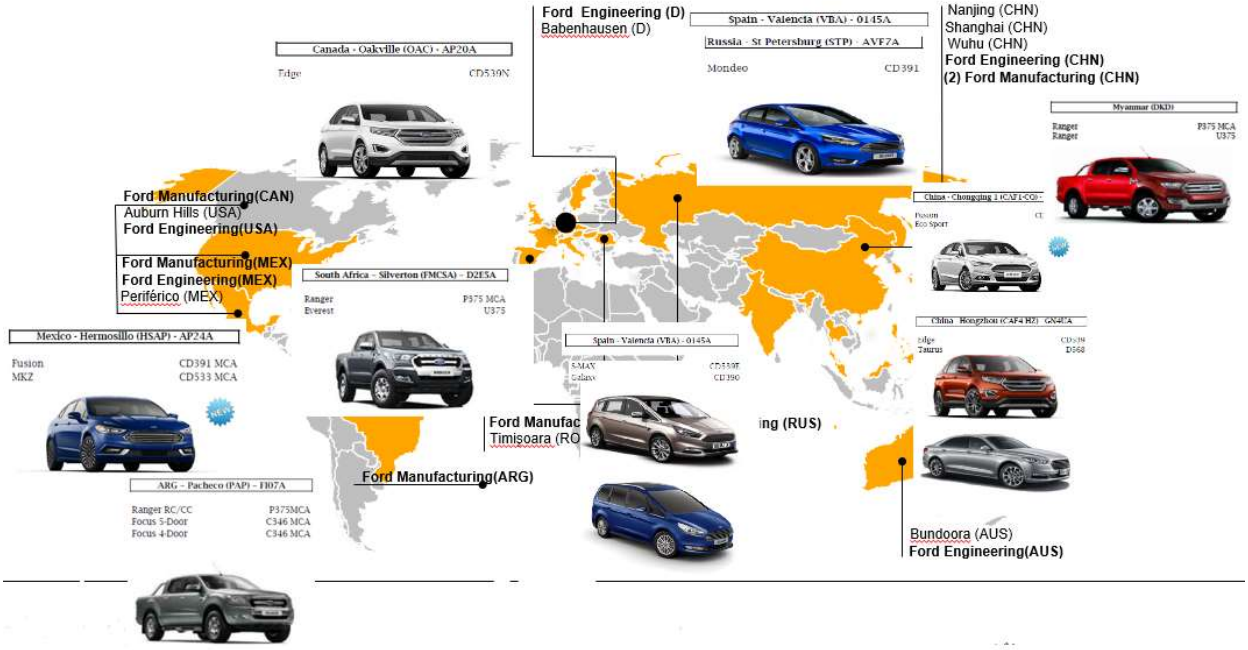


Figure 9 CD4 IPC Exploded view

These 2 variants have common components such as the lighthousing, the front mask, back cover, pointers, the speaker, pointer lightguide, acrylic rings and some dials applique that will be the same depending on the market, components that are different in these 2 versions are the microcontroller, the printed circuit board assembly, the display, the display housing and of course, some parts of the software.

This project is currently being manufactured at 3 different production locations at China, Rumania and México and several Ford manufacturing plants around the world, R&D locations for this project at Continental are at México and the United States, customer engineering locations are at United States, Europe, China and Australia, making it a complex platform with a wide variety of attributes and requirements to comply.

Continental and Ford WW Footprint



1.5. Scope and delimitation

This intervention is directed specifically to work on the CD4 project software team and process, it is not intended to include any other customer or team, in within the disciplines of the project itself only the Software and Systems test are of interest for this thesis, it shall include all Continental locations where the CD4 IPC software is being developed. The following chart represents the scope and delimitation as described above;

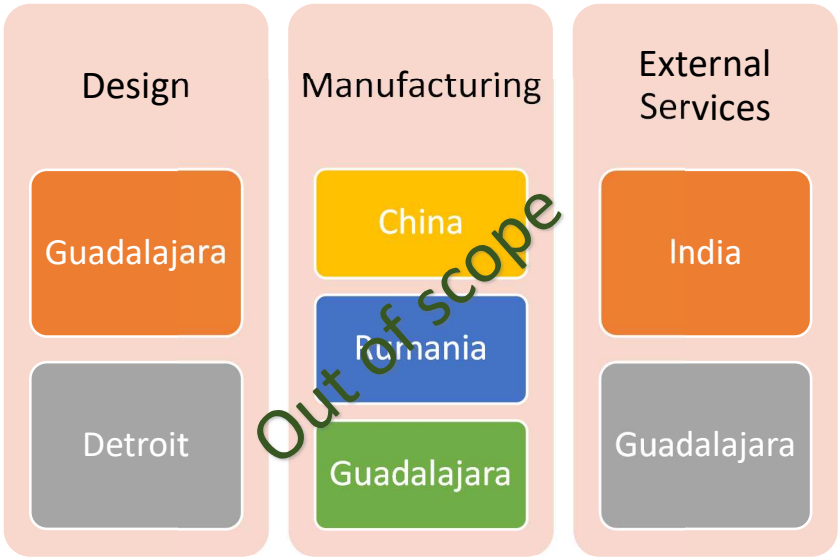


Figure 10 Groups in scope

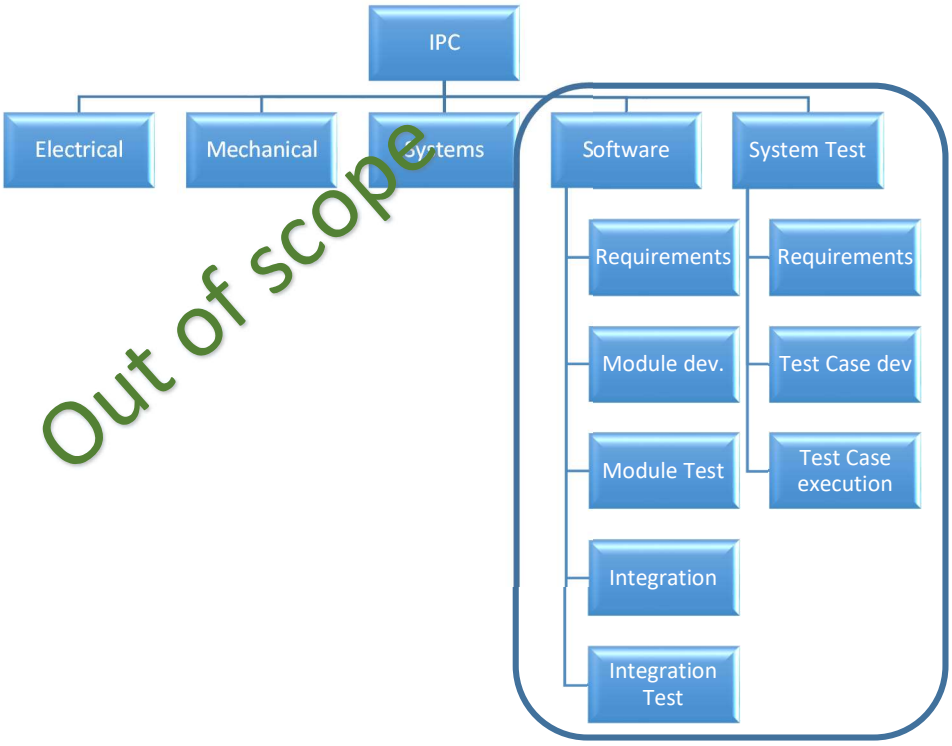


Figure 11 Design areas in scope

1.6. Goal and importance of the intervention

The goal of this intervention is to assess the current situation, establish a baseline, define metrics for this baseline and implement a problem-solving methodology that helps finding the root causes of the problem we are facing. It is highly important that these issues are fixed to regain trust from the customer and avoid spending thousands of dollars on rework activities and penalties. The director's team is now monitoring the situation and updates are expected accordingly.

1.7. Timing Plan

GANTT CHART

	Task Name	Duration	Start	Finish	%	Pred
0	**SW Development Process Improvement**	**179 days**	**Mon 05/02/18**	**Thu 11/10/18**	**2%**	
1	Optimize base line VSM with SW teams input.	3 days	Thu 03/05/18	Mon 07/05/18	0%	
2	Use Ishikawa tool on the marked steps from baseline VSM.	5 days	Tue 08/05/18	Mon 14/05/18	0%	1
3	Develop metric strategy for marked steps from baseline VSM.	2 wks	Tue 15/05/18	Mon 28/05/18	0%	2
4	Management Project Kick off document preparation-A3	3 wks	Tue 15/05/18	Mon 04/06/18	0%	2
5	Management review meeting	1 day	Tue 05/06/18	Tue 05/06/18	0%	4
6	**True North Definition**	**35 days**	**Thu 26/04/18**	**Wed 13/06/18**	**0%**	
7	Develop Hoshin	2 wks	Thu 26/04/18	Wed 09/05/18	0%	
8	Develop Functional Strategies	1 wk	Thu 10/05/18	Wed 16/05/18	0%	7
9	Develop Metrics for Functional Strategies	3 wks	Thu 17/05/18	Wed 06/06/18	0%	8
10	Develop Monitoring Charts	5 days	Thu 07/06/18	Wed 13/06/18	0%	9
11	**Plan Development**	**87 days**	**Mon 05/02/18**	**Tue 05/06/18**	**8%**	
12	Prepare Tree Diagram	2 wks	Thu 03/05/18	Wed 16/05/18	0%	
13	**Develop Initial A3**	**37 days**	**Mon 16/04/18**	**Tue 05/06/18**	**0%**	
14	Define Gap	3 wks	Mon 16/04/18	Fri 04/05/18	0%	
15	Develop Fishbone	2 wks	Mon 07/05/18	Fri 18/05/18	0%	14
16	Identify Importance of causes (Pareto)	2 wks	Mon 21/05/18	Fri 01/06/18	0%	15
17	Update A3	2 days	Mon 04/06/18	Tue 05/06/18	0%	16
18	Develop SWOT Analysis	1 wk	Mon 05/02/18	Fri 09/02/18	###	
19	VSM Current state	2 wks	Mon 21/05/18	Fri 01/06/18	0%	15
20	**Plan Deployment**	**15 days**	**Mon 21/05/18**	**Fri 08/06/18**	**0%**	
21	Develop action plans (A3 child)	2 wks	Mon 21/05/18	Fri 01/06/18	0%	15
22	Update tree diagram with action plans	3 days	Mon 04/06/18	Wed 06/06/18	0%	21
23	Kaizen event implementation from VSM	1 wk	Mon 04/06/18	Fri 08/06/18	0%	19
24	**Plan monitoring**	**9 days**	**Mon 04/06/18**	**Thu 14/06/18**	**0%**	
25	Develop GEMBA strategy	4 days	Mon 11/06/18	Thu 14/06/18	0%	23
26	Develop Dashboard strategy	3 days	Mon 04/06/18	Wed 06/06/18	0%	21
27	Define Milestones review frequency	3 days	Wed 06/06/18	Fri 08/06/18	0%	5
28	**System Improvement**	**91 days**	**Thu 07/06/18**	**Thu 11/10/18**	**0%**	
29	DMAIC Deployment	5 wks	Thu 07/06/18	Wed 11/07/18	0%	15,9
30	Monitor results of corrective actions	3 mons	Thu 12/07/18	Thu 11/10/18	0%	29

