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Product Development Model Oriented for R&D Projects of the Brazilian Electricity Sector - MOR&D: A Case Study

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Abstract. The current article reaffirms MOR&D as a practical application through a case study in order to propose a production line design for a device that was created and developed previously in R&D projects within the R&D ANEEL (National Electric Energy Agency) Program. The lack of specific methodological models for product development in R&D projects in the Brazilian electricity sector generated the need for this specific knowledge. From a comprehensive research about respectable models of product development, the authors developed a suitable model for planning designs framed within the R&D Program of Brazilian Electric Sector regulated by ANEEL. The developed model promotes integration and dynamism between development stages and multidisciplinary teams. The model, named MOR&D, is comprehensive enough to meet the most types of R&D projects assigned to the R&D ANEEL Program and contains the main recurring concepts in product development, reason of its flexibility and adaptability.

Keywords. Product development models, Brazilian Electricity Regulatory Agency, electricity sector, concurrent engineering.

Introduction

The operation and maintenance services of electricity distribution networks often require from the electrician's teams a very close work to the energized drivers of medium voltage network, 13.8 kV and 34.5 kV systems. For this reason, multiple occurrences are registered annually, in which electricians, inadvertently or accidentally, do not respect the safety distances.

In view of this reality and the dynamics of the work performed by electricians, COPEL (Companhia Paranaense de Energia) chose to develop, within the Research and Development Program of the Brazilian Electric Sector [3, 4], an electronic device based on electric field sensing generated by the energized distribution lines, as an accessory

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to be attached to safety helmets, aiming to warn the electricians about the excessive proximity to the medium voltage energized network.

However, recent researches showed that up to now there was a gap characterized by the absence of a suitable model for R&D projects of the Brazilian Electric Sector with potential inclusion of products on market [9]. In this sense, through a wide approach about PDP methodologies the authors proposed a development model fully aligned to the R&D Program guidelines, whose application will be demonstrated in this text.

1. Design Description

The maintenance performed by electricians in electricity distribution lines presents a high risk of serious injury from electrical shock, particularly in cases where the electrician exceeds the minimum safe work proximity recommended on standards. The fact that there is no Personal Protective Equipment (PPE) on market for this condition justified the choice made by COPEL to perform two R&D projects, within the ANEEL R&D Program, for the development of technology in the form of an accessory to be attached to the safety helmet used by electricians.

In the first project, as shown in Figure 1, characterized as Experimental Development (ED) [5] of ANEEL Innovation Chain [6], the main technical features for electric field detection within the safety distance established standards have been defined [1], as well as verified the feasibility of a small device, with autonomy and reliability that could be adapted as a safety helmet accessory, that usually is standardized by the Power Company. In the second project, subsequent to the first, characterized as Head Series (HS) [7], we tried to develop a design with appropriate ergonomics and in a way that the equipment could be produced on an industrial series.

Following the ANEEL Innovation Chain (Figure 1), it is used the MOR&D (Product Development Model Oriented for the R&D Projects of the Brazilian Electricity Sector [8, 9]) aiming to structure the development stages a project proposal characterized as Lot Pioneer (PL), presented in the sequence, to the "Electric Field Sensor as Security Accessory for Helmets (PPE)" equipment, referred from here as "Helmet Sensor".

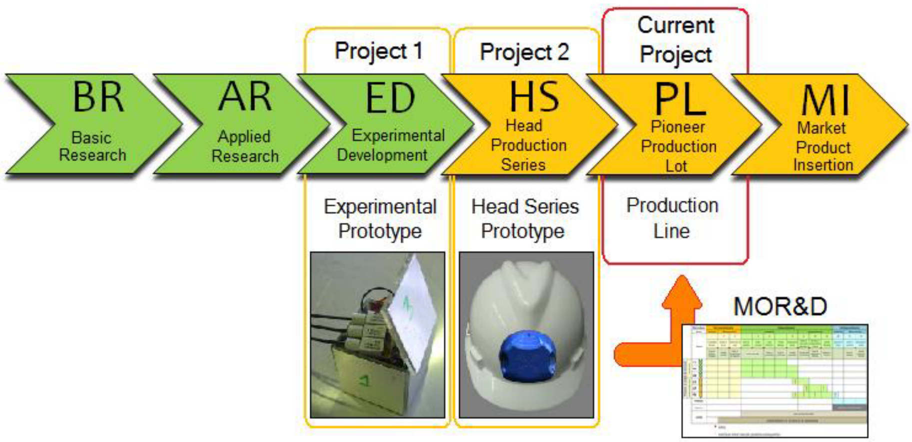

Figure 1. ANEEL Innovation Chain and the historical of the proposal of pioneer lot project.

