A PROPOSAL FOR A PRODUCT ENGINEERING QUALITY PLAN INSIDE THE AUTOMOTIVE INDUSTRY

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Abstract.. *The quality plan integration in the product development process, is the objective of this work. The subject is introduced by describing the motivation and the reasoning behind the importance of the theme, highlighting the process variability. It is discussed the traditional methods for quality development and tracking during product development, to introduce later on, new methods used inside the automotive industry.*
The Plan is introduced considering two approaches, the design development process quality and product quality objectives. The results from an investigation executed during three phases of the vehicle development process, support the proposal structured in the work process.

Keywords. *design, quality plan, automotive.*

1. Introduction

The ideal condition in the product development process is to have the process initiated with the quality objectives already incorporated. Because of that the subject is broached in two basic and distinct quality correlated aspects: the development process quality in a way to generate a product minimizing detrimental occurrences to its final quality, and the insertion of product quality objectives during the design phase.
The development process quality has a lot to do with error propagation during the work progression and the lack of complying with the information in time at the required level.
The product quality objectives insertion during the development phase, specific in the design stage, is the less costly and more effective method to implement a quality plan, because it does not requires additional costs ant permits adjusts for a more robust solution in order to guarantee the final product reliability.
To support the Quality Plan in face of those affirmatives, it was investigated the problems found during the vehicle production phase, the product design execution phase at production implementation stage, also called pilot, and during the development phase at concept, structure and integration sub-phases. These three families of data were obtained at GMB vehicle production, during the period from August 14th through September 11th, for the first phase; the pilot stage data were gathered during the implementation in production of the new CORSA Sedan and Hatchback vehicle models in the period from October through December 2001; during a new vehicle development phase, the current MERIVA, from October 2001 through February 2002, were collected the data covering the concept, structure and the beginning of integration sub-phases.
They are large projects, involving the development of complete vehicles that incorporate updated engineering information handling concepts, such as mathdata, conducted inside an suitable vehicle development process and under the influence of quality treatment factors not currently totally dissected, such as serviceability, danability and repairability.

2. Quality prusuance methodology along with the time

JURAN (1992) declares that the product characteristics and failure indicators are defined in its majority, during the quality planning. The competitiveness, the need for actions and fast answers to the market place, require innovative attitude with focus on the processes:

quality planning
process variation control
process and product continuous improvement

After the 50 decade the Japanese industry has introduced the TQM – Total Quality Management, (SHIBA, GRAHAM, WALDEN, 1997), looking for the quality excellence. It is a methodology well accepted and supported by some big successful companies at present time.

In a more deep analysis, it can be seen that the quality in TQM is always understood or focalized in the results, the product from an operation. It is not given emphasis to the quality of any process work, as a tool to manage results with quality, a purpose that would provide reliability to the characteristics of the result.
To attribute value to quality is to focalize the actions in the productive process stability, starting with its initial definition.
Some modern concepts and new quality approaching methodologies, when applied during development, can identify product and process critical points, accredit robustness to the design, provide performance optimization and can prevent non conformances.
SLACK (1993) says that quality pursuance is not only to monitor the processes and to register their performance, but also to analyze the performance behavior along with the time, propose solutions to any raised problem, improve the process, implement the resulted changes, as well as to control the changes effect in the performance. This takes towards the adoption of a standard problem solution cycle, which is essential in the quality plan continuous improvement and in keeping the effectiveness during its implementation.

