A FRAMEWORK PROPOSAL: HOW TO BUILD A TECHNOLOGY QUALIFICATION PLAN

Saulo Queiroz Figliuolo [1, a], Valter Estevão Beal [a], Luis Alberto Breda Mascarenhas [b]

[a] *Industrial Product Development, SENAI CIMATEC, Brazil*

[b] *SENAI CIMATEC, Brazil*

Abstract: There are methodologies that present the general workflow for new products and technologies development. Through these processes, the technology readiness scales became an essential tool to evaluate the development stage of the referred project. Many papers address these evaluations to guarantee that technology achieves the required TRL, however there is not a consolidated tool to support the process of creating a qualification plan. Within this focus, this job presents a framework proposal to obtain a qualification plan in order to optimize the development process and instigate the product or technology maturity progress. In this context, the FMECA has been applied in the new product functional structure, TRL / IRL assessment of the conceptual solution, as well as the internal company maturity to perform the new product development.

Keywords: Technology qualification plan, maturity assessment, FMECA, technology and integration readiness level.

UMA PROPOSTA DE ESTRUTURA: COMO CONSTRUIR UM PLANO PARA QUALIFICAÇÃO DA TECNOLOGIA

Resumo: Existem metodologias que apresentam o fluxo geral de desenvolvimento de novos produtos e tecnologias. Ao longo desse processo, as escalas de prontidão da tecnologia se transformaram em ferramentas fundamentais para avaliar o estágio de desenvolvimento do referido projeto. Muitos trabalhos abordam tais avaliações para garantir que a tecnologia atingiu determinado TRL, mas ainda não existe uma ferramenta consolidada para auxiliar o processo de construção da rota da qualificação da tecnologia. Com esse foco, o presente artigo apresenta uma proposta de fluxo de trabalho para obtenção da rota de qualificação de forma a otimizar o processo de desenvolvimento e fomentar avanço da maturidade da tecnologia ou produto. Neste contexto, utiliza-se como ponto de partida a FMECA aplicado a estrutura funcional do novo produto, avaliações de TRL/IRL da solução conceitual, bem como, a análise da maturidade interna da instituição para realizar o desenvolvimento do novo produto.

Palavras-chave: Plano de qualificação da tecnologia, avaliação da maturidade, FMECA, nível de prontidão da tecnologia e da integração.

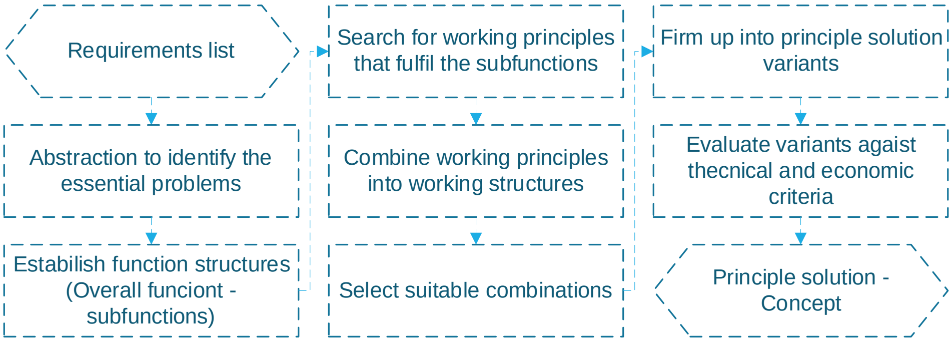
1. INTRODUCTION

Product development (PD) is an entire process used for creating new products or technology from the idea generation until bringing them to the market. All the activities into this process have significant impact in the quality, cost and time. In summary, the companies want to be more competitive by differentiating their output through product and process innovation [1].

There are some consolidated product development models and all of them are divided in phases [2] the most common phases are named as informational, conceptual, preliminary, detailed and manufacturing [3].

The phase where the basic solution is established is in the conceptual design. Activities like to identifying the essential problems, establishing functional structures, searching for working principles and defining the work structure are performed in order to specify the principle solution [4]. A schematic representation of these steps are shown in Figure 1.

Figure 1. Steps of conceptual design



Source: Adapted from [4]

After that, the technology will pass through many stages of maturity until it is ready to operate in the real environment and perform its final mission. These stages were divided and classified in a level called readiness level, starting from 1 as the state of basic research until 9 as a fully functioning operation [5].

In a general way it is possible to say that any kind of innovation of any type of technology introduces uncertainties and complexities [6]. In order to reduce, avoid or mitigate the risks involved into the innovative process a qualification procedure needs to be done. It will provide the evidence that technology can operate with an acceptable level of confidence [7].

Nowadays, several technology qualification methodologies are available from various industries and give quite different approaches in experience, focus and application. Indeed, all of them evaluate the solution to measure its readiness level [8].