2. Methodology

The research strategy was a case study with a qualitative approach in which the analysis unit were the R&D projects as defined by the ANEEL R&D Program [6]. As research method, it was initially considered the strategies used to prepare the Helmet Sensor equipment [5, 7], followed by the application of MOR&D [9] in elaboration of new PL project design structuring.

3. Considered Criteria

3.1. Technical Criteria

Because it is a research directing to electricity distribution networks, it was considered the variety of standardized network arrangements in COPEL Distribution, so that it is possible establish the configuration of the electric field in the safety distance for each case. Figure 2 shows some of the standard arrangements.

For this R&D project, the structure used as the study basis is the number 1, Figure 2 (standard N1), due to its higher frequency of use in the company distribution network. It was used to create models for electric field simulation in software applications as COMSOL Multiphysics [10] for the 13.8 kV voltage levels and 34 kV, according to the dimensions illustrated in Figure 3.

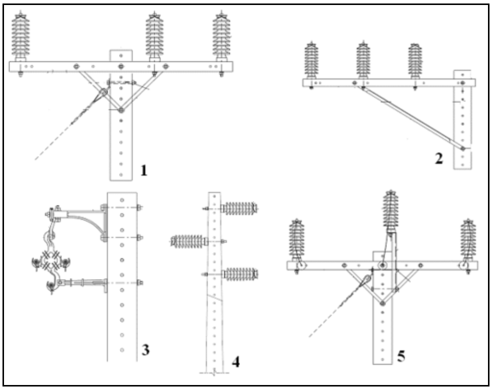

Figure 2. Distribution networks arrangements used as reference [5].

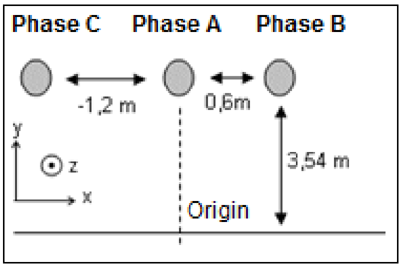

Figure 3. Simulation model [5].

In one example of simulation based on the three-dimensional model as described, it can be observed that the z-direction, indicated in Figure 3, has a lower intensity compared to the other directions (x and y).

Figure 4 illustrates the three-dimensional simulation result using COMSOL software [5]. In this illustration is represented the standard of the electric field in an instant of time, in the three directions, at two different levels: one plane perpendicular to the centre of the span evaluated from the line and the other near the post.

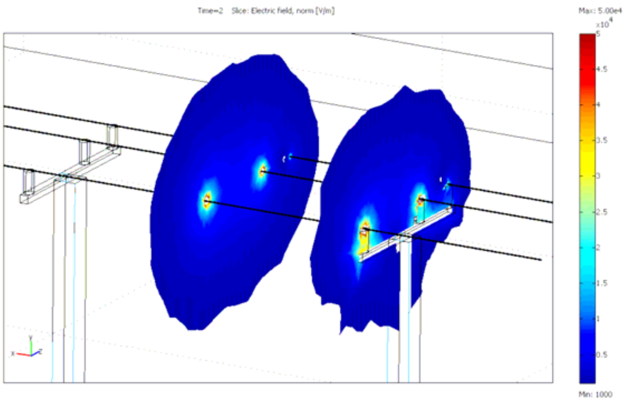

Figure 4. Simulation [5].

The plan near the post shows the influence of the insulators, cross and post in the electric field configuration. However, the simulation suggests that the presence of the post does not alter significantly the safety distances adopted. Thus, for the other analysis in this project it will only be considered the two main components of the electric field (y and z).

Another factor considered in the project is shown in Figure 5, which demonstrates the influence of an electrician located at the safety distance range (60cm from the conductor) and at 0.3m from the central conductor (Figure 3), making clear that the electric field is changes considerably when the electrician is at the local.