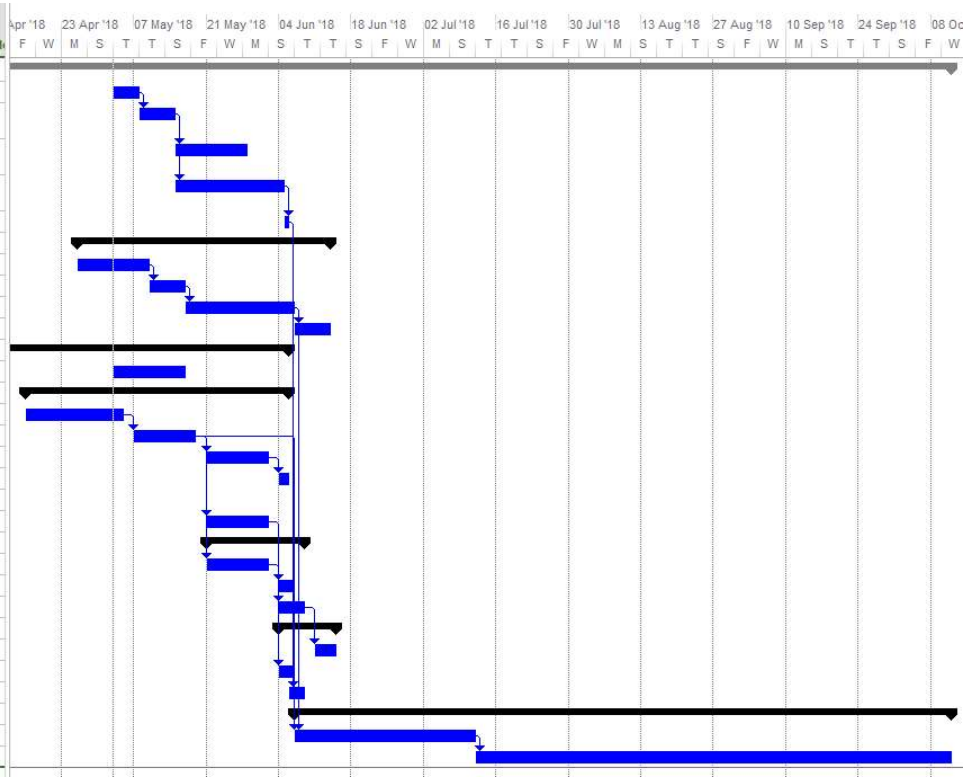
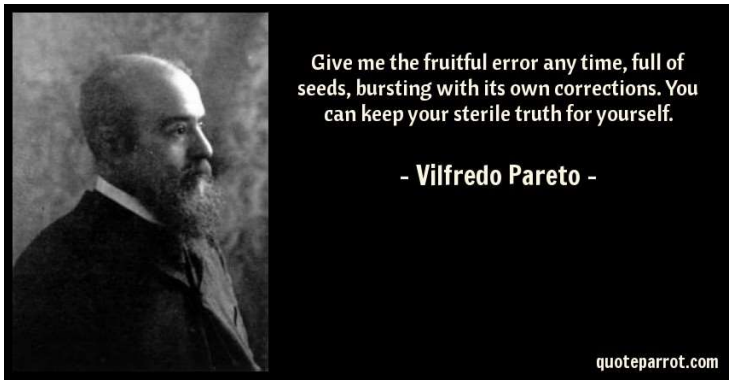


Figure 12 Main activities timing plan

1.8. Theoretical Framework

1.8.1. Pareto Analysis



(Pareto, s.f.)

Vilfredo Pareto was an Italian sociologist and economist, was born in Paris in 1848 from an aristocratic Italian family that was on exile. He studied mathematics and physics at University of Turin in 1869, he later became an engineer and studied philosophy and politics also, he wrote many articles where he analyzed economic problems with mathematical tools.

One of his most important work was "Political Economic Course" (1897) which includes his law of income distribution where he studies his theory that the distribution of incomes and wealth in society is not random and has a pattern shows in history and appears in all world and societies. (Britannica, 2020)

Pareto considered his greatest work the "Trattato di sociologia generale" written in 1916, in which he deep dives into the fundamentals of individuals and actions. His visualization of society had a big impact on sociology theories in the United States after WWII.

What is a Pareto Analysis? developed by Vilfredo Pareto it uses the principle named after him, also known as "80/20 rule", The Pareto Principle states that 80 percent of a project's benefit comes from 20 percent of the work. Or, conversely, that 80 percent of problems can be traced back to 20

percent of causes (team, s.f.). This analysis identifies problems, areas or activities that will have the highest impact, it helps with identifying priorities, organization, productivity and at the end has an impact in profitability.

There are systematics steps to take in order to implement a Pareto Analysis efficiently:

1. List effects or problems
2. Identify root cause for each problem
3. Add ponderation to each problem
4. Make groups from problems
5. Calculate scores for each group
6. Implement action items based on scores

To illustrate the Pareto Analysis, we take the following article written by Dr. Jacek Sitko (SITKO, s.f.) from the production engineering institute at Silesia Technological University. The article discusses a failure analysis on manufacturing defects from vehicle steering mechanism components, after assessing the proper factors needed for the analysis he starts structuring the course of action, his steps are as follows:

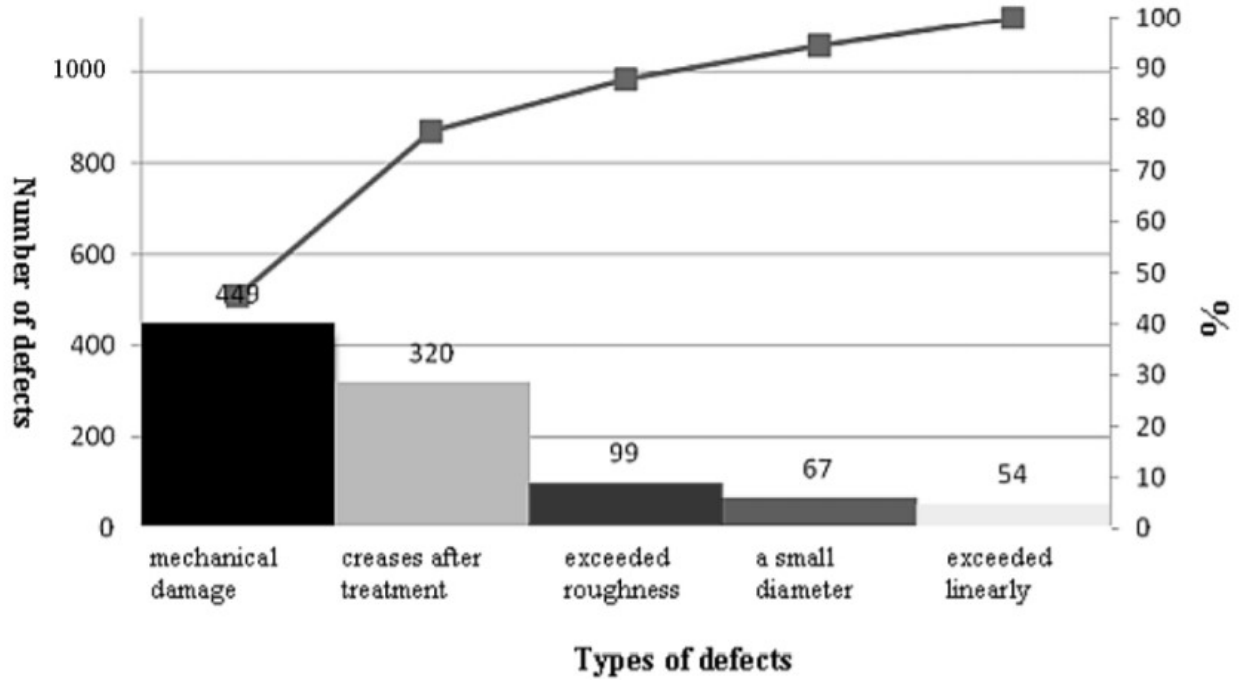
- Define the purpose of the study
- Identify the data on the examined phenomenon. The data collection process should determine the following;
    - Type of data
    - Measuring units
    - Person responsible for data collection
    - Period of time for data analysis
    - Procedure for managing data

- Order data from most to least significant
- Calculate percentage in relation to the whole phenomenon
- Design the document and matrix for organizing information.

Then Dr. Sitko proceeds to use different type of tools and methods such as the ABC method to evaluate value and usefulness in the examined period of time. This ABC analysis is in fact based on the Pareto analysis, in ABC each statistical group contains a few elements marked as A,B and C for categorization purposes. After using histograms and the Ishikawa diagram, he came up with the following analysis of defects and Pareto chart:

Type of defect	Month						Total
	I	II	III	IV	V	VI	
Mechanical defects	58	79	92	90	63	67	449
Scratches	7	5	9	13	7	9	50
Small diameter after grinding	11	12	10	8	11	15	67
Polishing – fall	4	3	0	0	0	2	9
Exceeded rectilinearity	12	17	10	11	0	2	52
Damage caused by the straightening machine	17	0	0	0	4	3	24
Creases after milling	49	55	56	71	53	36	320
Double engraving	4	5	0	8	2	0	19
Creases caused by the screw	23	0	0	0	0	0	23
Damaged thread	6	5	11	9	4	4	39
Failure to reach the cooling temperature	3	6	2	4	0	1	16
Max. power on the hardening table	2	1	3	0	0	3	9
Exceeded roughness	12	19	16	22	15	15	99
Hardening cracks	0	0	5	0	0	0	5
Burns caused by hardening table	4	2	0	3	0	2	11

In the analysis of defects table he identified the the 5 defects that caused the largest number of defected parts, then he selects these and create the Pareto chart as follows:



This Pareto chart establishes the causes that generate the biggest impact to profitability, with the information that this two graphs present, he was able to identify the two causes that are responsible for 77.76% of the total number of non-conformities, and with the use and complement of the Ishikawa diagram he deep dives into the causes and proper corrective actions to eliminate or reduce the defects to minimum.

1.8.2. DMAIC Methodology

In the early 80's, the need to measure and improve quality led Bill Smith from Motorola to create a methodology for this purpose, this was the first step towards DMAIC. General Electric was the pioneer on implementing Six Sigma into their processes with the goal to reduce waste, DMAIC is

then a methodology to become Six Sigma which is based on a data-driven quality strategy for process improvement, the acronym stands for the following (Institute, n.d.) (Terry, 2015):

- **D**efine: Goals, Customer CTQs (Critical to Quality), process involved, scope and boundaries.
- **M**easure: Collect data by measuring key areas of importance.
- **A**nalyze: Analyze the data collected and find areas of opportunity and gaps, sources of variation must be identified.
- **I**mprove: The process in question and work the sources of variation found.
- **C**ontrol: Create a monitoring plan and update or create documentation to maintain the new course.

DMAIC is a methodology widely used in the auto industry, is part of Continental´s tool box and has proved to provide a reliable guideline on the continuous improvement strategy.