3. Vehicle development process

In order to detail the quality plan in the vehicle development process, it is necessary to assume a disciplined development process. In the performed investigation, it was verified that the development process conducted inside the modern automotive industry is very close to the one practiced in the aeronautics industry currently in Brasil (CARBONARI, 2001), emphasizing virtual simulations or even using laboratory physical tests, which have provided satisfactory results to the industry.
With the QS 9000 implementation, that concentrates supplier requirements from GM, Ford and Chrysler in a global form, the product development process structure had a large disciplining incentive through the APQP – Advanced Product Quality Plan adoption.
The vehicle industry requires a more complex model, even though it may have inserted the APQP stages and concepts, so that the required different stages during vehicle development happen in a satisfactory manner, and the integration of certified suppliers come in the process at right time, with quality requirements observed.
The type of processes and concepts exposed up this point have motivated the derivation of a VDP - vehicle development process for the automotive industry, structurally formed by vehicle assembly line companies, in a manner to sponsor the Engineering Quality Plan. Figure 1 shows in a summary form, the process stages covering the activities from the creation up to the commercialization of a new vehicle in the market.

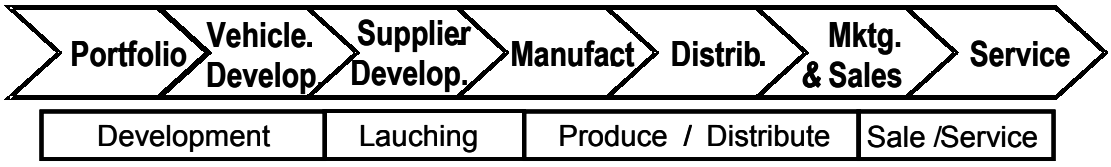

Figure 1. Creation and launching of a new vehicle in the market

Figure 2 shows the defined VDP structure with a detail level enough to understand the quality plan activities integration along with project development.
The phases and activities shown in Fig. 2, harmonize the entire project development process and keep together actions and decisions in a way to have a gradative and growing sedimentation process of product information and organization learning aggregation about the project, to permit the necessary control and attendance required by the Quality Plan implementation.