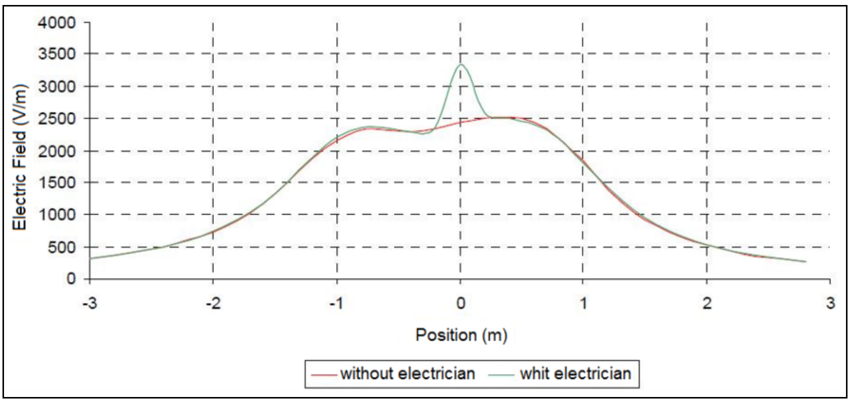

Figure 5. Influence of an eletrician in the safe distance range [5, 7].

Given the limit conditions presented and aiming alert the electrician about the imminent danger, the project proposed the development of an electronic device in industrial format and in minimum scale to allow field testing and market (Pioneer Lot). The technology based involved is the measurement of the electric field near the medium voltage network. The device must have reduced size and weight, have low cost and able to be incorporated into standard safety helmets according to the norms. It must also emit sound and visual signals every single time that the electrician approaches the medium voltage grid. Further, it should work permanently without user intervention, be powered by long-life battery, visually indicate the low load condition of the battery and have the self-test function.

3.2. Regulatory Criteria

The Research and Development Program of the Brazilian Electric Sector, derived from the Law No. 9991 of July 2000 [11], established the compulsory investment in research and development (R&D) by the concessionaires, licensees and authorized from electricity sector. The framework conditions for R&D projects in the program are established by the National Electricity Energy Agency (ANEEL) and are described in the "Manual for Research and Development Program of the Brazilian Electricity Sector" [6]. The activities related to R&D projects, according to the ANEEL's Manual, are those of creative or entrepreneurial nature, with technical and scientific basis, for generating knowledge or innovative application of existing knowledge, including new applications research.

Following the classic line established internationally [12, 13], but with the intention of achieving the productive chains, ANEEL ranked R&D projects in six categories, represented in the "ANEEL Innovation Chain" (see Figure 1). The possibility of implementing projects in order to improve products for industrial production and marketing makes clear the ANEEL R&D Program intention of encouraging technological innovation and as well as the development of practical solutions to the daily energy companies.

The merit of an R&D project is defined by ANEEL through four primary criteria that should be considered during the planning process: *Originality, Applicability, Relevance and Costs Reasonableness* [6], where *Originality* is eliminatory factor considered in the proposal evaluation. This criterion is assessed according the *Challenges* (complexity) and *Technological Advances and Innovation* inherent in the techniques applied to the project development and the products generated by them.

3.3. Development Methodology Criteria

The MOR&D (Product Development Model Oriented for the R&D Projects of the Brazilian Electricity Sector) was used to structure the project development phases. The model was designed based on ANEEL R&D Program guidelines and in line with key concepts and techniques recurrent in the Industrial Product Development Process (IPDP) [9].

Based on Product Engineering concepts, the MOR&D considers the interaction between the various stages of a project and the formation of multidisciplinary teams that will result in well-structured projects, fitted to the criteria set by ANEEL.

The MOR&D consists structurally in three macro-phases: *Pre-development*, *Development* and *Post-development*, represented in Figure 6. The macro-phases are subdivided into six sequential phases: *Initiation*, *Planning*, *Design*, *Implementation*, *Production* and *Maintenance*, which are divided into 14 steps of different activities.

The model suggests IPDP tools distributed according to their applications throughout the stages of the model.

The MOR&D was designed to be dynamic, adapting to the whole range of R&D projects in the electricity sector.