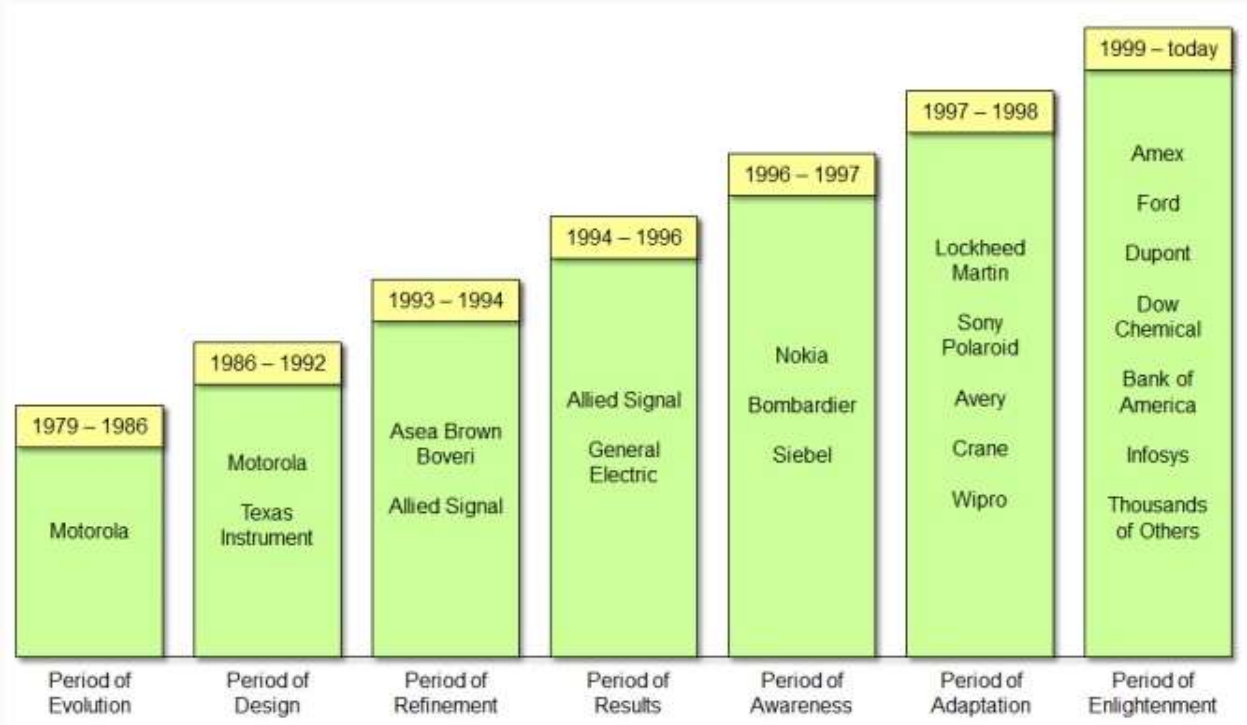


Figure 13 Six Sigma History (Institute, s.f.)

1.8.3. Voice of the Customer Three (VoC)

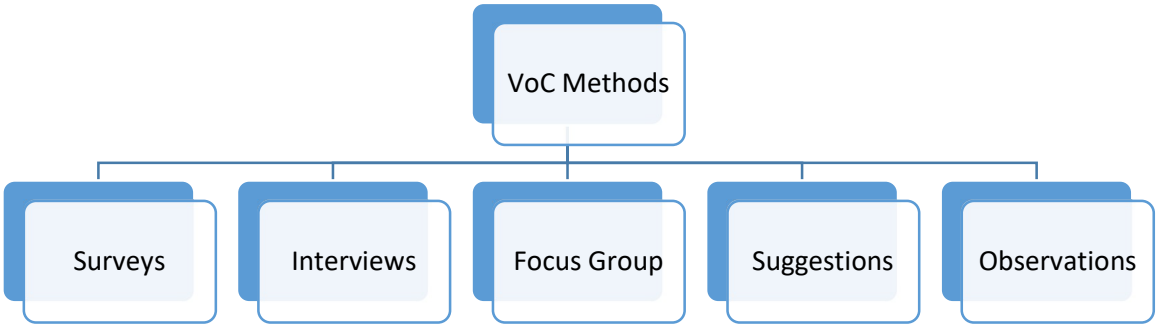
In todays fast paced changing environment, tech companies need to stay one step ahead of competitors, one key activity to achieve this goal is the clear understanding of customer expectations, any organization that lacks ability to listen to their customer is destined to failure, expectations translates to requirements, requirements translates to product development and testing, and a good reliable product translates to profitability, hence the importance to hear the different voices that have an impact on profitability.

The "voice of the customer" tree (VoC tree), is a method that allows to understand what the customer needs and wants, that information is then translated into Critical Customer Requirements (CCR) which are those requirements that the customer expects the supplier to meet. These CCRs then are used to assess the verification and measurement strategy where KPIs will be created, these KPIs are called Critical to Quality (CTQ) in VoC. The VoC must come as direct feedback from the customer, it needs to be the actual sentiment out of a specific situation, the more direct the feedback is the more accurate the CTQs will be (Dennis, 2009).

One important aspect of VoC is customer identification, customer requirements can come from different fronts, and they all should be considered as important, customer is the one who buys or uses your product or service and is the one that receives the process output. Customers normally fall into 2 categories as follows:

- Internal Customers: Customers within your organization that are the recipient of your processes output, these can be the management team, the manufacturing team, validation labs or any other functional group or employee in your organization.
- External Customers: Those outside and not part of your organization, they use your product or service, they can also have investment on your organization such as shareholders.

Is extremely important that no customer stays unheard, every voice, internal or external, can be a value adder to the organization and provide a competitive advantage. There are several methods to capture the VoC, these have different targets but the end goal is the same;



1.8.4. PESTEL

PESTEL is an analysis done that helps understanding the environment the organization is operating in, this is quite critical specially on developing new projects or technologies, it responds to questions such as; What is the political situation in the region?, what are the main economic factors?, what legislations are being currently discussed that could have an impact on the project?, what environmental factors affect the industry?, important questions that any business development manager needs to be aware off. PESTEL is the acronym for Political, Economic, Social, Technological, Environment, and Legal (Frue, 2018), these are practically the macro forces that any organization faces and that need to be monitored to react accordingly. These 6 factors are not the only ones, different ones can be added depending on the area or type of corporation, it can also be reduced to PEST in some cases.

Let´s review in detail the 6 more common factors of the PESTEL tool:

- Political Factors:

These include but are not limited to taxation, fiscal, trade, political stability and any factor which a government may influence the economy or an industry.

- Economic Factors:

Factors directly related to the economy and the impact on organizations profitability effects, one example of these factors is inflation rates and interest rates and the effects these have on products and services of corporations.

- Social Factors:

These are all factors related to social conditions and environment, these help corporations to understand needs and wants of customers hence providing a product that meets lifestyles, religion aspects, education levels among other key elements of society.

- Technological Factors:

These factors refers to all technological trends that can present a threat or opportunity to the organization. The R&D and manufacturing teams need to be aware of all technological innovation on their area and how it impacts its products market. Since technology changes quickly this is one factor that needs to be monitored frequently on all areas, automation, IT, hardware and software technologies among others.

- Environmental Factors:

These are all factors that have an influence on the surrounding environment, such as waste disposal, renewable energies, recycling methods and everything related to sustainability responsibility and its associated certifications.

- Legal Factors:

These are factors that must be complied with such as consumer laws, technical regulations, safety regulations, labor laws. A corporation needs to understand all these from all countries their products will be finally used.

The following PESTEL analysis shows the impact of each factor, the focus of this analysis is the automotive industry as a whole:

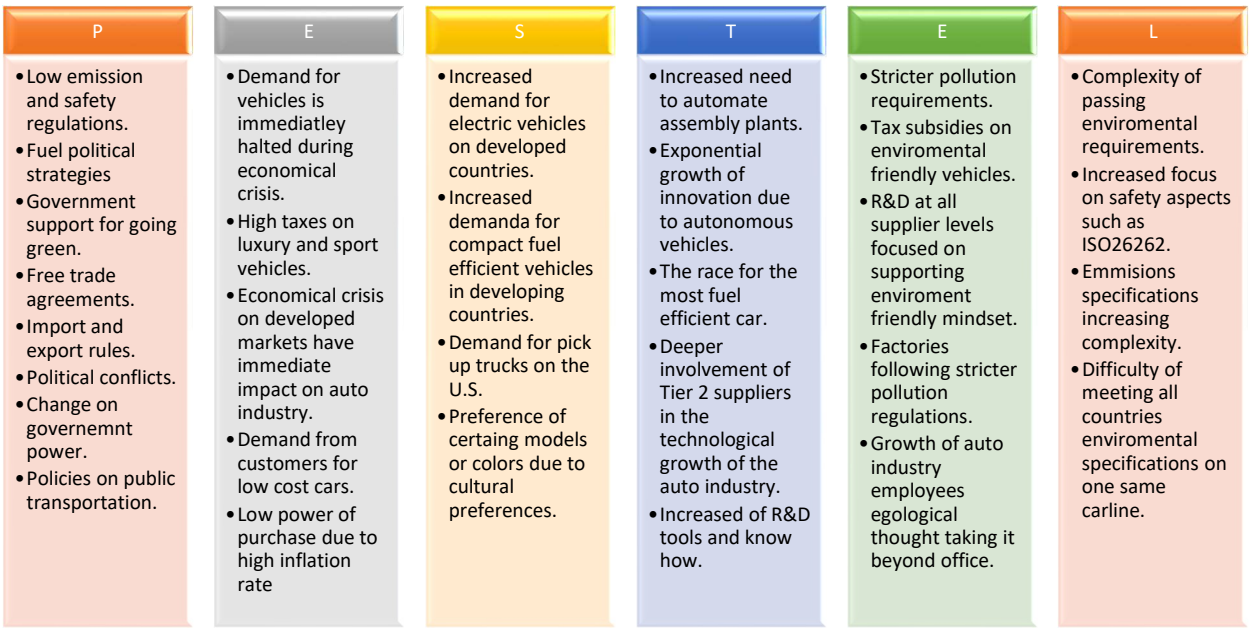


Figure 14 PESTEL Analysis

1.8.5. SIPOC

The SIPOC (Supplier, Input, Process, Output, Customer) diagram is very useful to help the teams understanding who their direct customer and suppliers are, what are they receiving as input to their task in the process, and what will they be providing as outputs to their next customer. It identifies clearly the boundaries and helps as a guideline for every team member to have healthy work environment by understanding the needs of customers and suppliers (Institute, n.d.).

1.8.6. VSM Value Stream Map

The VSM is a lean tool that requires the team to identify every step of the process from when the customer request came in all the way to the finish good and delivery, it shows useful information such as cycle time, headcount, process efficiency among other characteristics. The main goal of this tool is to identify waste and eliminate it, it is also a very good visual aid to walk the process specially for new team members (Dennis, 2009).

1.8.7. Jira Tool

Jira is a task management tool that allows to plan, track and manage the agile mindset on SW design, this tool was recently acquired by Continental and is key on the success of this project. Engineers were trained to operate the tool and understanding the type of data that they need to feed the tool with, this step is very important, as in any tool, if you introduce trash it will give you trash as output. The tool has the flexibility to create boards for activity status and charts for monitoring progress of different activities.

1.8.8. Define phase conclusion

The tools used on the define phase helped to define properly what the Problem and potential causes are. Something critical found is that on key steps we do not have KPIs that allow to have a correct measurement of the baseline, the VoC allowed us to prepare the path for KPIs that are aligned with the VoC. The problem at this phase points to be the missing measurement methods, missing process adherence and a team mindset that is not allowing to provide what the customer is expecting.

2. Measure

2.1. Voice of the Customer (VoC) Current Condition

The constant discomfort on Continentals performance for the SW push the management team to go through a deep dive on the SW development process. A critical activity took place which was for the PM to gather all feedback possible from the customer (internal and external) in order to prepare a VoC tree. The comments received were practically directed to the quality of the SW being delivered and the constant delays of each SW delivery. Complaints from our customer included activities from each phase of the Product Life Cycle such as requirements analysis efficiency, constant SW bugs found at vehicle testing at customer locations, late issues found impacting customer manufacturing builds, and others.

Feedback was also gathered from Continentals manufacturing team, which is considered R&Ds most important internal customer, the complaint was regarding the continuous SW releases taking place that does not allow them to industrialize the SW with enough time to meet the customer delivery dates.

2.2. Issues pareto from 8Ds

The following chart represents the quantity of issues categorized but its potential root cause, every issue reported by the customer and every internal high impact problem goes through the 8D process for a proper analysis of the condition, the goal is to identify the area that requires immediate attention and prepare and improvement plan to fix the evident areas of opportunity.

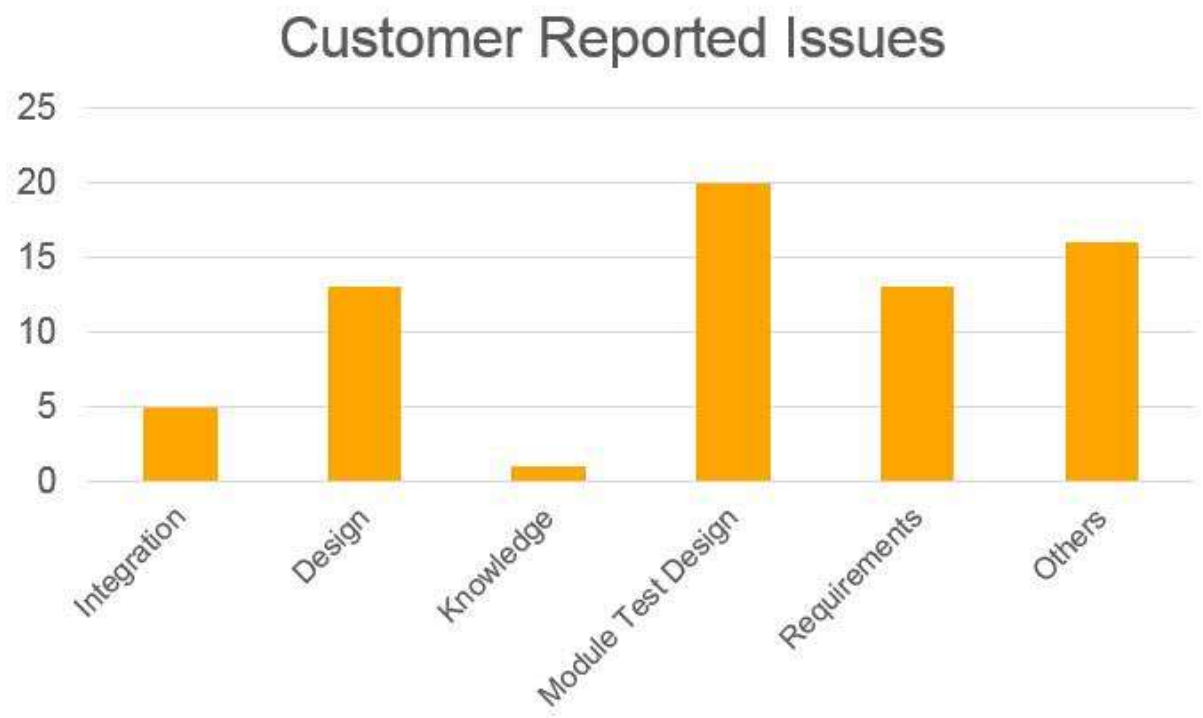


Figure 15 Issues Reported

2.3. Value Stream Map current condition

The following VSM represents the current condition of the SW development process, the scope is to clearly identify each step of the SW design methodology and asses which areas are the ones we will working to improve. In this case the VSM will not serve as a tool to reduce cycle time, lead time or quantity of people involved on each step as its original purpose is, but a tool to define where to stablish KPIs where currently do not exist.

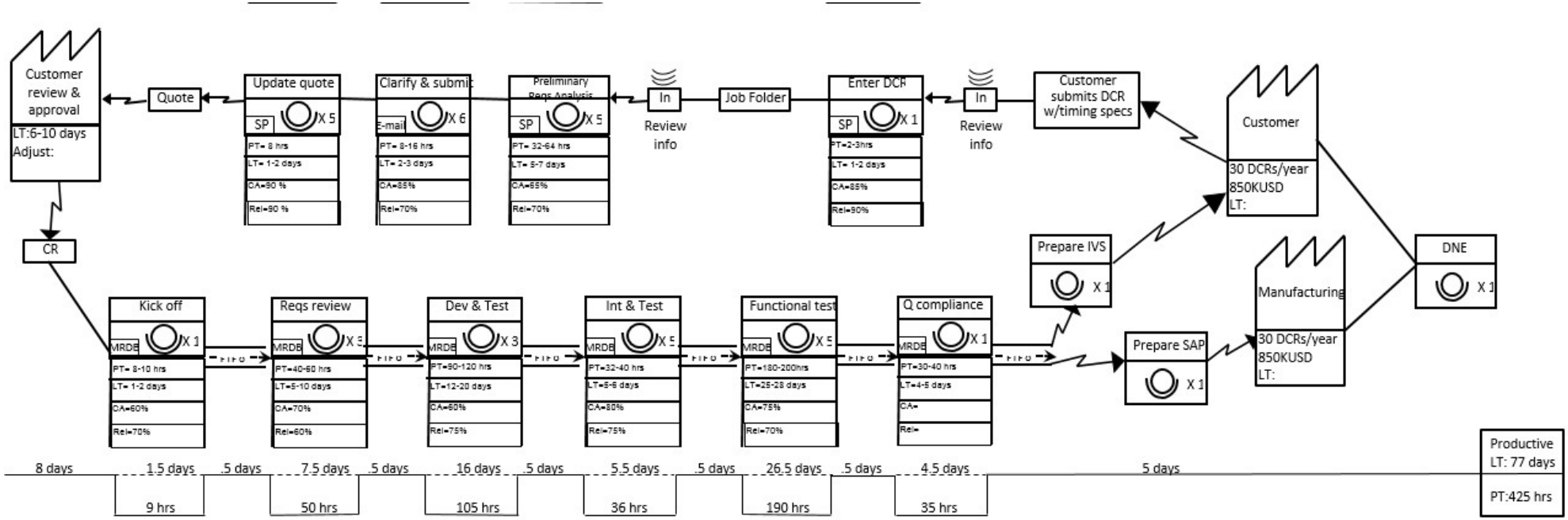


Figure 16 VSM Current Condition

2.4. Process conformance checklist

The Software Process Conformance Checklist (SPCC) is an evaluation of how good the team is on following the standard process for software development, this is a quarterly audit performed by a software quality engineer. It is important to note that a good SPCC score does not necessarily mean that the SW is being developed and tested correctly, it only means that the correct documents are being used and the processes being followed. The SPCC is one of the very few metrics currently available. The baseline score is 41% and shows opportunity areas on practically every phase.

Project	Next Gate	Sample	Process Conformance (number indicates number of checkpoints with this color)												% green or yellow checkpoints (weighted)	Number of high prio red violations	Number of red violations	Number of red & yellow violations
			Requirements Engineering	Software Development	Module Test	Integration & Integration Test	Software System Test	Test Management	Subcontract Management	Configuration Management	Reviews	Project Management	Measurement	Functional Safety				
CD4 Platform	G60	<Sample>	5	6	4	3	4	2		5	1	10	5		41%	12	45	52

Figure 17 SPCC Initial

2.5. Issues categorization

Based on customer feedback, and as output of the analysis phase the 2 areas of focus are Module Test Design and Requirements Analysis. This is where the highest issues are concentrated and where the VoC is telling us to put our efforts on.

Figure 18 Issues categorization

2.6. Conclusion measurement phase:

It is evident that there were not enough metrics that could allow the project team to stablish a reliable baseline and improvement plan, the newly created measurement system as shown above is linked directly to the VoC and the CTQs that our customer and company expect. The team was able to pull historic date to fill in the system however, fresh and up to date data will be used from February 2019 to September 2019, this timeframe will provide enough confidence on the information used for the analysis phase of DMAIC. These metrics are also helping to define the personal goals for each engineer with the expectation that it will serve to change the current mindset to one 100% focus on quality assurance along every phase of the SW development cycle

3. Analyze

3.1. SIPOC

In order to make every individual of the team aware of who the internal and external customers are, who provides the input for the process, what output is required and the customer's

requirements, a SIPOC diagram was created, this diagram is being shared with the complete team and group managers must ensure it is reviewed in detail.

4.

Suppliers (Providers of the required resources)	**Inputs** (Resources required by the process)	**Process** (Top level description of the activity)		**Outputs** (Deliverables from the process)	**Customers** (Stakeholders who place the requirements on the outputs)	
Customer	STSS	Requirements *Analyze customer specifications. *Agreements with customer.	SW requirements and timing received	SRSCs	Requirements *Create SRSCs for critical features. *STSS uploaded to DOORs *Agreements with	Design Team
Customer PM	Timing plan	Negotiate and agree dates internally and with customer		SW/FT timing	Timing plan including dates for integrations and testing loops, IVS,	PM
SW manager SWQE	Tailoring list	Follow process per tailoring list	-Requirements analysis. -Timing evaluation -SW development	SPCC score compliance	Comply with corporate score requirement	Quality Head PM
Requirements Eng. SW manager PDC Head PM	*STSS, SRSCs *Timing *Resources	*SRSCs and timing delivered properly *All resources allocated on time		SW designed and tested	*Module, desktop, integration test pass *Integration delivered on time to test groups *Traceability	Functional Test team Customer test group
SW team Test team Systems Team	*SW integrated and fully tested *Proper PN information	*Bug free SW *SW release per PM timing plan *PN matrix correctly filled up and agreed with customer	Upload SW to IVS and SAP	IVS and SAP packages	*IVS released to customer bug free and on time *SW released in SAP for manufacturing bug free and on time	Customer Manufacturing Team

Figure 19 SIPOC

Conclusion SIPOC:

After working with the project team it is evident that there is a misunderstanding of who the customers, suppliers and parts of the processes are, this SIPOC allowed to have everyone on the same page on who will provide and who are we going to receive requirements from

3.2. SWOT Matrix

A SWOT matrix was created including feedback from managers, discipline leaders and the quality team. The strategies shown below will be consider to create a framework including training and metrics that can support on the improvement process.

Strategies S-W Reinforce following processes trough quality training Define a methodology for increasing efforts estimation accuracy	**Strategies T-W** Increase understanding from team and consequences of SW issues 3.Imlement Agile and SCRUM methodology **(System)**
Increase SW development tools training and visibility **(Practical problem solving skills, six sigma (Variation reduction),Yokoten shared best practices,DFMEA-PFMEA(Go, see and fix), JIDOKA (Proactive and reactive), POKA YOKE, Standarize work, supplier performance improvement)**	Asses impact of Agile on SW development timing
2. Prepare training series from SW developers (Sr.) for SW delopers **(Certify team on A-Spice)** 1. Develop True North for the SW team **(Zero defect culture)**	5. Develop a proper test management tool **(No defect escape)** 4. Increase quality assurance mindset on team members. **(Include Management)**
Encourage use of quality checklists	External factor-customer (Time phase SW development planning rules) based on experience with Asian customers.
Define measurement systems basdes on FPY **Align org structure to Zero defect culture (design, process, suppliers, customer)**	

Figure 20 SWOT Analysi

3.3. Voice of the customer-Expectation

With the goal of understand the VoC and translate this into CTQs, a VoC tree was prepared where CCRs were identified and proper CTQ and KPIs defined, this tree includes most of the areas were the issues are found:

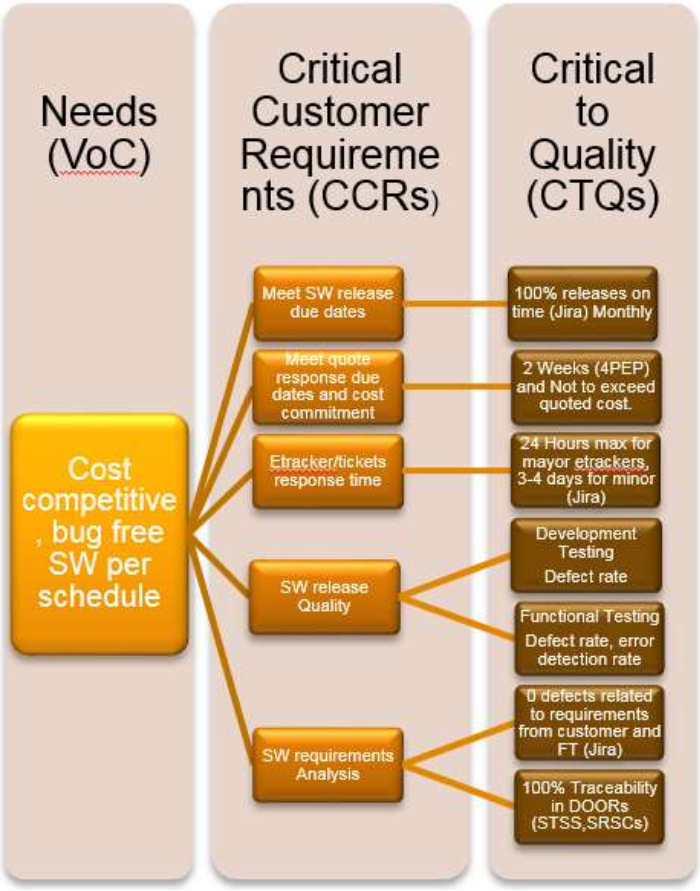


Figure 21 VoC Tree

3.4. Value Stream Map future condition

On the VSM the focus areas are identified. These focus areas are requirements analysis, which encompasses the analysis itself, documentation of the requirements analysis and the proper traceability to the results of the design. The other focus area is Development and testing which

encompasses impact analysis, update and creation of module specifications, module design, testing and traceability through the proper tools. As mentioned on section 2.4, the VSM on this project serves as a tool to understand clearly the different phases of the SW development process and point where the opportunity areas resides.

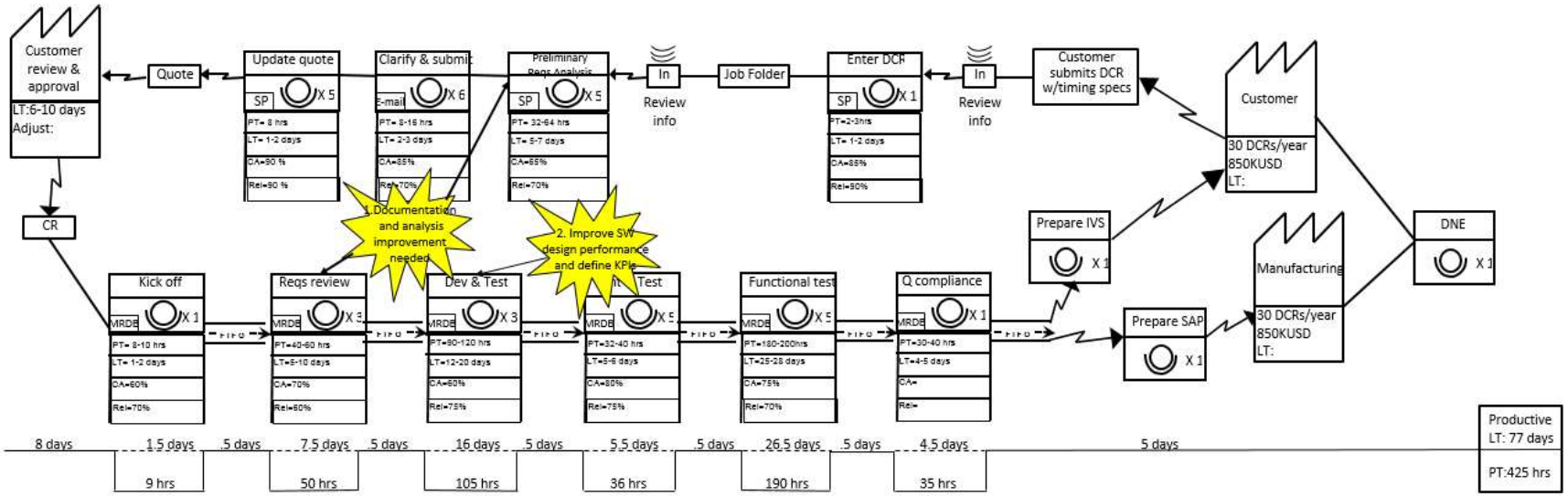


Figure 22 VSM with focus areas

3.5. Requirements Process Map

The following process map shows each step of the requirements analysis phase, each star marks the point where a KPI needs to be assigned, in this case these were placed on the analysis of the actual requirements to identify how efficient this activity is being performed. A KPI on the SRSCs creation step will allow us to measure the quality of the actual document, if the firsts drafts or first release of the document is being done properly then the rest of the document will be completed properly.

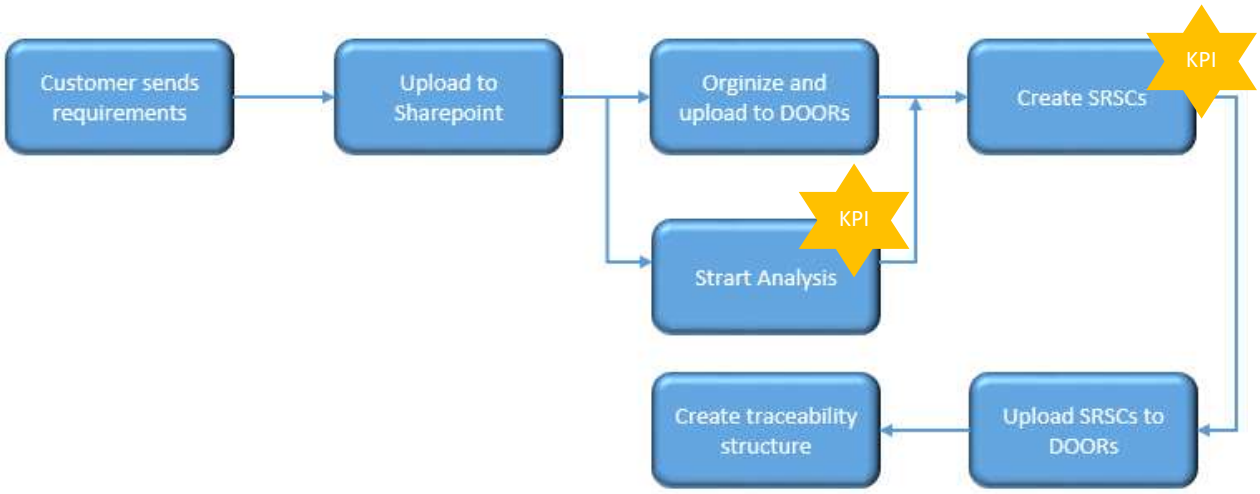


Figure 23 Requirements Process Map

3.6. Module design process map

This process map is for the actual design and testing of the SW module, this process is as important as requirements analysis since this is where the execution of the code takes place. The first KPI is placed on the module specification update and creation, this is the document that developers will take to start writing code hence, the importance of having a well-defined module specification. The second KPI is placed on the module test results, the intention is to measure rework in order to find areas of oportunity in the development phase where training or other options must be evaluated.

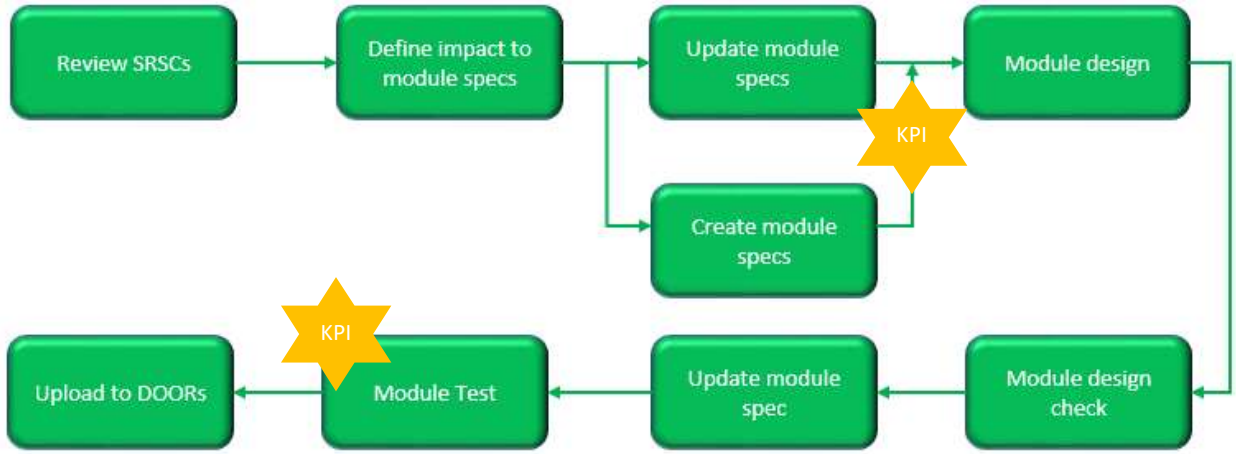


Figure 24 Module Design Process Map

3.7. Functional Testing metrics

On the Functional Testing Group there were some metrics already defined and some other newly created, these metrics include the level of automation for test cases, the hours spent on a full test as well as the test coverage for the project.

One of the immediate containment actions taken on the functional testing group was to assign 2 test automation specialists in Q1 2019, other ICA was to perform continuous functional testing immediately on the SW releases currently available, this allows to improve the performance of the SW to a certain level that would keep the customer satisfied.

The following charts show what the team will start monitoring from the Functional Testing perspective on automation quality and efficiency.

The team is currently in the process of using the tool DOORS for requirements management where test cases and test results will be traced back to each requirement. A test architect is also assign to the team to support on reviewing test cases and it[s implementation.

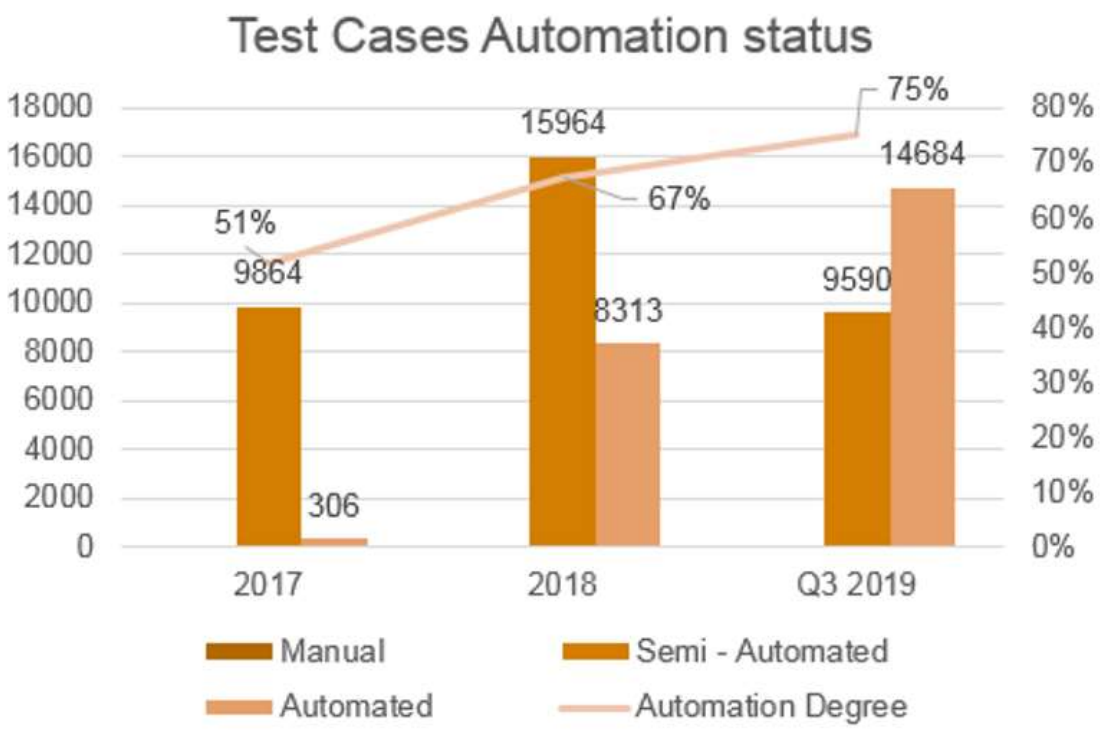


Figure 25 Test Automation Status

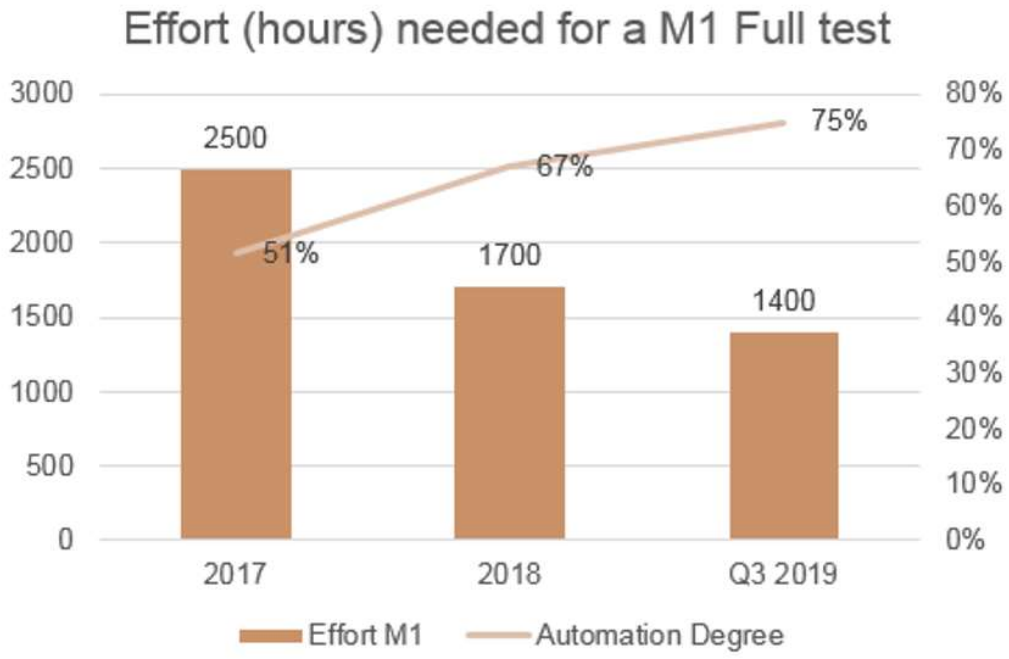


Figure 26 FT resources on full test

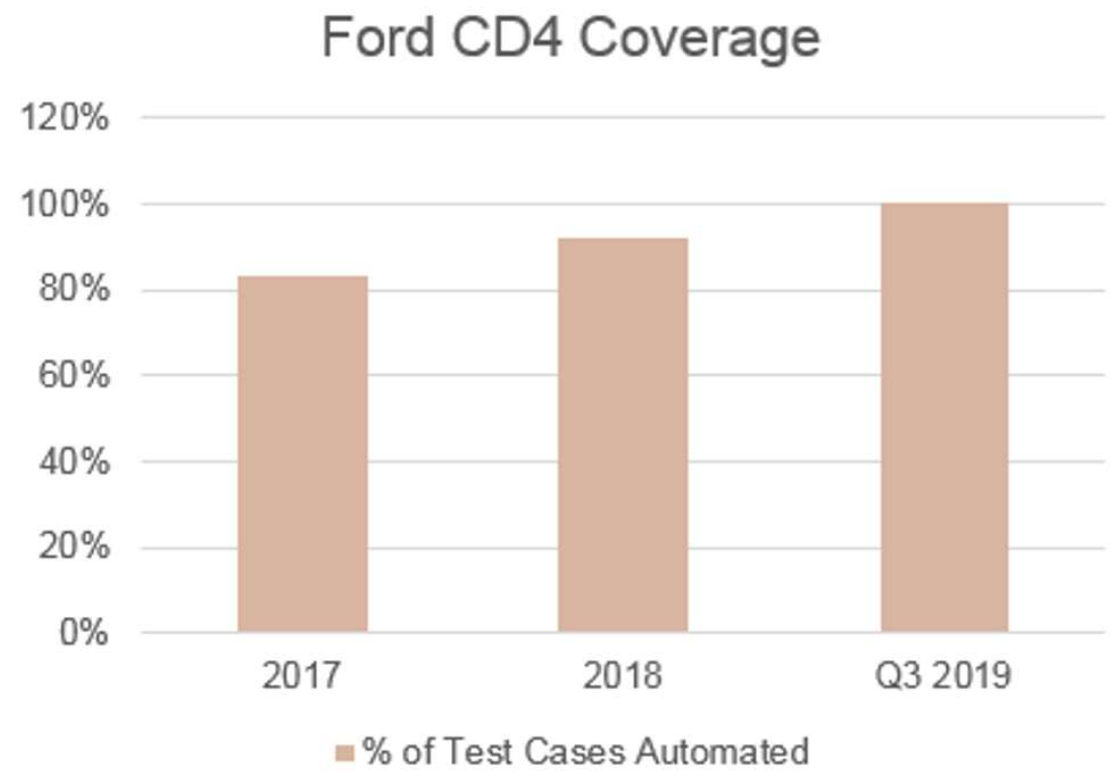


Figure 27 Test Cases Automated

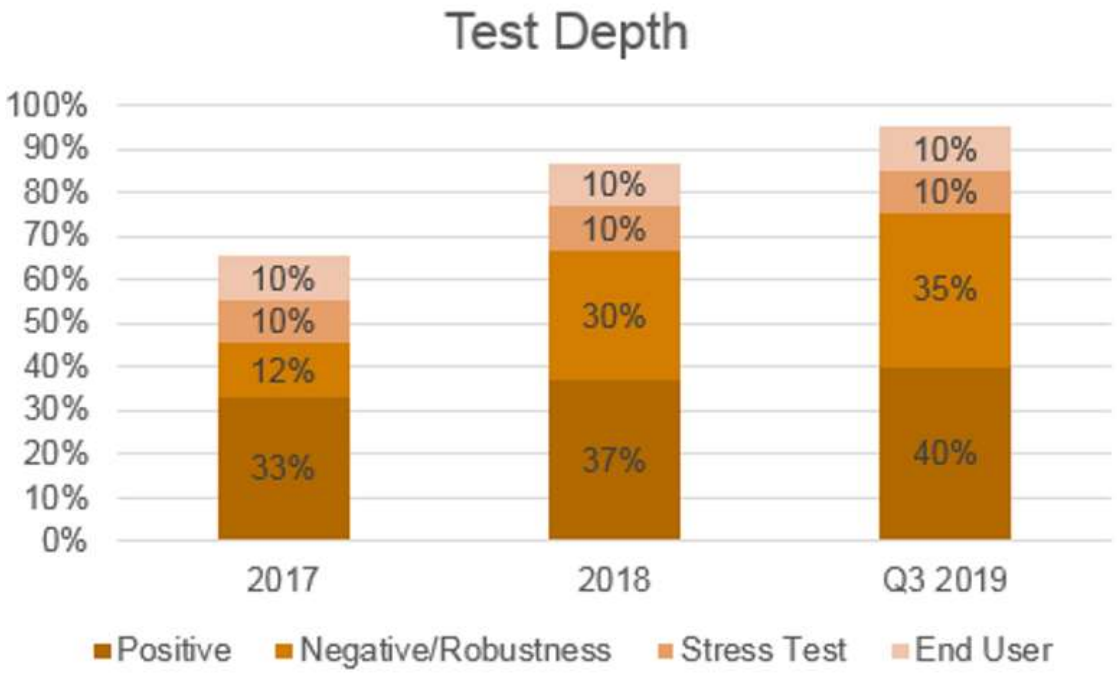


Figure 28 Test type

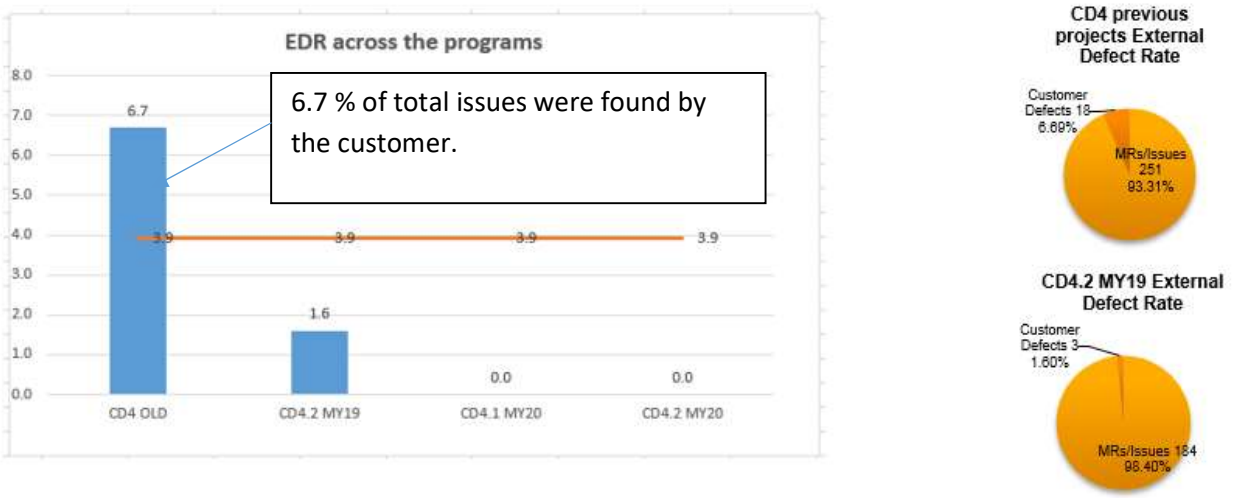


Figure 29 External Defect Rate CD4-Customer reported defects

3.8. Software Development Metrics

On the SW design side, completely new metrics had to be defined and created, a new tool for measuring software quality had to be used, in this case we moved from MRDB tool to JIRA. The following charts represent the metrics that were created and that are being used to make SW design more robust, it includes metrics such as:

1. Feature request vs issues: It reflects the ratio between new features requested by the customer and overall introduced issues during the development phase.
2. Ticket return rate: Reflects efficiency on SW development by measuring quantity of tickets rejected during SW validation.
3. Top 10 PR components: It shows the list of the most critical components in terms of quantity of issues reported.

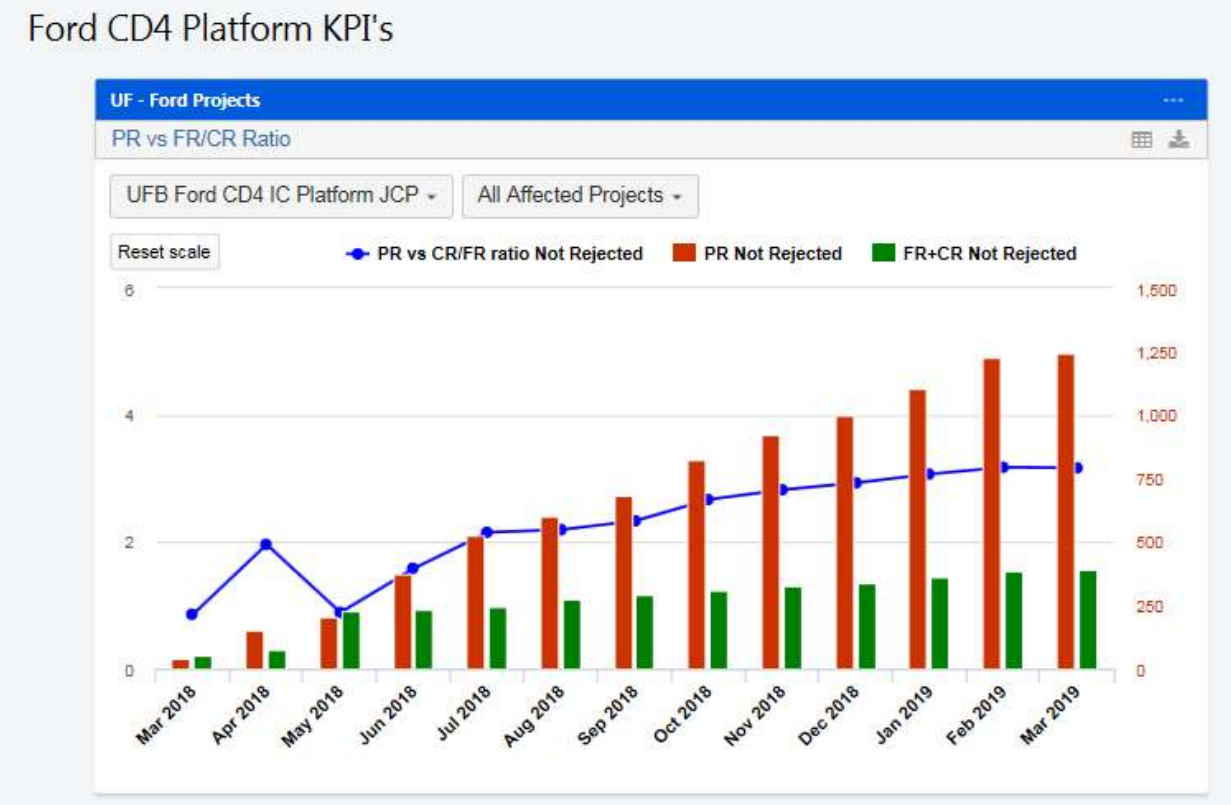


Figure 30 Feature request vs issues

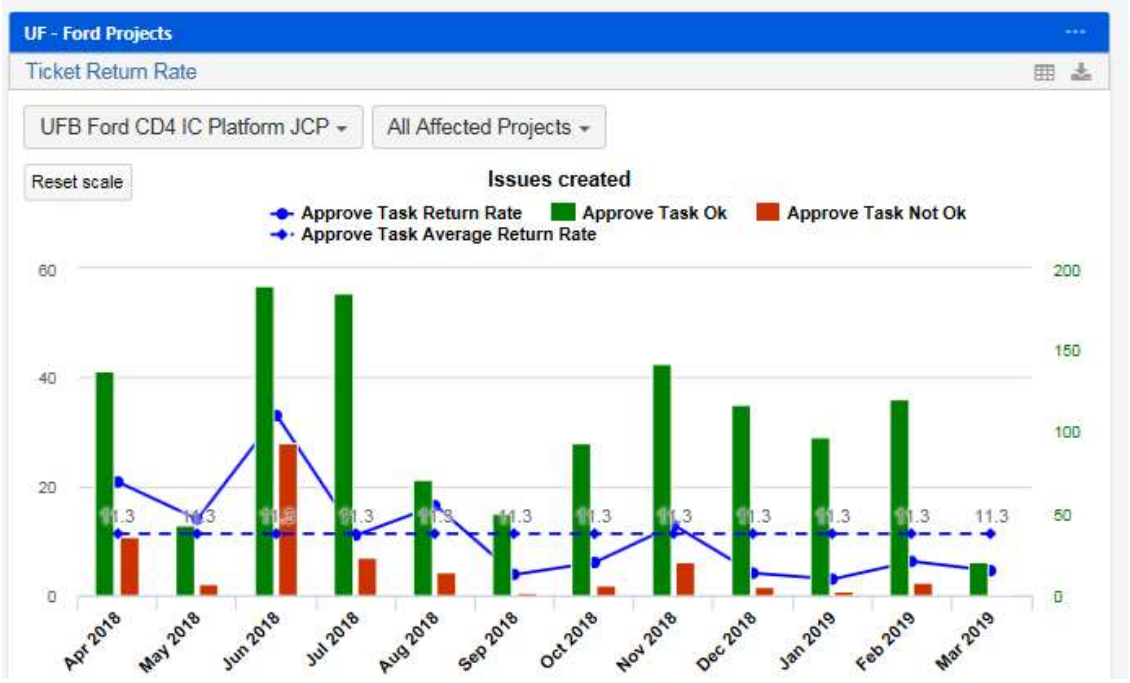


Figure 31 Ticket Return Rate

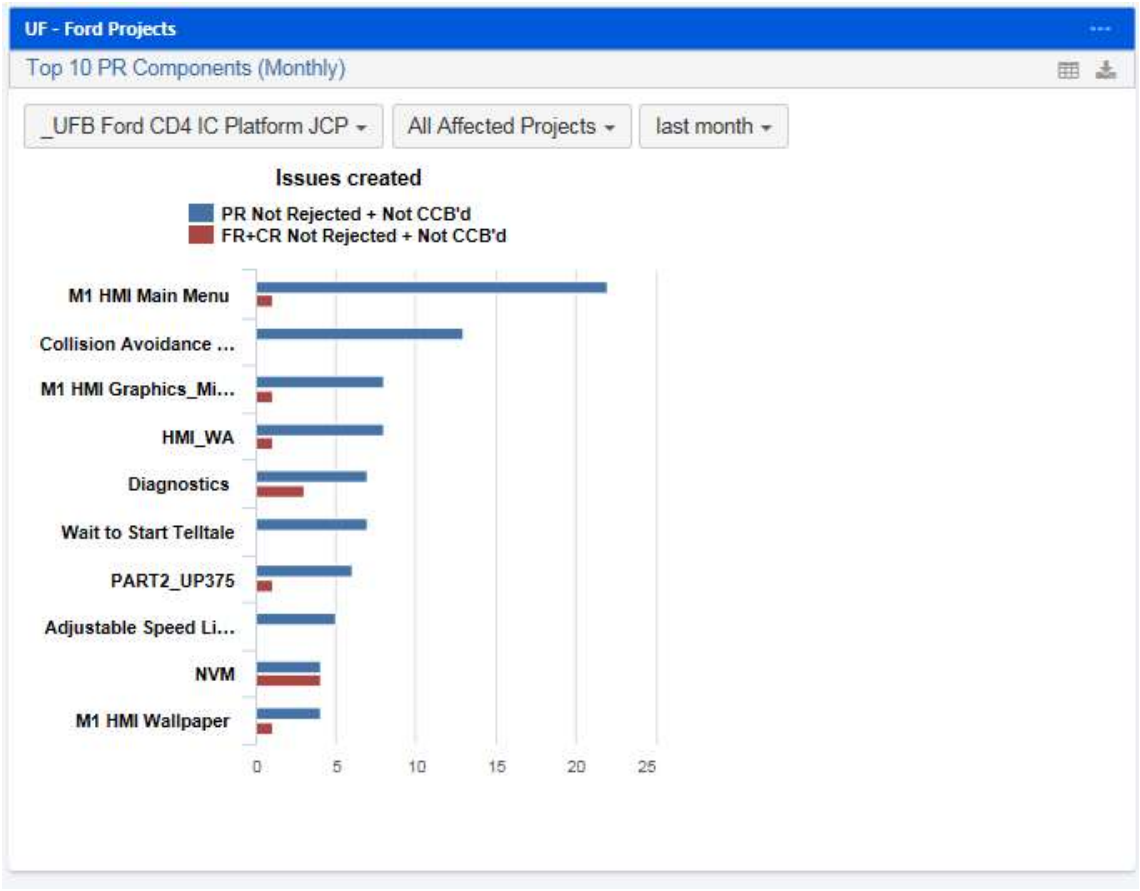


Figure 32 Top 10 PR Components

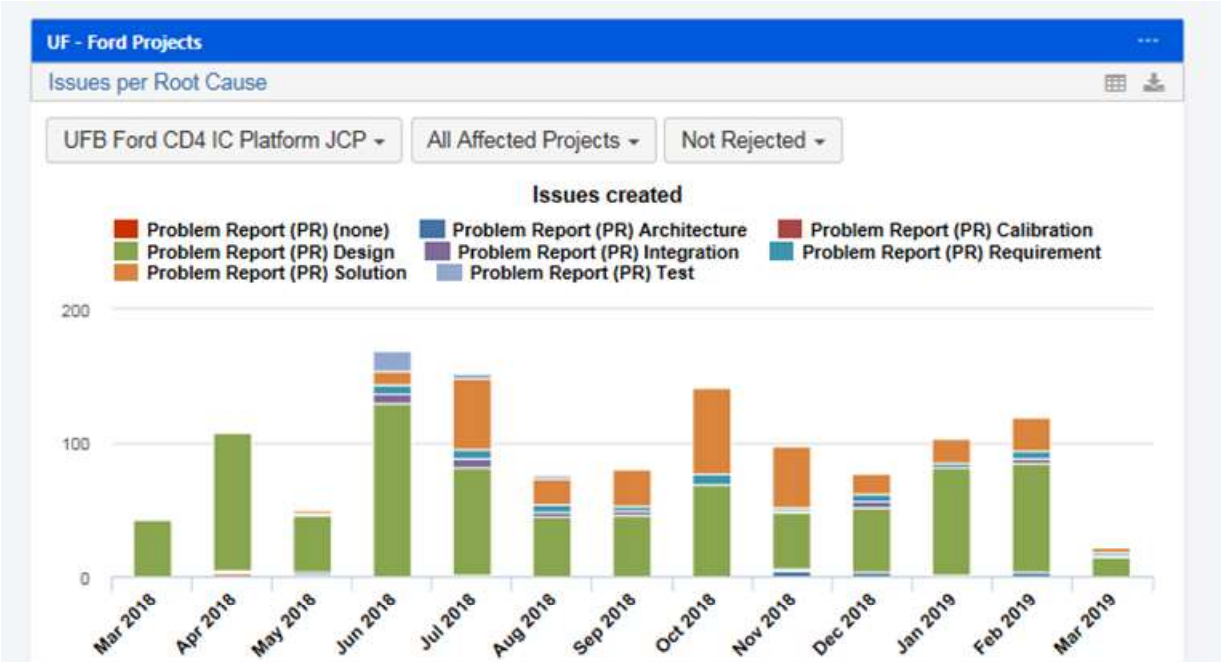


Figure 33 Issues Per Root Cause

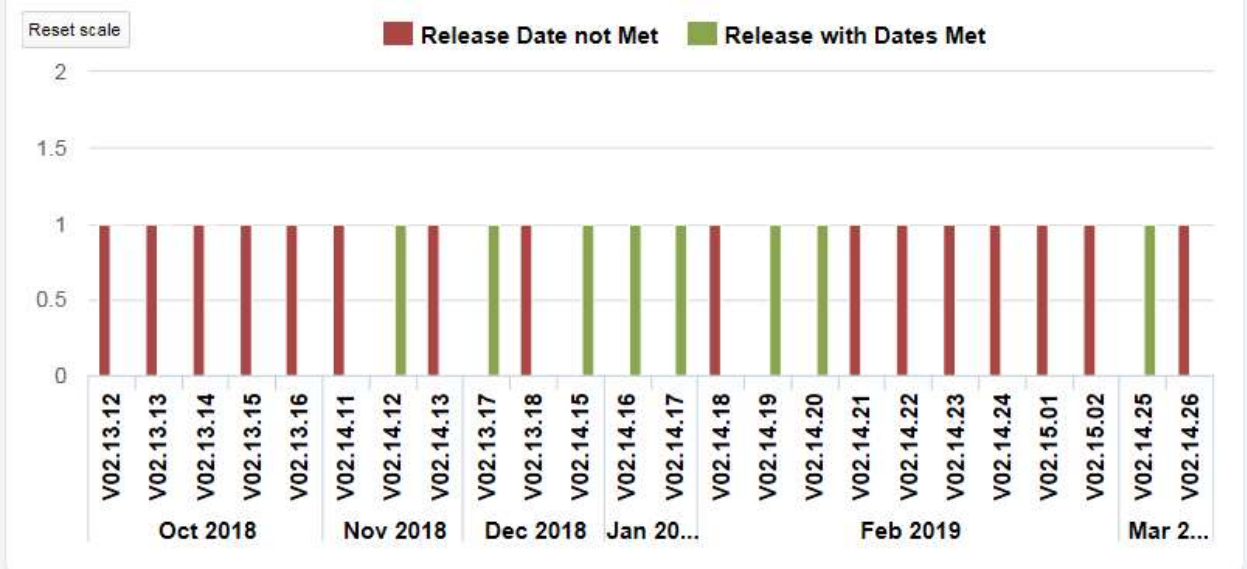


Figure 34 Releases status

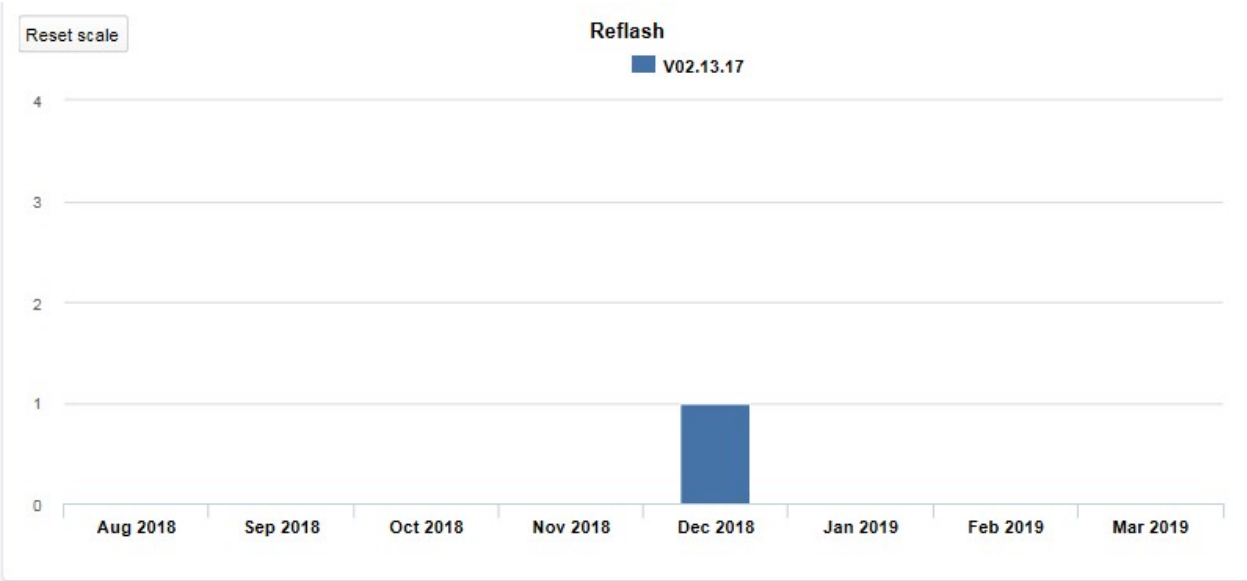


Figure 35 Reflash activity status

3.9. Measurement phase conclusion

It is evident that there were not enough metrics that could allow the project team to stablish a reliable baseline and improvement plan, the newly created measurement system as shown above

is linked directly to the VoC and the CTQs that our customer and company expect. The team was able to pull historic date to fill in the system however, fresh and up to date data will be used from February 2019 to September 2019, this timeframe will provide enough confidence on the information used for the analysis phase of DMAIC. These metrics are also helping to define the personal goals for each engineer with the expectation that it will serve to change the current mindset to one 100% focus on quality assurance along every phase of the SW development cycle.

4. Improve Conclusion

After working on all areas from mindset to measurement, it was evident the project team needed a change in all aspects, the creation of the teams True North helped improving the attitude of all individuals with significant impact to their deliverables, from my perspective this was a much needed change that had to happen first before anything else, improving attitudes and behaviors is the foundation for an efficient problem solving methodology.

Due to COVID 19 the auto industry had a huge negative impact on new projects and engineering changes, no SW engineering releases were implemented starting March, still we were able to get a SW change trough this improved process and metrics, the results speak for themselves, the SW process conformance checklist was prepared again and it showed a huge improvement of 100% score, eventough the evaluation only included one software release it showed we are moving in the right direction, the improvement on all areas was an evident success and all the tools used trough this process had an incredible value added that positioned this project in a better place in front of the customer.

3.1 SWQA Status Overview

Project	Next Gate	Sample	Process Conformance (number indicates number of checkpoints with this color)												% green or yellow checkpoints (weighted)
			Requirements Engineering	Software Development	Module Test	Integration & Integration Test	Software System Test	Test Management	Subcontract Management	Configuration Management	Reviews	Project Management	Measurement	Functional Safety	
CD4.1 MY20 FOE	<No.>	<Sample>	9	8	5	5	6	4		16	4	16	6		100%

Figure 36 SPCC score after improvements

3.3 Management Summary

The overall status of CD4.1 MY20 FOE is **Green** and Software Process Conformance Checklist score is 100%

Figure 37 Communication to upper management

There are some key points to take out of this assessment which I summarize below:

- A performance measurement and monitoring system is key to success.
    - The level of measurement we had on the project didn´t allow to identify clearly where we were failing, and the very few metrics were not properly defined.
    - The new measurement system and metrics allow for a deep understanding of where we are in the area of software development and testing.
    - Metrics are simple yet deep enough for everyone to understand and follow.
- Management team need to be closer to engineering workforce and listen!

    - A proper understanding of what the engineer thinks and needs is key to the success of a project, there were aspects that only the people that is doing the actual work will understand.

- Early training for new engineers is essential in all aspects.
    - The auto industry employs newly graduated engineers with no experience in the field whatsoever, it is essential that a proper training plan is followed to guarantee success.
- Consistency on what we think we are doing vs what we should be doing.
- It is a painful path, but we can always be better!

The road is still not finalized, we still need to consolidate the success and repeat it on the following software releases, the next steps need to be followed to guarantee the results shown were not a one time event:

- Continue the Trend!.
- Keep team spirit high and focus on true north.
    - It is the responsibility of the management team to maintain people focus on the True North and keep moving forward in the right direction.
- Pay attention on next SW deliveries and performance adherence.
    - January and February 2021 is a timeframe where new SW releases will be received, this in specific should be monitored closely to confirm the improvements are having the desired results.
- Keep improving metrics.

- The current metrics are efficient and show a good picture of the actual condition of the project however, it should not stop here, we need to keep thinking on more efficient metrics that allow us to identify problems on time and react accordingly.

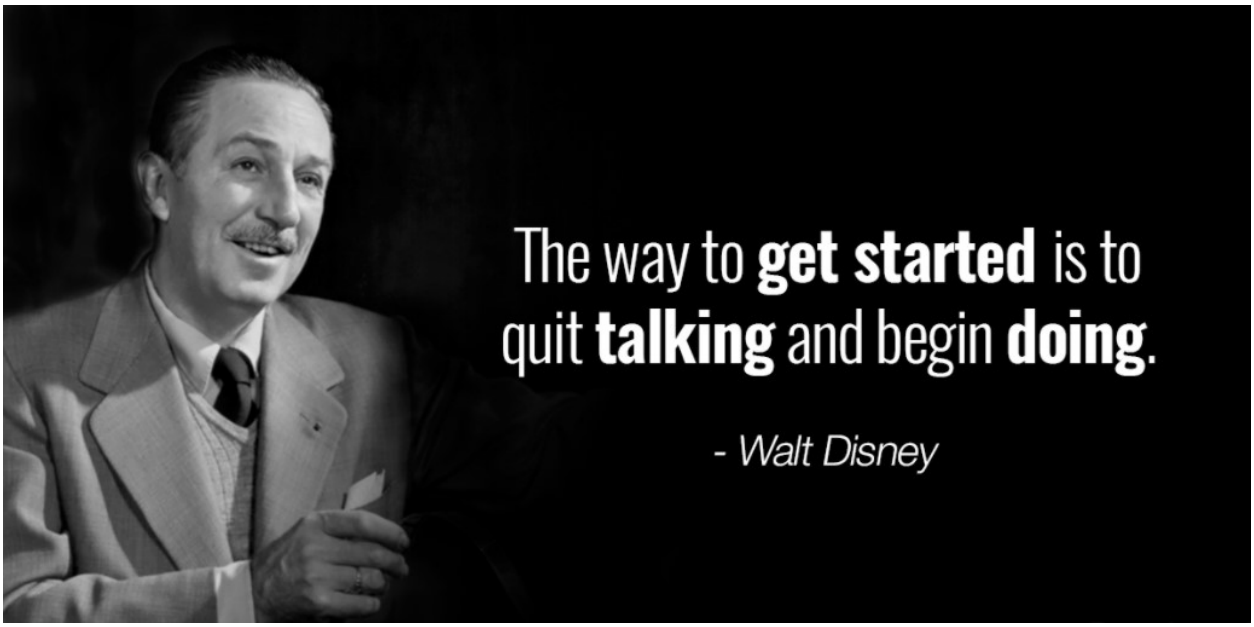


Figure 38 Final Quote Walt Disney

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