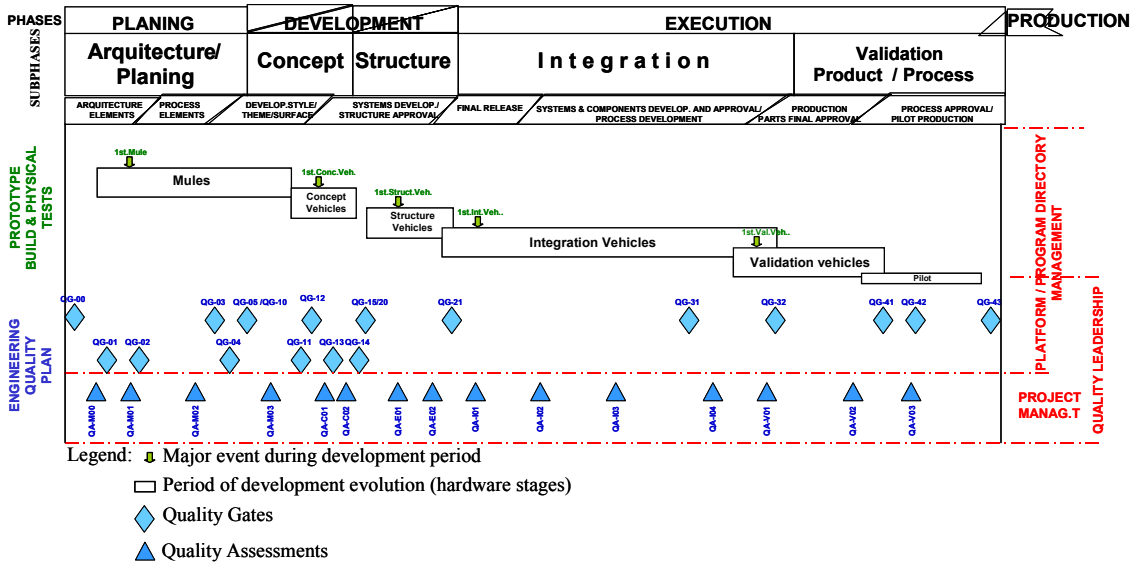

Figure 2 – VDP basic structure

4. Quality problems characterization

To characterize the problems of quality, it was developed a research about the discrepancies found, in three phases, one during the production phase, another one during the pilot stage, that corresponds to the validation phase of manufacturing process and implementation of a news vehicle in production, and the third one in the development phase, covering the sub-phases concept, structure and integration. Two hundreds and sixty seven cases were investigated during the development phase, 505 during pilot and 200 during production phase, all of them obtained from the official control of company service orders. It was developed a research methodology in a way to gather information about the origin of the problems (supplier or automaker); qualification (product, process or operations); area of incidence in the vehicle (body, internal finish, external finish, EE&VAC (electro-electronics, ventilation and air conditioned), chassis, powertrain and general). More details can be obtained from the Master Degree Dissertation, BARROCO, 2002.

Production phase – It was verified that the majority of the cases (72,0%) were identified during vehicle production and the others, during the sub-phase of product validation (15,0%) and from pilot (13,0%). These last ones, identified before the vehicle entering in production, were not solved and implemented in time not to affect the production, what in a certain manner indicates excessive delay from the organization to solve the problems and/or is a matter of critic problems in such level that may involve rework or rebuild of tooling and fixtures. Analyzing the incidence, it can be said that the majority (30,0%), classified as general, refers to parts standardization and alterations in minority components and of general use in the vehicle, whose effect is relatively small in the vehicle, but in some extent it can affect the quality of the final product and it should be taken care in time in the project development process.

It was also found that around 60,0% of the cases have been originated in the carmaker and the remaining in the supplier. On the other hand, 62,5% are due to product, 20,0% to the process and 38,0% are classified as operations, what in a certain form is in line with the vehicle area identified as general. They are not important in the development of this work, because they may not have causes not necessarily relate with the development of the project and its quality. It is important to detach that it is not expected that the addition of the percentages result in 100%, since some problems were classified as of both process and product due to the lack of better information about it, or because there are cases in which both causes do not subsist in a distinct form.

Pilot stage - It was found that 71,3% of the cases were originated in carmaker, which were classified near to half and half between product and process. These indices can show that the coordination process and project tracking, as well as the integration among areas of activities, should be improved. In the problems location in the vehicle, it can be detached the body with 46,0%, with EE&VAC in second with 17,1%, followed by the Internal Trim with 15,5%. The percentages are in harmony with the figure from the origin allocated in the carmaker, since it is still responsible for more than 80% of vehicle body design and build.

Development phase - In this phase the cases were identified in their majority (66,7%) inside the structure sub-phase and 29,6% already in the execution phase, what indicates that they escaped out of the control in the adequate moment for the solution. Despite of this, the majority was identified during the period when it was expected their occurrence, considering an efficient process of tracking and control. This was expected in the company, since the project under investigation in this phase, is more recent than the others, and has been under the control of an improved vehicle development process, more disciplined and integrated in the engineering organization. Due to the fact that the research has been performed during the beginning of the development conduction, it was verified that 87,3% of the cases has

been originated in the carmaker, with 73,4% attributed to the product and 35,2% to process. The high index relatively to the product is due to the fact of that in the beginning of the project it evolves more quickly with the releasing of information for manufacturing process definition activities, bringing with it a natural lag in the work development. Also in this phase the vehicle area with bigger contribution was body with 46,4%, followed by EE&VAC with 18,3%. This is justified by the biggest involvement, in this phase of the project, of architectural items with structural participation in the vehicle, what in special, body has the highest content.