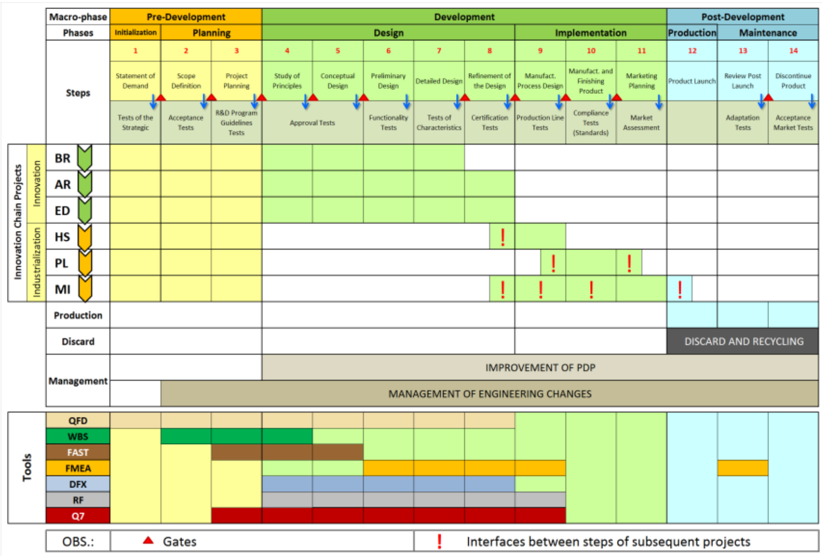

Figure 6. MOR&D [9].

4. Project Formalization

The MOR&D proposes interaction between the phases *Initialization* and *Planning* [9] (Figure 7). This process is characterized by constant revisions of the design proposal so that it is in full accordance with the customers wishes, the power utility strategies and criteria of the ANEEL R&D Program. Thus, in the *Initialization* phase, the starting point was the *Statement of Demand*, characterized by the need for specialized equipment and for whose *Tests of the Strategic*, it was considered the approval of the concessionaire regarding the results of the ED and HS projects carried out previously (Figure 1).

The preparation of the proposal followed with the *Definition of Scope* for PL project. In this step, as a complement to the results obtained previously, customer requirements were reviewed, organized and prioritized allowing the definition of the basic guidelines for the PL *Project Planning*, which contains the demands for the project and the expertise of the team, both summarized in Table 1. Implicit in scope, are also the results obtained in previous ED and HS projects, technology basis and primary industrial preliminary design for the product, respectively [5, 7].

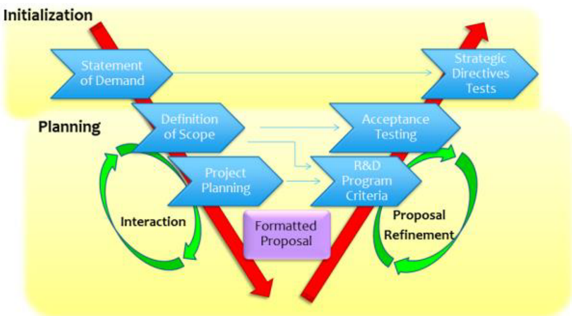

Figure 7. Pre-development Macro-phase [9].

Table 1. Demand prioritization and necessary expertise for PL project.

Order	PL project demands	Expertise (Disciplines)
1	Review the sensor HS project	Physics, Materials, Electrical, Mechanical Designer
2	Development of sensor test device	Electronics, Mechanic, Industrial Designer
3	Production line Desig	Industrial Projects, Mechanic, Electrotechnical
4	Production of Pioneer Lot	Industrial Projects, Electronic, Mechanic
5	Testar lote piloto em condições de campo	Industrial Projects, Electronics, Electrotechnical, Mechanics
6	End of Production line project	Industrial Projects, Marketing experts
7	Product marketing plan outline	Marketing and market study experts
8	Document and product launch	Marketing experts

Further, in the *Planning* phase, it was considered for *Development* the steps 9, 10 and 11, as suggested by MOR&D (Figure 8), which deal with the process of the *Implementation* phase to the manufacturing equipment developed previously, whouse dynamic between these stages are illustrated in Figure 9.

However, given the need for adjustments to the developed prototype in the previous CS project (Figure 1), in the preparation of the activities related to LP project, it was also felt a strong dynamic between the *Design* and *Implementation* phases, as suggested in Figure 9, to that there was a better match of technology to production processes and product refinement, given fullness in the wishes of customers. Therefore, it was added to the step 8 to the development methodology for this new project.

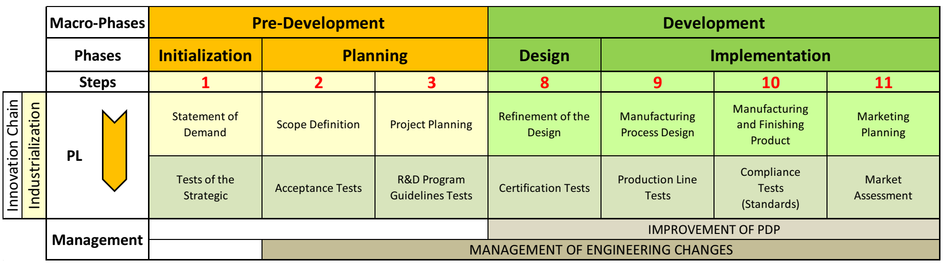

Figure 8. Development steps according to MOR&D [9].