Despite those processes, while the project is still at a conceptual level, how to create a roadmap for the technology qualification?

2. METHODOLOGY

Before presenting the new approach proposed, it is necessary to briefly review the Failure Modes Effects and Analysis tool and the Technology Readiness Level / Assessment process. These methodologies were applied to support the process of establishing the technology qualification plan into a new product development process.

2.1. FMEA / FMECA

One interesting point of the new products development is the paradigm of improving reliability while the low cost and short time-to-market are advocated [9]. A robust and widely used tool to perform the identification of hazardous situation through a formalized approach is known as Failure Modes and Effects Analysis (FMEA) and its vary named as Failure Modes, Effects and Criticality Analysis (FMECA) [10].

Although this tool is about 70 years old, the researchers keep studying and improving it. It is possible to see the increase of papers, the problems applied and the usefulness of this method [11].

The idea of FMEA is to identify, evaluate and prevent critical components or functional failures. High risk components are determined by a risk priority number (RPN) obtained by multiplying the index of Severity, Occurrence and Detection of and failure mode previously identified (RPN = S * O * D) [12].

There are many types or variations of FMEA and FMECA like [13]:

a) Concept FMEA (CFMEA), to analyze concept in the early stages, as a system and subsystem levels;

b) Design FMEA (DFMEA), to identify and prevent failure mods of products;

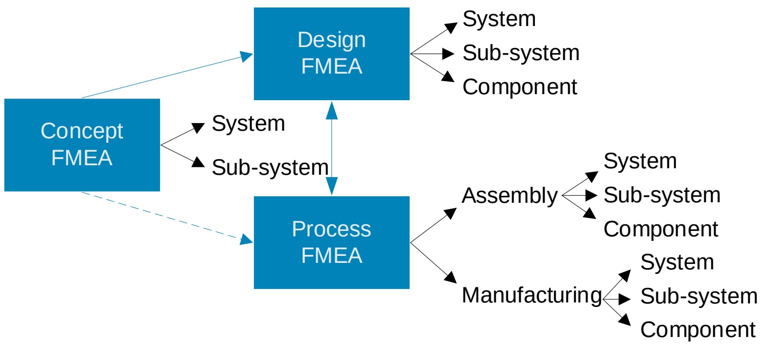
c) Process FMEA (PFMEA), with focus on the processes of manufacturing and assembly.

Figure 2 is a graphical representation of the relation through the tree types presented in this paper. As this job has focused on the conceptual phase of development, the concept FMEA or CFMEA better fits with this issue.

2.2. Readiness Level

The initial concept of Technology Readiness Level was created by National Aeronautics and Space Administration (NASA) however, nowadays it is widely used for many agencies around the world and research/development companies. Through the years, other alternative scales were created to better measure and evaluate the maturity of the development, such as integration (IRL), manufacturing (MRL), system (SRL), and so one. However, one very important part added in the product development was the Technology Readiness Assessment to ensure that specific maturity level was achieved [14].

Figure 2. Types of FMEA



Source: Adapted from [13]

As said before, a TRL scale is divided into 9 steps. At a first look, it seems to be clear although people worldwide may understand in a different way by the misaligned definitions [15]. Because of this, TRL has been widely studied by many authors and companies trying to establish an effective model to measure the TRL, in consequence, assessment methodologies were proposed by agencies and companies [15-18].

The technology readiness assessment used to be a very specific and detailed process and each agency inserted their own focus and expertise. There are many questions to be answered in a technology readiness assessment (TRA). Answering those questions, starting from the upper level until the lower one, should help the assessment team to define the correct TRL of the project [15].

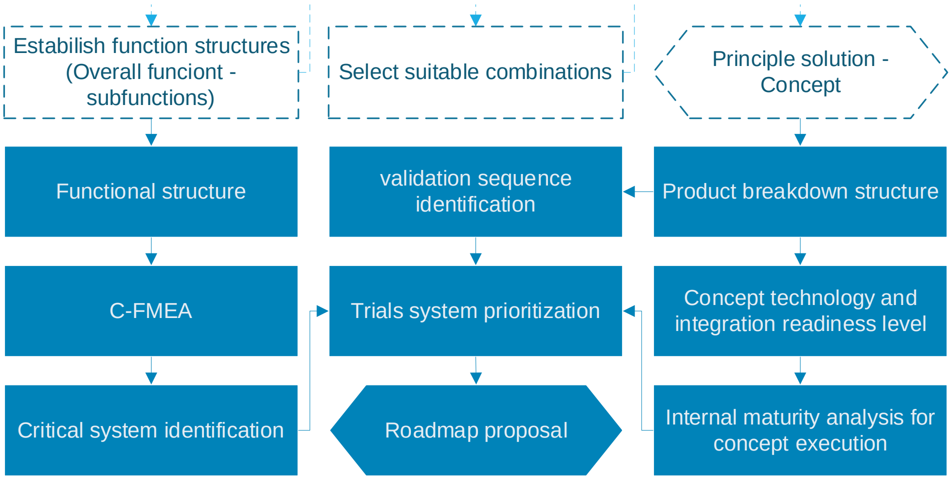
In a complementary way, although the TRL scales already identify the integration of the technologies, authors had identified that it did not adequately address the integration aspects of complex system development [19].