5. The quality plan and tracking process

The Engineering Quality Plan is developed with the focus in two approaches: the quality of the development work and the insertion of product quality objectives. The VDP basic structure from Fig. 2, shows two bands in its base, that define the moments of control and tracking of the Product Engineering Quality Plan and are driven by the quality leadership, in this case conducted by an specific management. They are constituted by the QA – Quality Assessments, tracking and control meetings followed by the management of the project; the QG – Quality Gates, meetings for actions tracking by the Platform or Program Directory. The building events shown in the "Prototype build & Physical Tests" area from Fig. 2, are cadenced and supported by virtual accession meetings, that precede each prototype build stage or vehicle tests, in a manner to minimize risks, to assure representation and to confer efficiency in the evaluations. The releasing of engineering design information for the whole organization is also cadenced by the mentioned stages.
The research described in the previous Chapter served to characterize the problems, to develop preventive recommendations, and to orient the content and the quality plan elaboration, in such a way to guarantee its efficacy. Substantiates the quality plan work part in the development.
The preventive recommendations resulted from the expressed analysis results in the previous Chapter and from the specific evaluation of the nature of each problem, which result is shown in Table 1. For the identified cases during the production phase, can be concluded that 31,0% could be prevented during integration sub-phase, period in which the components and systems are individually validated, integrated among themselves and verified their adequacy to vehicle project objectives. The 27,0% should have been found and resolved during the structure sub-phase, if the tracking plan had promoted it, because they involve components that make part of the product structure definition. It remained 8,5% that could have been intercepted and corrected during the concept sub-phase, by means of involving redefinition of characteristics of the product and/or design criteria that conditions the interaction among components in their assembly.

Table 1. Research and quality problems evaluation results

SEARCHED STAGES	DISCREPANCIES IDENTIFICATION STAGE	ORIGIN (*)		QUALIFICATION (**)			VEHICLE PARTITION							RECOMMENDED PREVENTION
		SUPPLIER	VEHICLE MANUF.	PRODUCT	PROCESS	OPERATIONS	BODY	INT. TRIM	EXT. FINISH	EE&VAC	CHASSIS	POWERTRAIN	GENERAL	
PRODUCTION	PRODUCT VAL. 15,0 PILOT 13,0 PRODUCTION 72,0	44,0	59,0	62,5	20,0	38,0	14,0	14,5	2,0	16,5	4,5	18,5	30,0	CONCEPT 8,5 STRUCTURE 27,0 INTEGRATION 31,0
PILOT	PILOT 100,0	36,0	71,3	55,2	50,3	4,6	46,0	15,5	8,2	17,1	8,1	3,3	1,8	CONCEPT 0,4 STRUCTURE 37,8 INTEGRATION 60,0
DEVELOPMENT	CONCEPT 3,7 STRUCTURE 66,7 INTEGRATION 29,6	17,6	87,3	73,4	35,2	10,1	46,4	7,1	6,0	18,3	5,6	6,4	10,2	ARQUIT./PLAN. 15,7 CONCEPT 70,0 STRUCTURE 12,7

Values in percentage (%).
(*) The sum of the values in a certain stage may not totalize 100%, since the available data in some cases were not enough for a correct definition; in these cases the origin was allocated to both.
(**) In qualification, some cases were classified as to belong to both process and product; this has resulted in a sum above 100%.

The other 33,5% are apparently away of the intention of this work, by means of resulting from initiatives taken in the production phase itself, like standardization actions, change of systems combinations to attend the last minute market options or even other cases originated from operation adjustments.
During the pilot stage, it was reached the conclusion that the big majority of the problems (60,0%), could be avoided during integration sub-phase, what shows itself viable by the information that 71,3% were identified as responsibility of the automaker. From the remaining, 37,8% would have conditions of being resolved during the structure sub-phase, which is reasonable, as the majority belongs to the body and is classified as product's.
The prevention of problems originated in the development sub-phase should be made in the concept sub-phase, in its bigger part (70,0%), for having the characteristic of demanding revision of design criteria, adjustment of architectural concepts, location of the systems on body surface, etc. We still have 15,7% that should have been avoided during the period of definition of vehicle architecture and its initial planning; and 12,7% can be avoided during the structure sub-phase and probably were, as they were identified inside this same sub-phase.
A small percentage of problems in pilot stage (2,2%) and in development phase (1,6%) was not achieved by the prevention criteria, because they are relative to operations in the organization that are too away from the intention of this work.