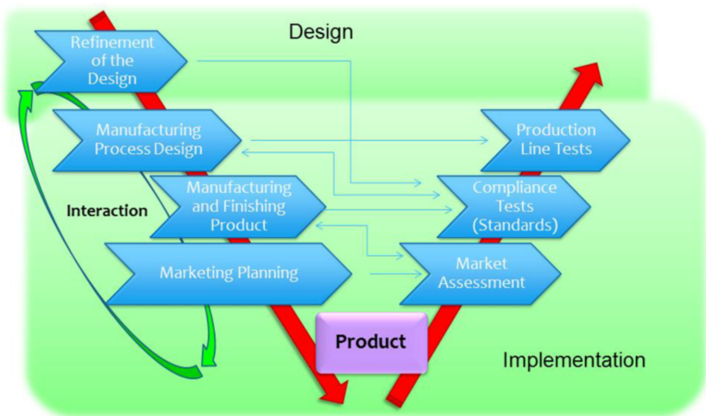

Figure 9. Development macro-phase (Implementation phase) [9].

As part of the phase of planning and taking the flowchart of Figure 10, we sought to formalize the activities of steps. For this, was made use of specific *Template* for LP projects, presented by the authors in the thesis document describing the MOR&D [9].

The colours that identify the stages of the project in the *Template* correspond to the colours assigned to the activities scheduled in Figure 10, allowing a rapid cognitive association of MOR&D to the proposed PL project.

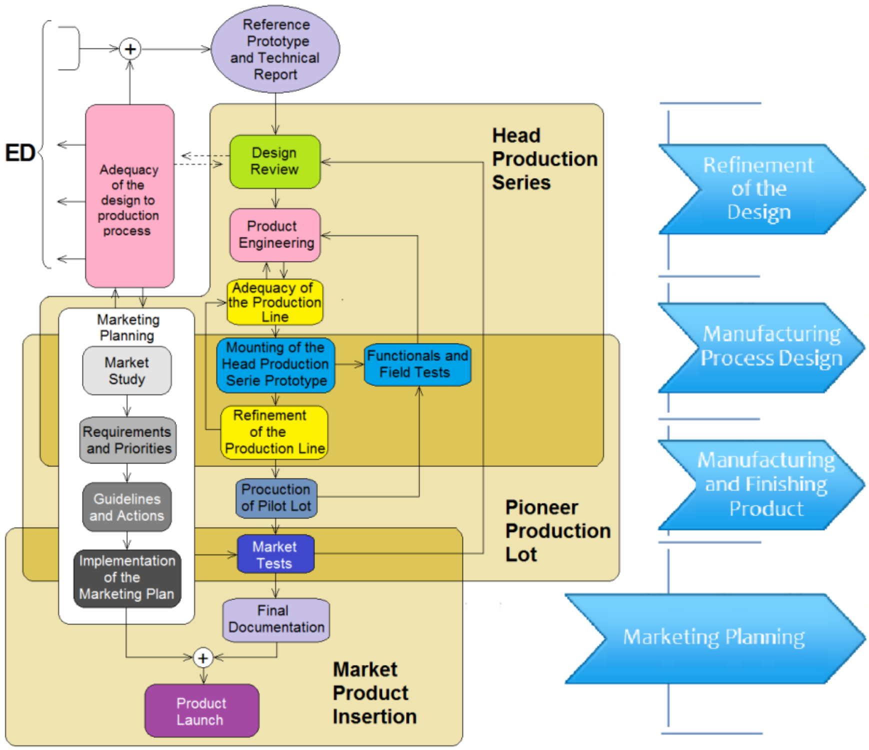

Figure 10. Activities assigned to the Implementation phase [9].

The execution of the steps that address the refinement of the technologies applied to the new product are assigned to the research team that developed the previous projects of ED and HS (Figure 1) supplemented by specialists in product engineering and marketing, which, concurrently, direct the product design to a production line that meets the market.

Finally, the project proposal was formalized in a specific documentation containing the *Description of the Project*, *Expenses Worksheet*, XML format file for registration in ANEEL and contract between research institution, safety material industry and the electricity concessionaire.