The Integration Readiness Level (IRL) is a very effective in system assessment giving the right multidimensional framework and facilitating the integration of System of Systems (SoS) [20]. As the TRL the IRL scale is also defined in nine grades starting from the characterization of the relationship till the completely proven mission [20].

2.3. The new approach

The proposed framework is made by multiple steps, once the system still at a conceptual level, this process starts deriving from specific activities shown in Figure 1 and some steps need to be performed to fulfill the roadmap of the referred product. Although activities names presented in Figure 3 are self-explanatory, follow the main idea of each and the suggested sequence of execution.

Figure 3. Roadmap definition framework



Source: Author

a) Functional structure: After to define the functional synthesis, a breakdown structure of the functions present in the solution shall be defined regarding the hierarchy decomposition;

b) C-FMEA: The main is to perform the conceptual FMEA in the functional system, although there isn't any solution assigned to the functions;

c) Critical system identification: Ordering the subsystems by descending RPN to identify the most critical one;

d) Product breakdown structure (PBS): After to choose the principle solution (concept), it is necessary to create the structure that define the hierarchy of components, parts, subassemblies and assemblies;

e) Validation sequence identification: The PBS present a possible assembling process passing by each assembly needed to achieve the whole system;

f) Concept technology and integration readiness level: Once the concept is defined, the project team need to evaluate each solution in order to identify the TRL and IRL of that set;

g) Internal maturity analysis for concept execution: This step is an evaluation of the project team and their technical capability to execute the solution development;

h) Trials system prioritization: It is a crossing evaluation of the subsystem RPN, the TRL / IRL of subassemblies and the execution maturity, where the Trial Priority Number (TPN) is calculated;

i) Roadmap proposal: Taking advantage of the TPN and of the validation sequence previously identified the roadmap with the tests, trials and experiments is created.

As the core of this process, the trial system prioritization, deviates from FMEA standard template and incorporates the TRL, IRL and the Internal Maturity Assessment

(IMA). The IMA was defined based on the NASA TRA [15] and adapted to help the project team to assess their capability to execute the concept development.

3. RESULTS AND DISCUSSION

At section, there are tow specifics points to present: the auxiliary assess template and the TPN scale.

The auxiliary assess template was based on the standards FMEA, however few more columns were added to enable some aspects like:

a) Set / subset: This column indicates the existing sets from the PBS and that set is part of a specific system;

b) TRL assess: It is to indicate the solution TRL level, from 1 to 9;

c) IRL assess: It is to indicate the solution IRL level, from 1 to 9;

d) TRL / IRL comment: To right down specificities from the assessment;

e) IMA asses: It is to indicate the team maturity level, based on Nasa TRA [15] with some adaptations;

f) IMA comment: To right down specificities from the assessment;

g) TPN: This column present the trial priority number using the RPN, TRL, IRL and IMA, the Equation 1 shows how to calculate the TPN.

$$\frac{RPN}{10} \times \frac{1}{TRL} \times \frac{1}{IRL} \times \frac{1}{IMA} = TPN \quad (1)$$

Once calculated the TPN is possible to see that its scale is from zero to 10, and a five levels division is proposed and presented in Figure 4.

Figure 4. TPN scale

RNP	TRL	IRL	IMA	TPN	Priority
30	9	9	9	0,0041	Insignificant
30	9	9	7	0,0053	Low
40	9	7	6	0,0106	Low
40	7	6	4	0,0238	Medium
50	6	6	4	0,0347	Medium
60	6	4	3	0,0833	High
70	6	3	2	0,1944	High
80	4	1	1	2,0000	Critical
80	3	1	1	2,6667	Critical

Source: Author

4. CONCLUSION

Using this approach, the identification of the critical systems and sets of the prototype became a more intuitive task were the issues since the beginning of the development process. The cadence of the tests, trials and experiments obtained by the PBS gave a helpful support to create the qualification plan.

As a further possible work, it is to connect this framework with an TRA process which better fits with the development and develop the full qualification plan regarding the specific agency requirements.

Acknowledgments

The authors gratefully acknowledge the SENAI CIMATEC and the SIINTEC staff.

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