In current large engineering organizations, the design information is generated electronically, generally called math data, which bigger volume is relative to body surface. A quality plan for the development process must incorporate a check list containing the standard activities, information formatting, correlation among files, dimensioning and information releasing procedures, consolidation with manufacturing processes and integration with suppliers, to mention the most outstanding ones. This check list orients the quality measurements during the tracking of the project development process.
Annex 1 shows the quality requirements in the development process, that include measurements of the check list requirements mentioned in the previous paragraph, verification of work plans and specially the reliability and reduction of warranty, serviceability, damageability and reparability plans, that must provide facility to access the vehicle with substantial effects in the cost of warranty and maintenance, as well as, to sensitize the insurance companies, which may reduce the value of the "prize" to be paid for the vehicle insurance. Other requisites relative to manufacture processes, product quality, those involving supplying sources and the final product validation plan, are shown in this check list, and substantially influence the development process quality.
It can be verified, that in the plan of Annex 1, there is already an integration with the product quality plan, important for both process and product quality plans to proceed together in the rhythm demanded by the chronogram of the project.
The product quality plan is formed by the internal and external quality objectives and the general quality character ones.
The internal quality objectives are formed by the criteria or established levels for the development work quality, incorporate quality measurements inside the carmaker operations and the supplying sources. The tracking process and control of the internal quality objectives, as well as, the ones of the product final quality, a continuous improvement process, formed by a problems solving standard cycle, shown in Fig. 3, a helpful tool, also for the introduction of new tracking methods, analysis and evaluation of the origin of discrepancies.
The external objectives are those developed in function of the business plan from carmaker, with the intention in mind to reach their strategic goals that assure the quality targets of the end product. It is from their deployment that is defined the internal objectives, and those of subsystems and components from the suppliers.
The general quality character ones, include the objectives focused in service, repair of damages and more comprising as reliability, warranty costs and quality competitiveness in the market.