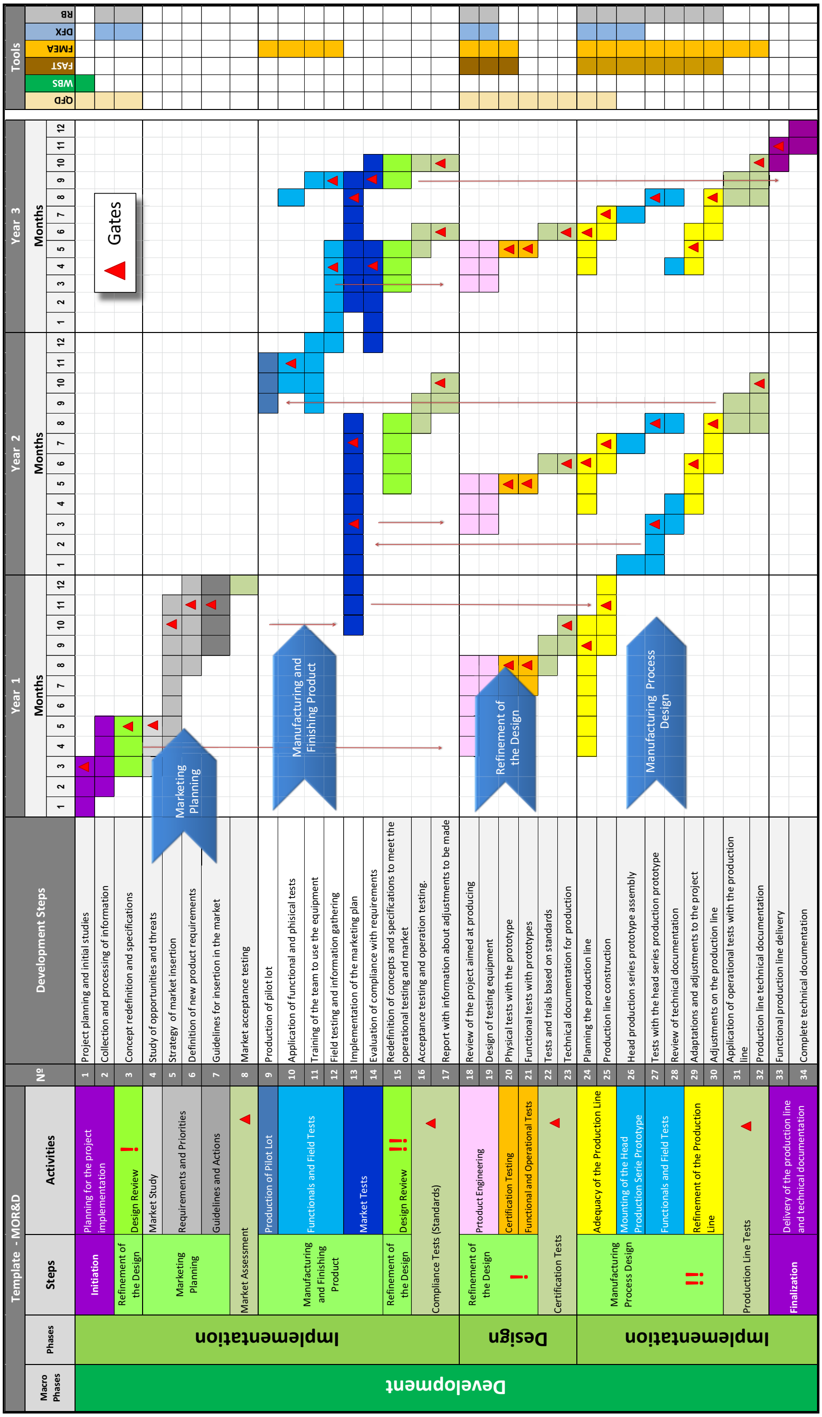

Figure 11. Post-Development macro-phase.

5. Final Considerations

The case study showed that the MOR&D is comprehensive and flexible enough to be adapt to the sequence of the project steps according to the development stage of the product technology. The template assigned to the model, enables and directs the flow of activities for the project execution, facilitating management during the development. In this work was demonstrated that the model application is promising, enabling to optimize the development process, detect potential problems beforehand, improve the allocation of staff and resources and, consequently, reduce re-engineering costs, making it possible to achieve higher quality products with more efficiency.

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