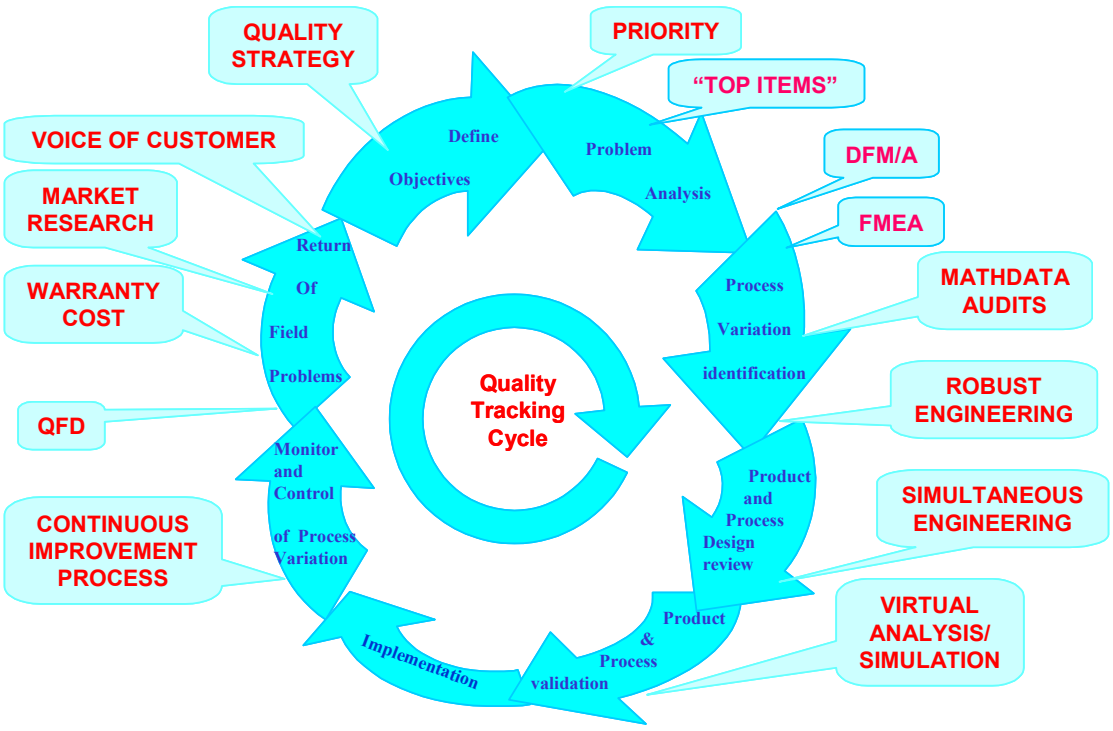

Figure 3. New problem solving cycle, new quality tracking methods, (adapted from SLACK, 1993)

The tracking process and control, follows step by step the rhythm of Program conduction oriented by the VDP and is done structured in the tripod: gates, check lists and action plans. The gates are formed by the QA and QG meetings, instruments for Program tracking. It is formatted a list of deliverables, the check list, that should be presented during the gate. In case of having some lacking or deviation from what was expected to be presented, the control is established through a plan of action, that should be attended and presented to the next gate, showing up the control of the pending actions. During the QA that precedes a certain QG, is prepared the information with the project multidisciplinary team, led by the quality and integration manager, who shows the entrances and answers expected in the gate. The gate

tracking process should be oriented by an approval criteria that define in which situation the gate should be approved, approved but conditioned to the fulfillment of an established action plan, or be repeated because it may put any way the Program in risk.
These criteria are established by the Platform Directory in a manner to guarantee the good course of the process and the reach of the established objectives, specially of timing, quality and cost.

6. Conclusions

The quality in the product development process is dependent from the discipline of the process. The traditional approaches of quality tracking, in general are structured to support corrective actions and they take the preventive process as an envelopment demanded subsequently.
New approaches, as the use of robust engineering in the beginning of the product planning phase, assure the control of product design critical points and the adoption of a standard process for problems solving, with emphasis in the process variation. They bring stability and equilibrium in the handling of discrepancies, conferring quickness and agility in the decisions and provide priority to the preventive approaches in the process.
A tracking process formed by a plan of gates, checklists of the deliveries in the gates and action plans, guarantees the reach of product quality objectives and the regularity of the work process. The Product Engineering Quality Plan in the Automotive Industry, despite of being specific, permit to be adapted and can be used in the industry in general. This is even more evident, wherever have a similar situation, that is, customers to be attended, competitive market, design engineering, manufacture engineering and product manufacturing, since the concepts and the envelopment in the engineering organization are identical.

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8. Apendix

Quality requirements in the development process

1.LAE – List of Arquitectural Elements, complete / frozen
2.Project development criteria, aligned (product design, manufacturing process and style)
3.LCA - List of Aligned Criteria, closed
4.LCA incorporated in the physical model
5.Execution plan for the workshops of math date
6.General plan for design studio activities
7.Design studio Physical model development plan
8.Packaging development plan
9.Drafting activities development plan
10.Plan of Analysis and virtual simulation
11.Prototype and physical models build plan
12.Evaluation and physical tests plan
13.Analysis, development and validation integrated plan
14.Product critic items integration plan (S&R-squeaks & rattles /DQ&V-design quality & verification /JE- jewely effect /DH-design harmony /Weight/ Fuel Economy/ etc.) 15.Reliability and warranty account cost reduction plan
16.Dimensional engineering plan
17.Robust engineering plan
18.Vehicle accession integration plan:
    18.1. Serviceability plan
    18.2.Damageability plan
    18.3.Repairability plan

19.Product quality integration plan
20.Process quality requirements integration plan
21.Project development measurements: