Breakthrough ideation and lean product development in the ceramic industry

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“Se esse é o seu tempo, quando havia ela de vir senão no seu tempo?”

Alberto Caeiro

Abstract

The companies' focus on innovation is growing due to the globalised world and the increasing market competition. The ceramic industry is considered a low-technology market, and there is scant information in the literature about the development of new products.

Breakthrough ideation and Lean Product Development in the ceramic industry presents tailored solutions - models and tools - for a ceramic process industry's new product development. It proposes *Voice of Customer* and *Breakthrough ideation* to create ideas for potential new products. Regarding the management of new product development projects, it proposes project tailoring, project portfolio and capacity management, a stage-gate model, project initiation, planning optimisation, Obeya control boards and meeting agenda. All concepts and materials which served as the basis to design the solutions are explained and referred to in the literature review. Methods for enhancing Kaizen culture to facilitate the implementation of the new product development tools are also explained, and the specific adaptation for the ceramic company analysed is approached.

Ideação Disruptiva e *Lean Product Development* na indústria cerâmica

Resumo

O foco das empresas na inovação está a crescer como resultado do mundo globalizado e da crescente competitividade do mercado. A indústria cerâmica é considerada um mercado de baixa tecnologia e a informação na literatura sobre o desenvolvimento de novos produtos é escassa.

Ideação Disruptiva e Lean Product Development na indústria cerâmica apresenta soluções à medida - modelos e ferramentas - para o desenvolvimento de novos produtos na indústria de processos cerâmicos. Propõe *Voice of Customer* e Ideação Disruptiva para a criação de ideias para potenciais novos produtos. Relativamente à gestão de projetos de desenvolvimento de novos produtos, propõe o tailoring de projectos, gestão de portfólio de projectos e de capacidade, um modelo de *Stage-Gate*, iniciação de projectos, optimização de planeamento, quadros de controlo *Obeya* e agenda de reuniões. Todos os conceitos e materiais que serviram de base são explicados e referidos na revisão bibliográfica. Para facilitar a implementação das novas ferramentas de desenvolvimento de produtos, são também explicados métodos para melhorar a cultura Kaizen na organização e é abordada a adaptação específica para o caso.

Acknowledgements

Firstly, I would like to thank Kaizen Institute Portugal for the opportunity to develop this project and to learn in formal and informal environments each day. Within the organization, I must thank all my colleagues for the teamwork and learning opportunities, especially Afonso Monteiro - for clarifying any doubt regarding project management and Kaizen approaches for project-based, and Hugo Carneiro and André Pinho Oliveira for all the support and shared knowledge.

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Obrigada

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Abbreviations and acronyms

FFE – Fuzzy Front End

GPL – Global Priority List

KPI – Key Performance Indicator

LPD – Lean Product Development

LPM – Lean Project Management

PDCA – Plan, Do, Check and Act

PM – Product Manager

QC – Quality Control

R&D – Research and Development

RSEM - Root-Square Error Method

SME – Small to medium enterprises

SMED – Single Minute Exchange of Die

TT – Technological trends

TTM – Time to Market

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1 Introduction

The dissertation project presented in this document results from the intention to improve the performance of the research and development team of a ceramics industry group hereafter called CeramicProvider. The project was developed at Kaizen Institute Portugal, a consulting firm that helps companies adopt Kaizen and Lean philosophies by tailoring and implementing tools in the company's context.

This chapter follows the presentation of both companies, their values, purposes, and areas of activity. Then, a framework of the project is made, its detailed description, problem identification and objectives. Finally, the methodology and document structure are presented.

1.1 Kaizen Institute

Kaizen Institute is a consulting group with various locations worldwide, offering consulting, qualification, training and education services and benchmark tours (World Economic Forum 2022). Kaizen Institute has its headquarters and oldest location in Zug, Switzerland, founded in 1985 by Masaaki Imai. In 1999 Kaizen Institute Portugal was founded in Porto. Kaizen Institute Portugal is composed of offices in Porto, Lisboa and Coimbra (Kaizen Institute 2022).

Kaizen is a Japanese word composed of *Kai* (Change) and *Zen* (Better) used in Japanese culture to designate continuous improvement (Kaizen Institute 2022). When applied in business, Kaizen refers to continuous improvement involving everyone, every day, everywhere (Imai 1930). Kaizen philosophy is based on five principles represented in Figure 1:

1. Value creation for the customer;
2. Create flow efficiency;
3. Gemba effectiveness;
4. People engagement;
5. Be scientific and transparent (Kaizen Institute 2022).

Figure 1: Kaizen principles (Kaizen Institute 2022).

Using these five principles, Kaizen intends to achieve GQCDM goals. The letters stand for enhancing Growth, Quality, reducing Costs, improving Delivery and increasing Motivation and people development (Kaizen Institute Portugal 2022).

The Kaizen Knowledge Model in Figure 2 comprises Strat Kaizen, Value Stream Kaizen and Daily Kaizen. At its core the change model contains different tools and approaches to achieve GQCDM goals and assure long-term company value. Strat Kaizen focuses on developing the strategy for the company. From there, Value stream initiatives are drawn and developed to change the paradigms of the company in different areas. Daily Kaizen focuses on daily management, standardization, training and coaching and advanced problem solving with top, middle management and functional teams. Daily Kaizen enhances the Kaizen culture and supports Value stream and Strat Kaizen (Kaizen Institute Portugal 2022).

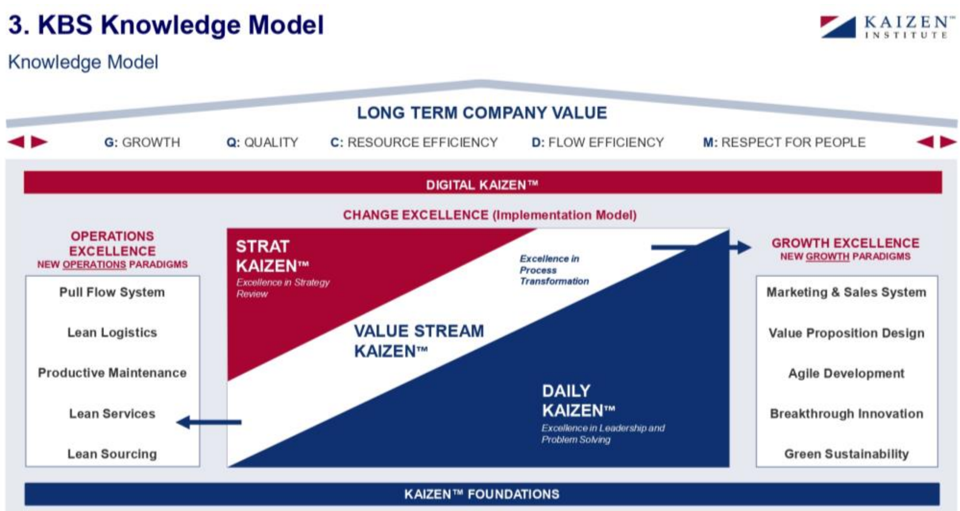

Figure 2: *Kaizen Business System Knowledge Model* (Kaizen Institute Portugal 2022)

1.2 CeramicProvider

CeramicProvider operates several mines and factories in Portugal. Products range from sand and materials with little processing from the mine extraction through commercialization of ceramic bodies or ceramic mixes, extruded pastes, and atomized powder. Most of the customers are ceramic businesses that use CeramicProvider products to create crockery, porcelain ware, pavement, or less common applications before selling them to the final customer.

1.3 Scope and objectives of the project

CeramicProvider group performs research and new product development in *Excellence Centres* (CE) located in three different factories (CE01, CE02 and CE03). The R&D team develops new products adapted to the future technologies and challenges of the ceramic industry.

The project with Kaizen Institute intends to reduce time to market, increase the number of new products released and increase the sales income of new products. The scope is the innovation and ideation phase, the process of new product development and upgrading existing products with the teams from all CEs.

Deliverables from the project involve implementing tools and routines to help ideate, manage and develop R&D projects within the CeramicProvider group. The solutions presented in Chapter 4, set during the dissertation project, are addressed to CE01, chosen as the pilot. The solutions given were designed in order to achieve the goals of the broader Kaizen project for the pilot CE.

1.4 Project methodology

The initial month was dedicated to knowing the project context, the company fields of work and the everyday activities of the functional team of R&D in all CEs. A description of the current situation was created with CeramicProvider's functional and management team. The process mapping and opportunities identified served as a basis for the solutions proposed and implemented. The literature review started along with the current state description and extended until the proposed solutions were developed. The implementation of the solutions started afterwards. Summary of the conclusion withdrawn along the project and future works were defined. Finally, the abstract was made. In the final stage, the dissertation was reviewed, and feedback was implemented. The Gantt chart of the project is presented in APPENDIX A.

1.5 Dissertation structure

The dissertation starts with this introductory chapter. Then, the literature review approaches the different innovation types, new product development, ideation, and lean project management concepts and their relation. Chapter 1 presents the current state description: the organizational structure, the process mapping, capacity and portfolio management, the metrics of relevant indicators for new product development (such as Time to Market (TTM), new products revenue and the number of new products released), team communication and meetings and daily laboratory work. Also in Chapter 1, the opportunities for improvement were identified. The proposed solutions for the opportunities identified follow in Chapter 4. Customized tools specifically designed to answer CeramicProvider's needs based on the literature are presented. Conclusions withdrawn during the project course and results obtained are summarized in Chapter 5.

2 Literature review

Innovation is considered a key factor in driving organizations to wealth creation and ensuring their competitiveness in the market (Dunlap, Kotabe and Mudambi 2010; Alegre, et al. 2008). A new product is an innovation, an implementation of a new idea. Ideation is the first phase of developing a new product, with techniques enhancing the diversity and quality of its outcomes. Then follows the creation of a concept, the technical product development, and finally testing and launching (von Zedtwitz, Friesike and Gassmann 2014).

When confronted with managing New Product Development (NPD), the question of whether it should be considered a process or a series of projects arises. On the one hand, a process is a “recurring activity that transforms inputs into outputs”, and in NPD, there is transformation and repeated steps from one new product to another. On the other hand, each new development cannot be precisely the same process as the previous product, so the output can be innovative and unique, falling into the definition of a project “non-recurring activity that transforms inputs into outputs” (Mascitelli 2011, 55-56). The author states that using project management techniques for NPD would be effective but exceedingly time-consuming. In addition, that standard work is needed to capture and leverage knowledge so experiences and learnings from the past can be used and reduce wasted time, potential errors, and missteps. Therefore, to manage NPD, both the characteristics of a process and a series of projects should be considered. The ratio between process and project must be adapted to each type of new development: if for a new shoe development, each new design follows the same steps and it can be considered primarily a process, for a new customized heavy machine, its attributes will follow most of a project (Mascitelli 2011).

Although there is no consensus on the *Lean Product Development* (LPD) definition (Leon and Farris 2011), LPD is being adopted by many companies since it is said to be a critical element to keep being competitive in a globalised world (Dunlap, Kotabe and Mudambi 2010). *Lean Product Development* is a term first coined by Womack, Jones and Roos 2007 in the book “The Machine that Changed the World” to refer to lean thinking applied to new product development.

Lean thinking has five principles: specify the value and identify the value stream for each product, create flow, pull system from the producer and pursue perfection. By understanding and applying these principles, full use of lean techniques and a stable process can be achieved (Womack, Jones and Roos 2007). Lean concepts and principles have been primarily used in manufacturing with the Toyota production system and after applied to other areas of enterprises: lean office, lean accounting and lean supply chain. Applying lean thinking to New Product Development is applying the referred principles to the information flow (Mascitelli 2011).

Similarly to lean manufacturing, lean product development intends to eliminate waste, enhance value-creation and enable organisational learning. Although some points are making lean principles more challenging to apply to Product development, namely the fact that it is not a recurring process, and each development project is slightly different, with associated risk, uncertainty, novelty and discovery, some techniques can be applied to achieve a leaner process in developing new products (Mascitelli 2011).

Mascitelli 2011, the author who evidences the question of whether the NPD is a process or a series of projects, suggests project management techniques supported by templates as a way of compromising the standardisation of processes and the uniqueness of projects, complemented with specific techniques for NPD, such as *Production Preparation Process* (3P). Also Pons 2008 says that NPD can be managed using *Lean Project Management* (LPM) techniques and other specific methods for NPD, since LPM is not enough by itself.

Kaizen Institute Portugal 2022 proposes the knowledge model presented in Figure 3, where five approaches support the process of developing a new product and reaching breakthrough GQCDM: Lean Project Management, Set-Based Engineering, Lean Product Design, Production Preparation Process and Agile Software Development. It summarizes techniques and approaches found in the literature in a structured way. No relation, hierarchy or structure was found in the literature that considered relating two or more techniques. To allow an easier understanding of the present document, the division presented is the one followed here.

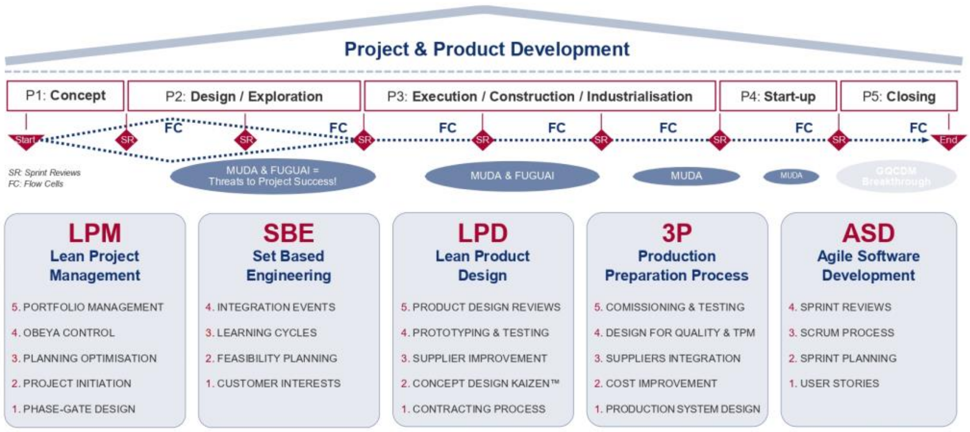

Figure 3: Knowledge model for new product development.

LPM tools are generally helpful in managing NPD projects because of their greater applicability and impact on NPD (Pons 2008). The tools summarized by Kaizen Institute Portugal 2022 for LPM and novel variations of the LPM techniques will be further explained.

2.1 Innovation types

Clausen and Pohjola 2013 define breakthrough product innovation as the process of producing new products in the market and incremental innovation as producing products new to the company but not new in the market. Breakthrough innovation usually starts a cycle where incremental innovation takes place. First, a new product family is created and then upgrades to the initial product are made. Incremental innovation usually occurs in production efficiency, product quality, or both. The disparities between the two types of innovation can be managed, and their coexistence allows the business to survive in changing conditions.

Kaizen Institute Portugal 2022 divides innovation into three types, as posed in Figure 4:

- *Breakthrough*: usually implying the creation of a new family of products, is the most disruptive type of innovation

- *Next Generation*: results in improved existing products
- *Incremental/Cost reduction*: generally intended to reduce the cost of a product.

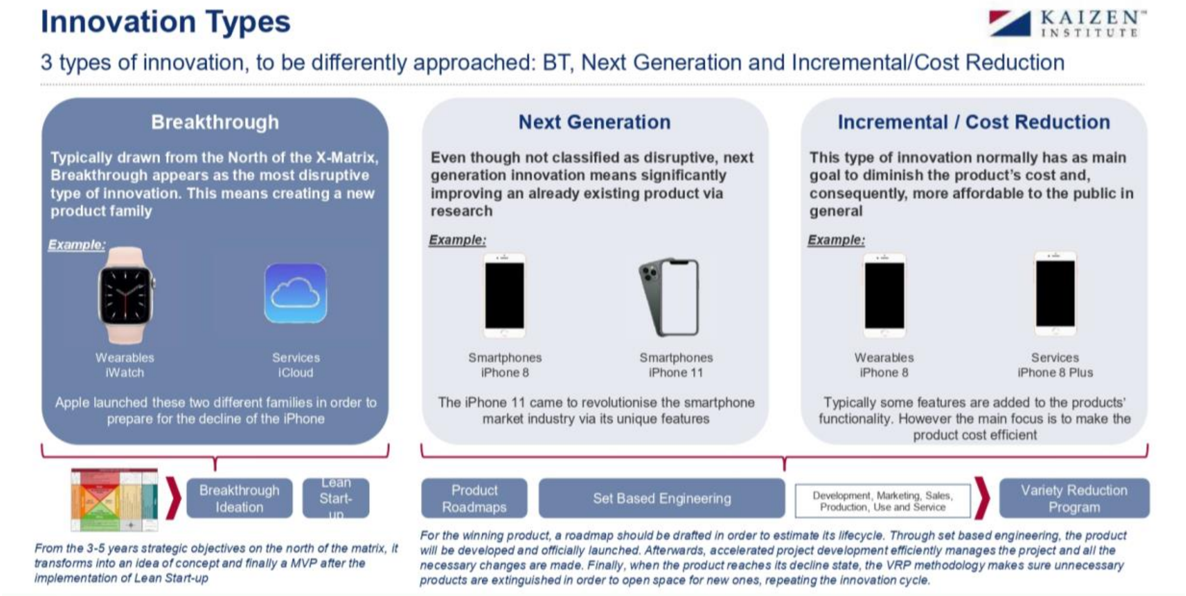

Figure 4: Innovation types (Kaizen Institute Portugal 2022).

2.2 Product Development Funnel

Since the 1970s Product Development Funnel concept has been used to represent the process of new product development, expressing the more numerous projects in the inlet and fewer projects in subsequent phases of development, abandoned projects and rejected ideas make the shape of a funnel as represented in Figure 5.

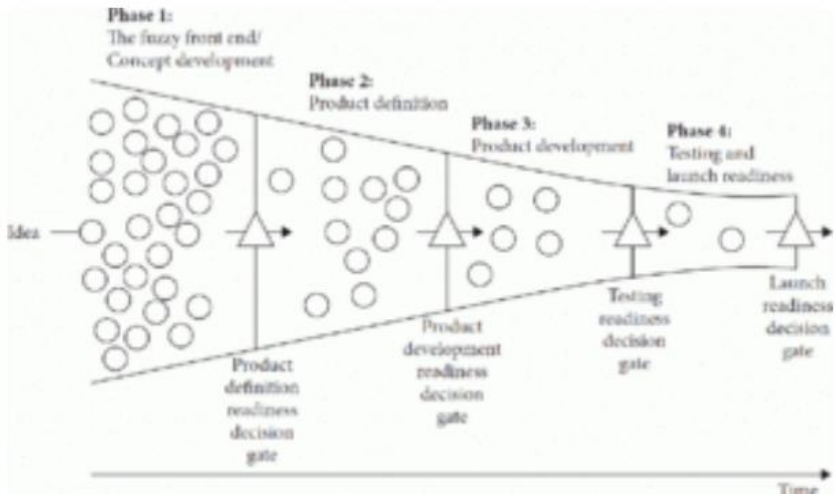

Figure 5: Product Development Funnel (von Zedtwitz, Friesike and Gassmann 2014).

The Product Development Funnel can be divided into four different phases: (1) Fuzzy front end (FFE)/concept development, (2) Product definition phase, (3) Product development phase and (4) Testing and launch readiness phase. At the end of each phase, there is a review of which products proceed within the funnel or which ones are abandoned.

Phase one is the start of a new product, the ideation phase. An idea, a new solution for an existing problem or an improvement for an existing product is born. Ideas for new products can originate from different sources and techniques, which will be further detailed in Section

2.3.1. The term “Fuzzy front end” is mainly applied to this phase when it is about more radical innovation, where there is no apparent logic and difficult repeatability. According to the literature, four tasks generally compose the fuzzy front end: Opportunity identification, opportunity analysis, idea genesis and idea selection.

Product Definition is phase two. It combines a technical and market analysis to define fundamental aspects of product architecture and key functional and technical features to integrate market specifications.

Phase three represents the core of NPD, requiring physical and human resources for the physical creation and implementation of the product.

Finally, the process is completed by testing and launching the product on the market. In this phase, product pricing, distribution channels and market-entry date should be defined (von Zedtwitz, Friesike and Gassmann 2014).

The Product Development Funnel represents the traditional NPD approach and serves as a guideline for the present document to approach all phases of NPD. It should be noted that, although most processes leading to NPD follow the Product Development Funnel, some novelty ideas for idea creation, adding to the agile process, might not follow the traditional funnel phases (Lee and Ostwald 2022).

2.3 Ideation

To create new innovative and winner products, ideation is the genesis of all process. Studies from psychology, design and management converge in the study of ideation techniques, creativity enhancers and their effectiveness (Lee and Ostwald 2022).

While most authors agree that ideation is the process of generating new ideas, some authors define ideation as a broader concept that encompasses both the process of having new ideas and idea selection. In ISO:56000 2020 ideation is defined as "the process of generating, sharing, and evolving ideas and concepts".

The literature demonstrates several methods, frameworks, and tools for approaching the problem of ensuring the dynamics and creativity inherent in ideation while providing structure for evaluation and improvement (Riel, Neumann and Tichkiewitch 2013).

Riel, Neumann and Tichkiewitch 2013 consider the ideation process as the broader definition presented. It proposes a stage model after identifying six key success factors for ideation based on literature review and expert interviews:

1. Top management involvement: The call for ideation activities as well as the commitment and transparency of the top management regarding ideation activities should be clear to all employees;
2. Defined focus: The company's strategic goals must be established. From there, the areas on which innovation should concentrate must be made evident so stakeholders and employees may be directed in that direction;
3. Networks involvement: Organisational culture must guarantee that every employee actively contributes to ideation activities. Integrating internal and external stakeholders improve the innovation potential by involving different perspectives from the first stages of NPD;
4. Creativity: Creativity enhances the output of ideation regarding the quality and quantity of ideas. The corporate processes need to be modified to include time, space, and tools for ideation activities;

5. Entrepreneurship: Ideas should be elaborated and presented to a responsible team. The previously referred key points serve as the basis to create the environment to do so. To complement the pitch of ideas, entrepreneurship skills can be developed: enthusiasm, leadership, goal orientation, personal accountability and interpersonal skills. Most companies analysed by paper 21 created ideas competition contributing to increasing ideas' quantity, quality and level of maturity;
6. Organisational orientation: A transparent process target-oriented should be clear about what steps need to be done from communicating a new idea, the selection process, and the conversion of ideas, as well as getting feedback and guidance for the next steps.

The proposed stage-gate model is presented in Figure 6. It was developed to facilitate the management of the fuzzy front end in the landscape of most corporate organizations. In order to preserve its broad application, the authors purposefully do not present specific ideation support activities to such tools. The general stage-gate model is composed of three stages and four gates. The three stages ensure the consideration of the key success factors explained earlier.

- *Prerequisite* define all the activities for top management to guarantee the right frame and support to the ideation properties;
- *Generation* is the phase for ideation execution. At this stage, the focus is to facilitate idea generation. At this point, creativity and ideation tools might be used. Some tools are presented in Section 2.3.1;
- *Selection* is composed of idea analysis and selection. The selected ideas are passed on to the NPD team. The rejected or postponed ideas are treated so they can be capitalised in another manner or later.

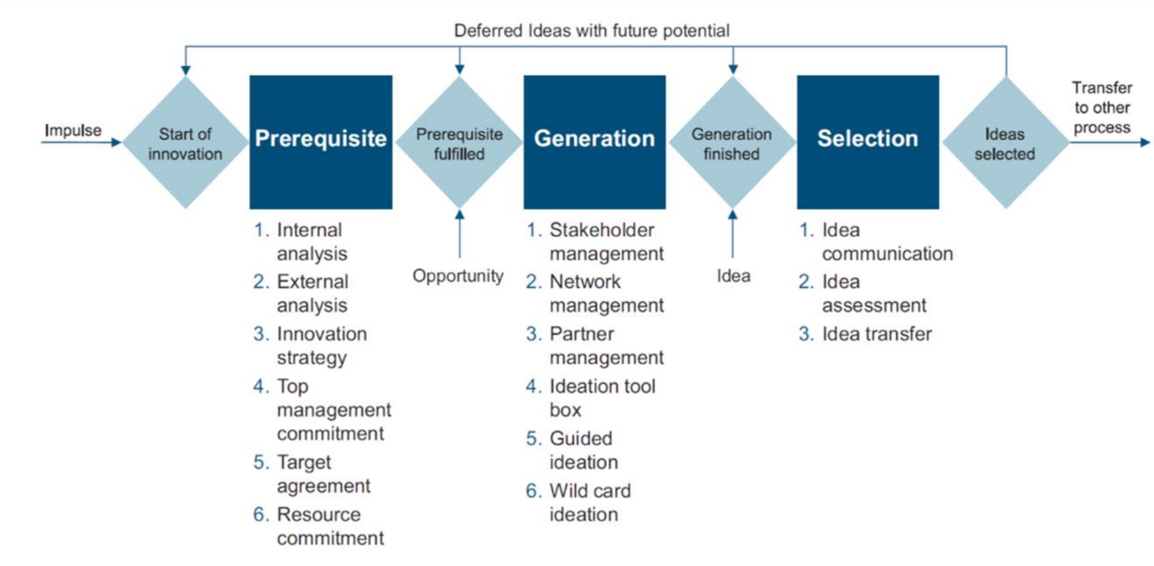

Figure 6: Ideation process stage-gate model (Riel, Neumann and Tichkiewitch 2013).

2.3.1 Ideation and creativity techniques

Specific tools can enhance creativity and generate new ideas (Riel, Neumann and Tichkiewitch 2013). Tauqeer and Bang 2020 identify and cluster the most used techniques in three waves according to their problem identification capability and generated solution novelty, as represented in Figure 7.

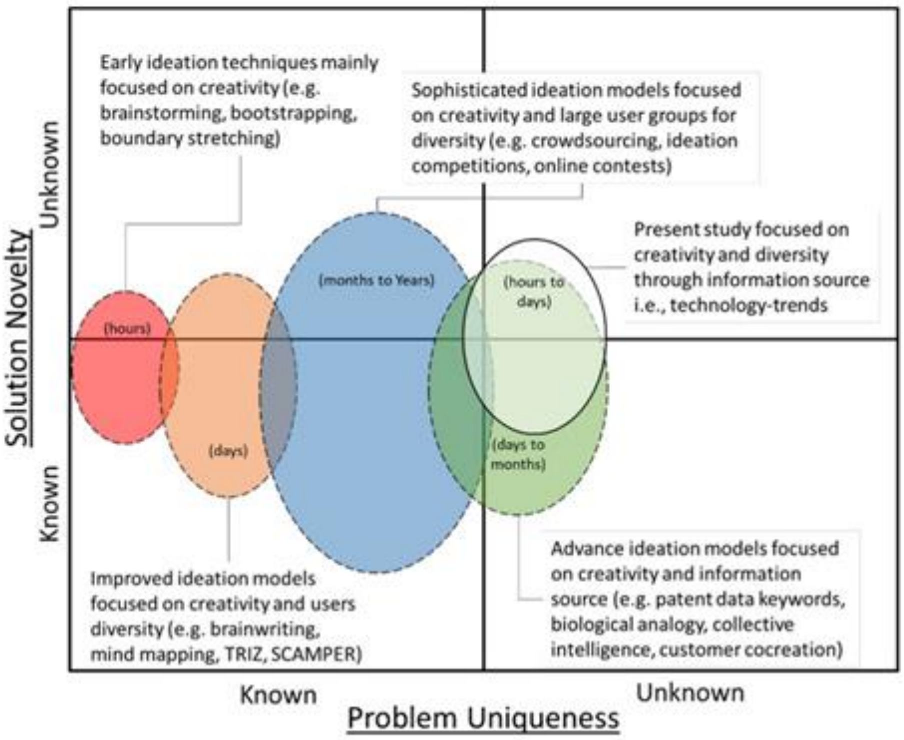

Figure 7: Ideation techniques clusters (Tauqeer and Bang 2020).

The techniques referred to are summarized below according to which wave they belong, accompanied by the main characteristics of that cluster.

Wave 1 | used to generate known ideas with limited novelty or primarily traditional for acknowledged problems. It is quick to apply and has instant results. They can be applied by a subject or a group of people.

- Brainstorming
- Bootstrapping
- Boundary Extension

Wave 2 | used for acknowledged problems, useful to systemize creativity when involving a group of people. Its systematic approach enhances the novelty aspects of the solution. It takes one to a few days.

- Brainwriting
- Mind mapping
- Force-fit game

Wave 3 | entails a large number of people and data, resulting in a high number of ideas. They allow the identification of unknown problems. It requires months and years due to the effort to identify good options from a big pool of submitted ideas.

- Crowd Sourcing (Tauqeer and Bang 2020)

Other techniques can be found in the literature and placed within the waves identified. The novel techniques encountered in the literature are summarized and placed in the previously presented groups. It should be noted that the clusterization of these new techniques was made by the author of the present document based on the novelty of problem solution and identification and time to get results from the information provided by the techniques' creators in the literature where each technique is presented.

- Morphological analysis with technological trends | Wave 2 - Tauqeer and Bang 2020 present a technique combining morphological analysis applied to product breakdown and technology trends. It consists in populating a matrix with the product breakdown in the first column and technology trends (TT) more suitable chosen from a TT list in the first row. Then, the users are challenged to think about how to apply each TT to each part of the product.
- SCAMPER | Wave 2 – SCAMPER is an acronym where the letters stand for Substitute, Combine, Adapt, Modify/Magnify, Put to Another Use, Eliminate, Rearrange/Reverse (Fiadotau and Sillaots 2020).
- TRIZ | wave 2 – a methodology based on logic and data. It usually begins with the abstraction of a given problem to identify and apply solutions found to similar problems (Da Silva, Kaminski and Armellini 2020) .

Design thinking and Voice of the Customer (VOC) are buzzer words when thinking about creativity, ideation and innovation (Micheli, et al. 2018). While some authors classify them as specific techniques, others consider them as approaches (Da Silva, Kaminski and Armellini 2020).

- Design thinking is focused on the end user. It is achieved by in-depth comprehension and direct observation to identify end-user demands, which are occasionally not communicated clearly through secondary research or interviews. These insights serve as a basis for developing new solutions to the identified problems (Da Silva, Kaminski and Armellini 2020). One or more ideation techniques can be used within the design thinking approach.
- VOC is a process to get customers' insights. It is a market research technique to get information about customer wants and needs, collecting qualitative and quantitative data, "organized into a hierarchical structure, and then prioritized in terms of relative importance and satisfaction with current alternatives" (Aguwa, Olya and Monplaisir 2017, 136)

While design thinking is more related to observational methods, Voice of Customer (VOC) focus on getting customers' feedback.

2.3.2 Breakthrough ideation

Breakthrough ideation is the genesis of disruptive innovations, leading to a more complex and fuzzy process. The thinking processes associated are more erratic, and links are made between pieces of knowledge not connected before (Gillier, Kazakci and Piat 2014).

2.4 LPM

Lean thinking intends to reduce waste and improve efficiency. Lean project management applies lean thinking to project management by applying specific tools. There are various techniques in the literature.

2.4.1 Project portfolio and capacity management

Limited resources require the selection and prioritization of projects. Project portfolio management has four main goals: (1) maximize its value for the given resource demands, (2) balance (mix of projects), (3) being aligned with the organization's strategy and (4) right number of open projects for the resources available (Cooper, Edgett and Kleinschmidt 2000).

To achieve the goals previously presented, the list of active projects must be revised and updated regularly. Open projects are evaluated and consequently accelerated, killed or reprioritized. The projects in the pipeline are evaluated, selected and prioritized. The allocation of resources should be adapted to the list of active projects (Mascitelli 2011).

Mascitelli 2011 suggests creating a Global Priority List (GPL), where the prioritization of all projects is visible across functional areas. GPL facilitates resource allocation and helps resolve resource conflicts. The first question to address is what ideas generated in the ideation phase should be included in the GPL. Not all ideas are winning ideas, and it is necessary to filter them at an early stage. Since ideas can come from different sources, there is a need to harvest and test them while balancing the accuracy of the test results with the effort and time required. The solution proposed in the book *Mastering Lean Product Development* (Mascitelli 2011) is to register the basic information about each idea in a one-page template: origin; name for the new product; target market(s) segments; problem(s) the new product proposes to solve; new product concept and how it can be obtained. The basic information, if possible, should be complemented with market research or sales projections to sustain product viability.

From the basic information, the first screening of ideas is made by filtering ideas with market potential and pre-sorting them. Afterwards, the selected ideas should be verified, selected and prioritized by a committee composed of senior managers responsible for reviewing and updating the product development strategy for the firm. These should be done in a periodical meeting where current open projects are briefly reviewed, and significant project changes are identified. For new ideas, the ones selected are passed to the next stage, where a Business-case brief is made, where product concepts are fleshed out, and substantial market research and quantitative estimates of profitability are made by a member of the committee of senior managers. Once more, the collected information and results should be presented in a predefined template. Business-case template proposed by Mascitelli 2011 can be consulted in Appendix B. The representation of the filtering process is represented in Figure 6.

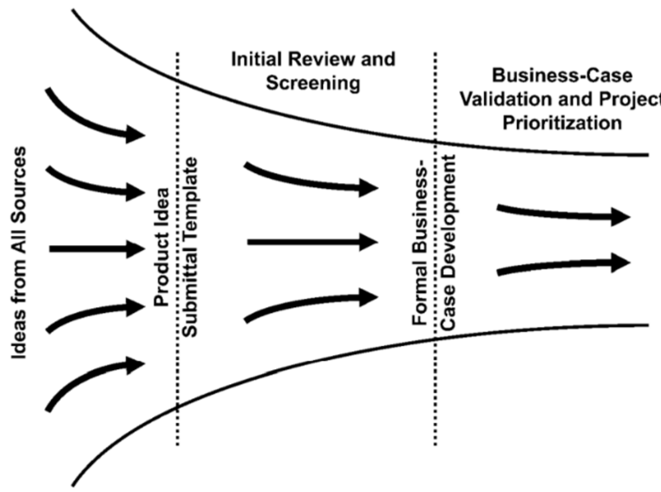

Figure 8: Selection and prioritisation of new product development ideas (Mascitelli 2011).

After the selection, prioritisation of projects can be made. To prioritise projects, the most common approach is "two-dimensional portfolio planning". Placing the product opportunities in a field defined by two axes: the projected profitability of the new product (Net Present Value or equivalent) and its strategic impact on the firm. This approach does not consider the resources required for new product development. An approach incorporating a the third dimension can be used by substituting the project profitability by "project efficiency", calculated by dividing the estimated profitability by the number of hours in development estimated (Mascitelli 2011).

In practice, the GPL is constructed based on a table (example in Table 1) considering the product's profitability, development hours, project efficiency, strategic importance, and priority score. The inputs allow calculating the overall project ranking to serve as a guide when defining the prioritization of the project. The steering committee defines the final prioritization, which can differ from the calculated score since “there is no metric, or combination of metrics, that can substitute for the collective insight of a firm’s management team” (Mascitelli 2011, 4).

Table 1: Projects rating method (Mascitelli 2011).

Project Designation	Net Present Value (NPV in $K)	Risk Adjustments			Risk-Adjusted NPV - (in $K)	Estimated Development Hours	P = Project Efficiency (Risk-Adjusted NPV / Est. Development Hrs.)	S = Strategic Importance (1 - 10)	Overall Project Rating (P x S)	Actual Priority
		Market Risk (0-100%)	Technical Risk (0-100%)	Schedule Risk (0-100%)						
Widget	1000	1.0	1.0	1.0	1000	1500	0.7	8	5	?
Thingamajig	500	0.8	0.4	0.8	128	2500	0.1	3	0	?
Whatchamacallit	700	1.0	0.8	1.0	560	500	1.1	7	8	?
Dohicky	2000	0.6	0.8	1.0	960	1000	1.0	10	10	?
Gadget	300	0.4	0.6	0.6	43	500	0.1	5	0	?

Poor resource capacity management is the most common root cause of long development cycles and delayed time-to-market, so portfolio management must be accompanied by capacity management. The first step to capacity management is to assess the available resource capacity so the mix of open projects can be matched to the available resources. The approach to understanding the impact of capacity management on productivity is the application of a concept regularly used in manufacturing, the Theory of Constraints (TOC): there is a constraining resource that limits the productive capacity of the system. Due to the complex and unpredictable nature of new product development, constraints change over time, making it more challenging to address this problem.

The practical approach proposed to capacity management is the usage of a set of rules allowing to define of a maximum number of projects assigned to each developer, prioritization and scheduling of projects’ tasks, the amount of time allocated per developer to projects, and time-slices to enable focus and synchronization, demands and tasks of projects should be visually managed and their responsibility assigned to a developer (Mascitelli 2011).

2.4.2 Stage-Gate Model and Event-driven Design

Stage-gate systems consider New Product Development as a process with recurrent activities in all new products. Stage-gate applies process-management methodologies to NPD. Once again, the understanding of this methodology can be achieved by comparing it with the physical manufacturing of a product. The way to ensure the quality of the product is to focus on reducing variability and assuring the quality of the process. As working stations separated by quality checkpoints in manufacturing, in project management, there are different phases separated by quality checkpoints - the gates. Each phase is composed of a set of activities. The gates, the entrance to each phase, work as control points and are characterized by having a group of deliverables or inputs, criteria points to allow exit, and an output. Deliverables are the inputs of a gate, criteria are the points that must be used to verify the project and the outputs are decisions at the end of the gate, whether the project continues, is closed or archived. The deliverables of the project serve as input to the gate, where the review points are criteria to decide the output of the gate. The output is the decision of what to do with the project, procced to the next stage, close it or archive.

Stage-gate is the most widely used technique for project management and planning, namely for NPD projects. Novel alternatives are being suggested. However, the stage-gate model can be seen as a governance process with no methods for development teams to use. Mascitelli 2011 proposes an alternative denominated by Event-driven, which can be implemented to complement stage-gate. The event-driven model has meetings or events planned with an agenda, deliverables and required personnel. The duration of an event should be tailored to each event. The list of events should be tailored to each project. Hybrid models are also being developed as alternatives to the traditional Stage-Gate Model. Cocchi, Dosi and Vignoli 2021 propose a hybrid model where stage-gate, design-thinking, lean start-up and agile can be used alone or combined.

2.4.3 Project Initiation: A3, business case, risk analysis and type of project

As previously approached, to initiate a new project for NPD, some information should be clear about the product concept, profitability and required resources. In addition, it is important to identify the major risks for the project. Therefore, the importance of the creation of the referred start-up A3 model, a template to ensure that all criteria are defined.

First, before starting a New Product Development it is needed to clarify what is the scope and objectives of the development. Secondly, define the involved team and its structure. Thirdly, the deliverables along the process and their schedule. A deliverable is a tangible and transferable item, such as simulations, prototypes and documentation. The initiation workshop should define the project charter and clients' requisites. In addition, an analysis of risks, regarding probability and impact is recommended so possible solutions can be designed and prepared.

2.4.4 Planning optimization: Critical Path compression and Last Planners

Critical Path Compression

The critical path comprises the series of required dependent tasks taking the longest time to complete, defining the estimated time to market. The critical path should be analysed and compressed to reduce time to market. One way to do so is to take two tasks from the critical path done in series and perform them in parallel. On the one hand, the project duration is reduced, but, on the other hand, the risk increases since the information resulting from the first one is not available yet for the second task. In this case, communication frequency between both teams should be increased to reduce the risk.

Another technique is subdividing the tasks identified in the critical path in internal and external activities. These terms are primarily used in lean manufacturing during Single Minute Exchange of Die (SMED) improvements. Internal activities must occur when the previous task has finished to create value with low-risk. An external activity can be performed at any time without increasing risk. An example from manufacturing is the preparation of a new toolset to exchange a die, in project management can be the preparation and writing of the report of a test as external activities and the exchange of the die itself and the realisation of the test as internal activities (Mascitelli 2011).

Project Buffer

When the critical path is compressed, a project buffer should be added to the project planning to absorb the impact and delays provoked by delays and uncertainties inherently associated with the course of the project. On the one hand, over-dimensioned buffers can lead to the loss of potentially lucrative contracts due to uncompetitive project bidding. On the other hand, small buffers, if not capable of absorbing the uncertainty of the project duration, lead to a need for replanning and emergency procedures can lead to late delivery and increased project costs.

Recent literature focus, She, Bo and Hall 2021 consider not only the critical path, but a critical chain. The previous methodologies focused on the critical path, which usually resulted in excessive buffers. By focusing on the critical path only, the interactions between critical and non-critical chains can be missed. The paper proposes a method that creates three types of buffers to protect the project from uncertainties and resources bottlenecks:

- a *project buffer* at the end of the critical chain addressed to the overall project;
- *feeding buffers* at the end of non-critical chains to preventing them to prevent them from becoming critical
- *resource buffers* to act as alerts for resource availability on the critical chain.

Different forms of estimating buffer sizes can be found in the literature. The cut and paste method was introduced by (Goldratt 2017) to estimate a single buffer considering the safety time removed from the task estimation time during the critical path compression and adding safety margins. The cut and paste method is also applied to the Project buffer and feeding buffers (Hegde, Jain and Das 2021). Other authors use the Root-Square Error Method (RSEM), for example (She, Bo and Hall 2021). In practical terms, companies with low maturity in project management can struggle to dimension the project buffer. Kaizen Institute Portugal 2022 suggests a buffer representing 15 to 20% of the total time estimated for the project after critical path compression. The visual representation of buffer consumption is often plotted using fever charts where the % of Critical path completion is compared with the % of resource/Safety buffer consumption as posed in Figure 7.

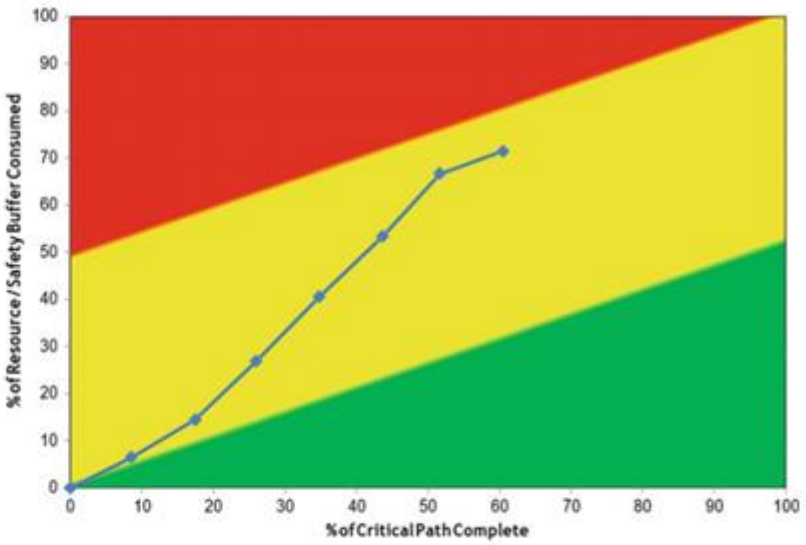

Figure 9:Fever chart representation of %Buffer consumption versus % critical chain completion (Hegde, Jain and Das 2021).

Last Planner System

The last planner system converges with some of the techniques presented previously. The last planner system is a planning system composed of five levels. A *Master* schedule with a representation of the milestones, phase durations and overlaps. A *Phase* schedule where tasks' sequence and condition of satisfaction are clarified. *Lookahead* planning, where task descriptions are refined and broken down into manageable pieces to facilitate operations design, is used to identify and remove activity constraints. The *Commitment* planning results in a *Weekly Work Plan* where activities for the week are established, and the *Learning* phase where plan failures that occurred are analysed, and countermeasures are defined (Poudel, de

Soto and Martinez 2020). Kaizen Institute Portugal 2022 materials simplify last planner usage to *Last Planner 6 Weeks* and *Last Planner 1* Week to a checklist confirming no hindrance to the tasks planned for the next six weeks and the following week, respectively.

2.4.5 Project tailoring

When developing an approach for a company to manage its new product development, the approaches defined must be accordingly to the perfect ratio of process-project to its own NPD reality (Poudel, de Soto and Martinez 2020).

Riel, Neumann and Tichkiewitch 2013 identify the main factors affecting development processes related with the organization, the project, product, and personnel related variables.

- Organisational | organisational size; organizational structure, organizational type – Purpose, production size and inventory, selling products, organisational maturity, project management, documentation, computer and tool support, tool use learning, selection of tools, organizational design capacity.
- Project | project size, project complexity, project type, project constraints, project novelty.
- Product | Product type, product complexity, product level of hierarchy
- Personnel | team size, level of maturity, design capability
- Development lifecycle contextualization framework | size variables, type related variables, complexity related variables, maturity related variables, capacity and capability related variables

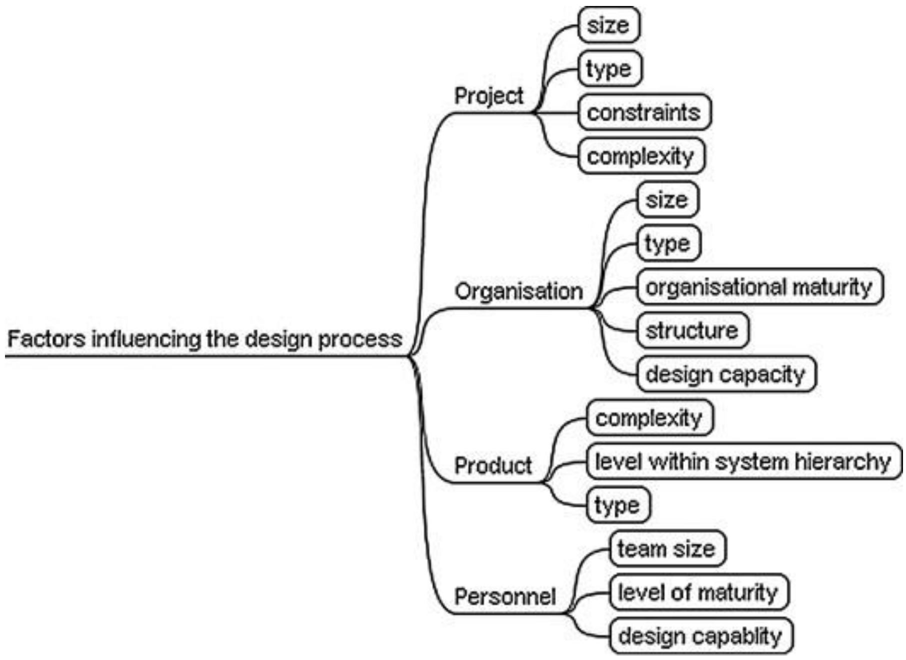

Figure 10: Parameters influencing the new product development process (Riel, Neumann and Tichkiewitch 2013).

If the nature of the projects is diverse within the same team, then flexibility must be given to project managers in what tools to use. However, selecting the right tools might not be simple, thus, methods for customizing tools to each type are being created (Poudel, de Soto and Martinez 2020). Among which matrix models, such as the one proposed by Cocchi, Dosi and Vignoli 2021 presented in Figure 11, can be found. The tool presented allows choosing between stage-gate and hybrid models combining stage-gate, agile, design thinking and lean start-up by considering knowledge about the product category on one matrix axis and knowledge about users on the other. When more factors are being considered, these can be rated to a specific project, and the approach can be chosen based on a final score calculated using a weighted average. For this tool, the impact of each factor must be previously defined and kept constant within the organization. The template (in Portuguese) used by Kaizen Institute Portugal is presented in Figure 12 and in APPENDIX C.

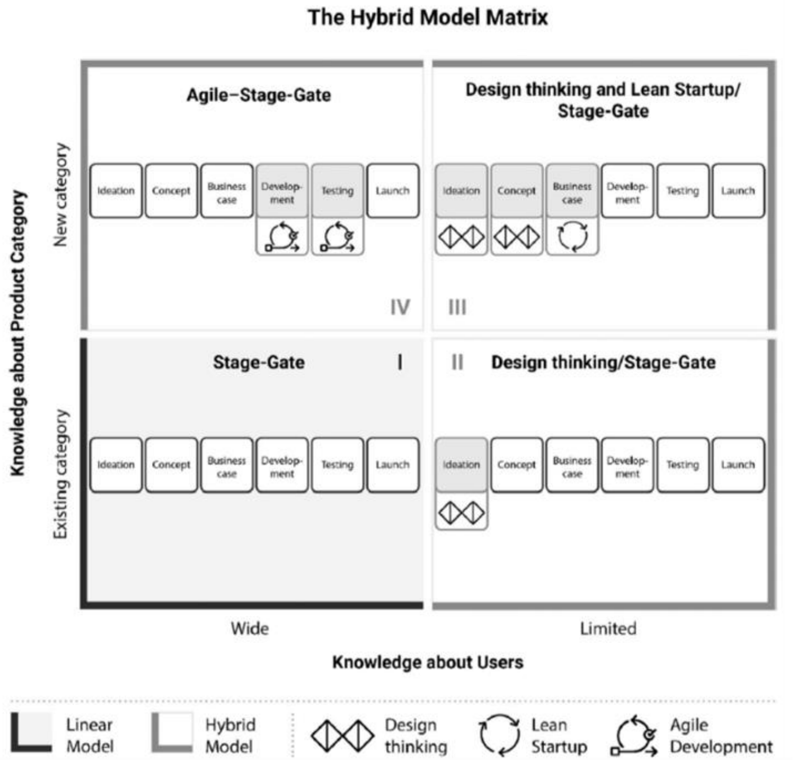

Figure 11: Hybrid model matrix (Cocchi, Dosi and Vignoli 2021).

				CLASSIFICAÇÃO					
				1	2	3			
Dimensão	% Ponderação	Parâmetro	% Ponderação	Baixa	Média	Avançada	Ponderação Final	Inserir Classificação	
Inovação	25%	Necessidade de prova de conceito	50%	1 Parâmetro	2 Parâmetros	3 ou mais parâmetros	13%	1	0%
		Tipologia	45%	Nova Funcionalidade	Novo Produto	Nova Gama	11%	1	0%
		Necessidade de avaliar concorrência	5%	Não	Sim	Sim	1%	1	0%
Criticidade	10%	Data Limite/*Time to Market*	25%	> 12 Meses	3 a 12 Meses	< 3 Meses	3%	1	0%
		Visibilidade no mercado	25%	Sem impacto nos media	Com impacto em alguns media	Com impacto em todos os media	3%	1	0%
		Novas Normas Legais	10%	0	1	2 ou mais	1%	2	50%
		Impacto em caso de falha	40%	Impacto na produtividade	Perda de Lucros	Perda de Reputação	4%	2	50%
Cliente	5%	Interno ou externo?	5%	Interno	Interno com implicação de externo	Externo	0%	2	50%
		Impacto nas Vendas €	55%	< 100k	1000 k a 1M	> 1 M	3%	1	0%
		Alinhamento estratégico U.N	40%	*Could Have*	*Nice to Have*	Must Have	2%	1	0%
Complexidade	60%	Duração estimada	50%	Até 1 mês	1 a 6 Meses	Mais de 6 meses	30%	2	50%
		Tipo de Mudanças	35%	1	2	3 ou mais	21%	1	0%
		Recursos Necessários	5%	Sem equipa a tempo inteiro	Sem equipa a tempo inteiro	Pelo menos uma equipa a tempo inteiro	3%	1	0%
		% do projeto executada por	10%	0%	Até 50%	Mais de 50%	6%	1	
Total	100%					RESULTADO:	100%	Baixa	18%

Avaliação	Ponderação
1	0%
2	50%
3	100%

Figure 12: Project tailoring rating method.

2.4.6 Obeya control

Frequent stand-up meetings with all team members involved in a project facilitate communication among team members favouring work synchronization, positive peer pressure to be productive and a sense of urgency, among other positive outcomes. Stand-up meetings, known in other areas as Daily Kaizen meetings or Scrum meetings, are short and frequent meetings with a defined agenda and schedule supported by visual management to evaluate and plan work.

In the case of project management tools, namely product development, this visual support is called the Obeya room. The meeting should happen in a defined physical or virtual space, in the laboratory, the hallway or elsewhere. It should be a place close to the workplace of the team, with a board where the Obeya room elements can be easily accessed. The board must have relevant information for the team: the work plan for the near future, problems to solve, KPIs that allow keeping track of progress status and other elements essential for the team.

Two tables can be used to present the planned and unplanned tasks for the next two weeks. A third table, placed at the board's centre, allows the distribution of the tasks for the next week by day. Other elements can be included. It is advisable to have Key Performance Indicators (KPIs) to track the progress of the project: project buffer consumption graphs, snake diagrams, for example. It is common to create a place to register improvement ideas and their progress, a PDCA cycle or another system to document problems that arise. It should be noted that only relevant elements to discuss in the meetings should be included (Mascitelli 2011).

2.5 New Product Development in the ceramic industry

Most ceramic companies are small to medium enterprises (SMEs) with an average of fewer than 250 workers (Alegre, et al. 2008). Concerning the New Product Development in the ceramic industry, according to Agost, Company and Romero 2011, the ceramic sector is a "low-technology market" and therefore struggles to balance between formality and flexibility. Their methods are adjusted to the current needs of their contexts. The referred paper analyses a series of tile companies in Spain. The New Product Development process has different origins for NPD projects, lacking a solid hierarchy and fashion pressure. The absence of solid leadership in NPD process management and, consequently, lacking detailed planning of tasks. (Flor and Oltra 2004). Safari and Shaabani 2018 conclude that customer involvement in NPD of the ceramic industry has a direct and positive impact on NPD performance. To the best of our knowledge, the literature is scarce regarding NPD in the ceramic industry.

Low-technology market industries introduce less than half of the first new products in national or world markets. Despite innovation being more common in high-technology markets, it is associated with revenue growth in both industry types. In the high-technology industries, the interaction between knowledge assets and innovation has a significant impact, while in low-technology industries, training and innovation interaction pose a more significant relation (Thornhill 2006).

3 Current state description

CeramicProvider considers research and development of new products essential to guarantee its sustainability in the context of the present and future challenges. The present section elaborates a detailed definition of the AS-IS state. First, it explains the structure of the human resources involved in achieving new products. The flow mapping of the process follows, accompanied by an explanation of the main steps. Later, capacity and portfolio management are presented. From portfolio analysis, it follows sales and time to market analysis. Finally, team communication and a daily basis in the laboratory are approached.

3.1 Organisational structure

Different teams are involved in the creation of new products. In CeramicProvider, an Innovation Committee is responsible for the pipeline supply of projects, while R&D and laboratory teams are in charge of developing the technical characteristics of the products. Additionally, the commercial team accompanies the clients throughout the process, either to collect ideas for new products or to get feedback about the performance of a new product. Teams' compositions are presented below to understand each part's involvement in the process.

Innovation Committee:

- R&D team leader
- Administration
- Commercial team leader
- Ceramic specialist consultant

R&D team:

- R&D team leader
- Product managers

Laboratory team:

- Product managers
- Laboratory technicians

Commercial Team

- Commercial team leader
- Commercial team member

3.2 Process Mapping

The team identified eight phases from ideation to product launch in the market: Idea Capture, Project Opening, Specification Definition, State of the Art (Research), Industrial Development in the laboratory, Internal Prototype - Internal Industrial Test (IIT), Customer's Verification Prototype and Project Closure. The graphic form of the process mapping can be consulted in Appendix D.

The process starts with the identification of a need, which can be done by the administration board, the commercial team, the innovation committee, product managers, the laboratory team or production. The most common needs in CeramicProvider are reducing the thermal expansion coefficient of ceramic bodies, changing the final product's colour, or using more abundant raw materials to achieve the same characteristics of an existing product. Other less common needs and more breakthrough ideations can exist. After the ideation phase, the ideas require approval from the administration board to proceed.

In the next step, the project passes on to the R&D team. One product manager (PM) is assigned to the project. Hereafter the PM estimates TTM and plans deliverables for each phase. The R&D team leader adds the new project to the Guideline file, an excel file where the open projects are documented.

Then, the PM establishes and clarifies the product specifications and proceeds to literature research to complement the knowledge gaps that might exist for the new product requirements. PM is also responsible for updating the knowledge database and saving relevant documents. During the state of art phase, the R&D team leader is in charge of providing support to the product manager if needed.

When the PM has enough information to formulate a mixture of raw materials to achieve the specified characteristics, the project enters the industrial development phase, and laboratory tests are conducted to test the hypothesis. Sometimes, the tests are performed by the product manager or laboratory technicians. The PM evaluates the results to verify whether the characteristics follow the ones expected and decides if another iteration with a new formulation is needed. If the PM considers that enough iterations have been made and the results are according to the specifications, the best hypothesis is selected, and the process can proceed to the internal prototype phase.

An internal industrial test (IIT) should be scheduled on an accorded date between PM and production and registered into the pilot plant plan. After the prototype execution, the prototype can be shipped to the customer if the process control and final product test values are valid.

An agreement with the client should be made to plan the date for the test, prepare the documentation and accompany the trial in the customer's industrial environment. In this phase, the approval of the results is made by the customer.

Finally, after the new product gets approval from both PM and the customer, project closure should be done by calculating TTM and preparing product documentation and datasheet. From this point on, the product can be launched in the market, allowing for production in response to orders placed.

Each project manager is assigned to a type of product; for example, one person is responsible for porcelain and one for clays. When a new product does not fit clearly in only one typology, the administration board decides who takes that project. Along the process, there is no accompaniment of planning compliance with the initially estimated time and no estimation of costs is performed. The product definitions are established in an initial phase, although the team identified requirement changes or lack of information for values regarding product specifications during the mapping activity. The current existing file to NPD management is heavy and requires too much time from the team to be updated. Most of the time, the team does not use it. The project manager decides if literature research is necessary based on knowledge and experience in similar products. Dedicated time to literature research has high variability. Development of the laboratory product can run simultaneously with the literature research. The availability and cost of raw materials are not easily accessible. A mixture for a new product can be developed, and lacking raw materials during the industrial test, customer test, or production can make the product unviable.

For testing the product characteristics, similar conditions to the ones where the product will be placed in customers are aimed, for instance, if the product is pressed before baking and the baking conditions (temperature and type of oven). The pilot plant allows tests on a larger scale with small batches of product. Despite having a production plan for the pilot plant, emergency productions are common for specific orders or tests and occur without a formal request making the plan seen by the team as not trustworthy. IIT is not always performed. PMs decide if it is necessary, whether because they consider the product results in the laboratory as viable or because it is too complicated to schedule production in the pilot plant. If not as expected, the results from the IIT require a new mixture formulation and new industrial development in the laboratory.

After the PM approves the product, the customer tests it under actual application conditions. Sometimes, the prototype is lost when sent to the customer, or customer response takes a long time and delays the end of the project. Finally, when both the CeramicProvider team and the customer approve the product, a high cost and quality ratio or no availability of raw materials can stop the project, and the product does not proceed to the launch phase and production.

The process is subjected to loops when the results are not according to the ones expected. Estimations done by the functional team show that 25% of loops exist in the laboratory testing phase, 5% in the IIT and 40% in the customer prototype phase.

3.3 Capacity Management

A new project is assigned to a Product Manager based on the type of product. If the type of product is evident, then the project is given to the PM responsible for that type of product; if the type of product is not evident, then the administration board choose the PM based on their judgment and familiarity with the team members. No tool is available, making it simple to view the load by PM. When selecting a PM for a new project, this factor is not taken into account. The number of projects for each PM varies from zero to eleven at the moment of the analysis (APPENDIX E).

The laboratory team accumulates functions of new product development with quality control (QC) of raw materials, final product and process control of the production in the factory where the Centre of Excellence is located. The time estimated dedicated to R&D, QC and other tasks range from 20% to 98%, 0.5% to 40% and 5% to 75%, respectively. The collected data in detail can be consulted in Appendix D. There is no planning or tracking of the time spent on each task. The team expressed the generalized feeling of lacking time for R&D. Comparing APPENDIX E and APPENDIX F, it can be drawn that there is no direct relation between time allocation to R&D and the number of open projects per PM.

3.4 Portfolio management and TTM

The data from previous projects were analysed to calculate the current time to market, the number of new products and the revenue obtained with new products. Open projects are registered in an excel file named *Guideline*. Its fields record a unique code attributed to each project: opening date, the origin of the idea/request, type of project, approved (Y/N), family/type of product, excellence centre, factory to be produced, Product Manager, name of the project, commercial contact, market/customer, request date, request description, intervenients, completion dates of each phase, action in progress, final result, calculated TTM and additional information. The R&D team leader is responsible for updating the file.

The *Guideline* has 82 projects, from which 14 were opened in 2020, 36 in 2021 and 10 in 2022, compared to 20 closed in 2021, 2 in 2022 and 60 remain open (Table 2). Considering the data until the end of 2021, 40% of the projects were closed.

Table 2: Number of project analysis.

	2020	2021	2022
Closed Projects		20	2
Opened Projects	14	18	10

From the 22 closed projects, 20 successfully resulted in new products and one was abandoned because the customer lost interest. It should be noted that not all projects developed are registered in the file. Some customers or commercials communicate new projects directly to the product managers and the project follows without official tracking or accompaniment from the R&D team leader.

CeramicProvider considers 4 types of projects:

- P1: Solicitation of customers and potential customers for new product development;
- P2: Market studies and monitoring of technological trends;
- P3: Request for continuous improvement;
- P4: Circular economy projects.

The project is classified according to its origin as P1, P2, P3 or P4. There is no apparent relation between the types of projects identified and TTM. The functional team states complexity of the projects can have a significant variation, and it is not directly related to their origin. However, the team refers to P4 as usually taking longer. For P4, the main reason is the customer's distant due date for finishing the project, generally being governmental financed projects.

Time to market was calculated by comparing the project's closing date with the opening day registered in the *Guideline* file. The TTM per type of project is 1460 days for P1,445 days for P2 and 104 days for P3. For P4 was not possible to calculate since no closed project of this type is registered in the guideline. The 22 closed projects from the file were used to calculate an average value of TTM, resulting in 243 days. TTMs registered vary from 14 to 645 days.

3.5 New Products Revenue

For calculating the number of new products and associated revenue, it was considered the products with the first revenue income registered in the three previous years than the year analysed. Products renamed or that had the code changed for commercial reasons were removed from the list of new products, leaving only those that came through R&D programs. The production responsible of each factory made the identification of R&D products or existing products with new references.

Analysing 2019, 2020 and 2021 sales, the number of products released was 48, 48 and 32, respectively. New products revenue represents 23.4%, 29.1% and 13.5% of the unconsolidated sales of 2019, 2020 and 2021, respectively. Last year, a decrease in 10 percentual points (pp) in the revenue was observed along with the number of products released from 24 to 16. For all CEs, the number of new products and the generated revenue remained constant or decreased, except CE02 from 2019 to 2020.

Table 3: New products revenue / total non-consolidated sales of the group (%).

	2019	2020	2021
CE01	5%	5%	3%
CE02	12%	17%	10%
CE03	7%	7%	0%
Total	23%	29%	13%

Table 4: Number of new products per CE.

	2019	2020	2021
CE01	22	12	18
CE02	14	20	6
CE03	12	16	8
Total	**48**	**48**	**32**

In 2021 new product revenues represented 13% of the total non-consolidated sales of CeramicProvider: 6.6% of total sales resulted from products released in 2019, 4.2% from products released in 2020 and 2.7% from products released in 2021.

Table 5: 2021 revenue analysis.

Released in 2019	6.6%
Released in 2020	4.2%
Released in 2021	2.7%
Total revenue of new products 2021	**13.5%**

Figure 13 illustrates the importance of various product types in 2021's new product sales. One product type account for 71%, followed by 11% and 9%, with the remaining product types accounting for less than 3% each.

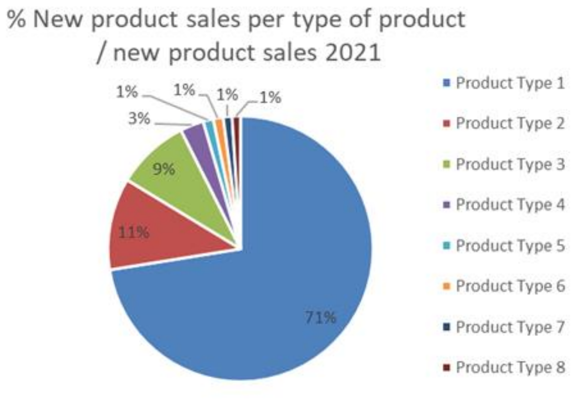

Figure 13: New product sales per type of product / new product sales in 2021.

3.6 Team communication and meetings

The innovation committee established a quarterly meeting to discuss strategic ideas according to the development of the business, the potential use of by-products, technological trends in the market and specific products. Although a defined frequency is established, only one meeting occurred last year. No agenda is defined for the meeting.

There is no set protocol for introducing new initiatives to the R&D team; it can be done either personally or via email. It should be noted that some projects are started by the PM immediately following a customer request or production, with no formal presentation.

In CE01, the status of open projects is updated by the R&D team leader with each PM individually. A biweekly meeting is planned for CE01 and CE03, but it only happens if the R&D team leader believes there has been progress or changes to discuss in the meeting. No observation of these meetings was possible since none occurred during the project's duration.

For each product type, a weekly meeting is primarily focused on QC. The participants are the PMs who manage products of that type and production responsible for the factory producing these products. Customers’ feedback is discussed, and the feedback is collected by the production responsible with commercials and direct interaction with the client. The PM reports any anomalies detected in QC tests and the progress in R&D projects for that type of product

Regarding Daily Kaizen meetings of the natural team of the laboratory, only CE03 has a weekly meeting structured accordingly with the Daily Kaizen level 1 principles and rules (presented in Chapter 2). For CE01, a maximum of two PMs are in charge of a type of product, and no planning with other team members is done. In CE02, product managers distribute the laboratory tests (QC and R&D) by speaking with the laboratory technicians throughout the day, since which tests each technician focuses on most is already established.

3.7 Laboratory daily work

The laboratory team performs tests to verify the quality of the product along the production process and before being sent to the customer. The raw materials are characterized by chemical composition. For the in-process product, it is vital to verify the rheologic properties, chemical composition and their evolution with the additives required for the process. Finally, green, dried, baked physical properties and the final colour might be required for the final product to assure compliance with customer specifications. Tests performed in the development of new products are similar.

Muda hunting, a Kaizen tool to identify and quantify waste, was used to better understand the daily basis in the laboratory. *Muda* is a Japanese word used in Kaizen business culture to refer to waste. *Muda hunting* was performed by shadowing the laboratory team: accompanying laboratory team members in their daily tasks to identify and quantify Muda in everyday work. During the Muda hunting, times used for value-adding and Muda activities were quantified by direct observation and time tracking. During the shadowing exercise, the spaghetti diagram from Figure 14 was drawn. A Spaghetti diagram allows to observe the different paths that the laboratory team members accompanied followed and perceive the most common and repeated paths.

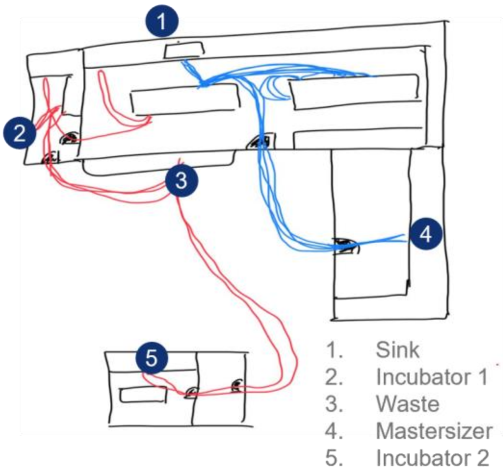

Figure 14: Spaghetti diagram.

During two full-working days, PM and laboratory technicians (in the CEs where it is applicable) shadowing was made. The CE01 data analysis resulted in 35% of Muda to 65% of added value represented in Figure 13. Being the main opportunities identified (Figure 14): transportation (56%), cleaning (16%), rework (23%) and waiting (5%). The main opportunities identified were:

- Movement to put samples in the incubators;
- Movement between pieces of equipment required for the same test;
- Rework in data register first in paper and then input to an excel file;
- Cleaning spaces and instruments after usage;
- Waiting for the sink to be free to perform cleaning or tests.

During the shadowing, it was noticed that different PMs and technicians perform tests differently, and no standard work is defined.

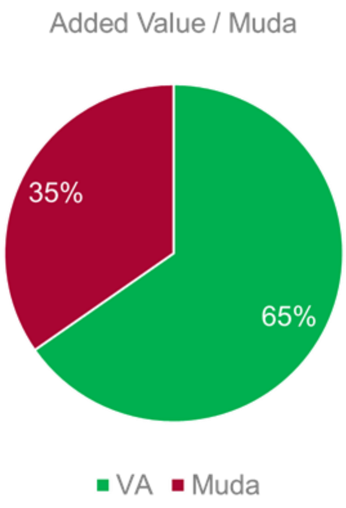

Figure 15: Time spent in added value and *Muda* activities.

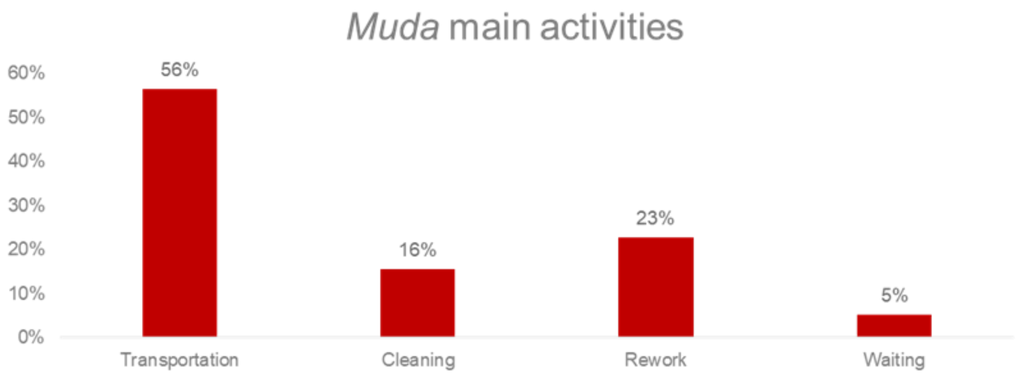

Figure 16: *Muda* main activities.

4 Proposed solutions

As seen in the previous chapter, from calculations based on the Guideline excel currently used and the sales revenue data, the following values resulted for 2021:

- Time to Market (TTM) - 243 days;
- Number of new products - 32 per year;
- Sales percentage of new products – 13.5%.

A specific objective value for new product sales was defined to obtain the strategic objectives for the company defined by the top management. Considering the previous figures as a baseline, the following objectives were defined together with the administration to reach the settled strategic goals:

- Time to Market (TTM) – 109 days (-55%);
- Number of new products – 40 per year (+25%);
- Sales percentage of new products – 15.5% (+2pp).

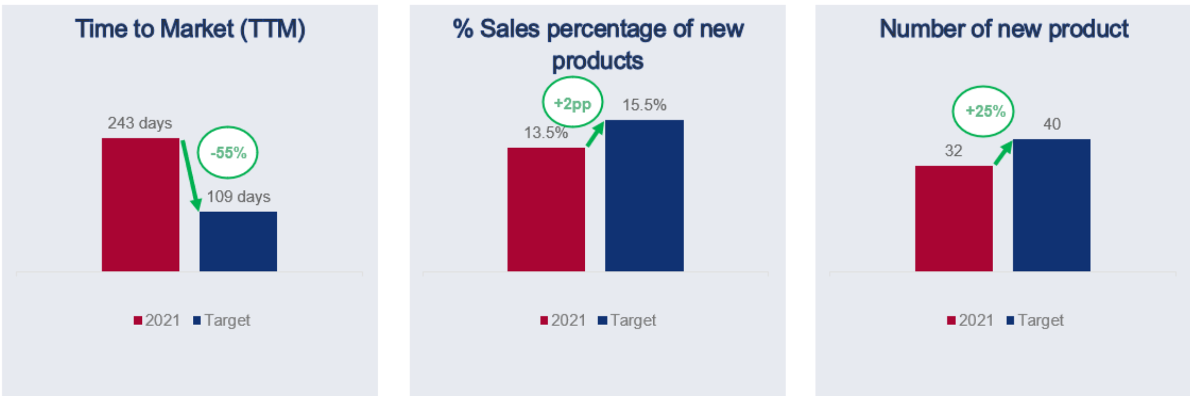

Figure 17: Baseline and target values of TTM, Sales percentage of new products and number of new products.

Based on the literature review, the proposed solutions for the problems identified follows. The solutions fit into four macro themes: Lean Project Management, R&D team organization, Improvement of R&D Process Standards and Ideation Process.

To allow a better understanding of the tools presented and their form of use, it is first presented, a TO BE process mapping. Then, the techniques for each macro theme follow.

The graphic form in APPENDIX G integrates the process mapping with the reference of when to use project management support tools and the proposed stage-gate model.

4.1 Process mapping

The proposed TO BE process is based on the AS IS and previously identified opportunities in Chapter 3.2. The new process focuses more effort on planning a project to avoid loops and repetitions. This, together with higher customer accompaniment during the customer test, is expected to reduce Time to Market and, consequently, the number of products released yearly.

The first step is the idea capture, which will focus on customers' preferences and breakthrough ideation besides the already existing idea sources. Each idea is then recorded in a template and subjected to an initial screening. The innovation committee verifies, selects, and pre-prioritises ideas during its meetings. From there, a member of the innovation committee forms a business case of the chosen ideas, which is nothing more than to complement the initial idea submission with well-defined and clear product concept and characteristics, market research and profitability estimates.

Portfolio management becomes important when there is a well-proven concept with a target customer and estimated profitability. Revaluating open projects to redefine their importance for the organisation based on the strategy, the project results and KPIs to decide which ones to keep going, to close and which ones from the business-case phase can proceed to product development, taking into account the capacity management and the mix of projects desired. Portfolio management results in a global priority list.

If a new project is open, a PM is assigned to that project. The PM is responsible for the project and the product when it gets into the production phase. The first thing is to define product goals and specifications, plan the deliverables for each phase, classify the project according to type (further explained in Section 4.3.1) and choose which planning methodologies and tools to apply. From there, planning optimisation and estimation of TTM can be done. Additionally, risk analysis and mitigation plans should be carried on. This information can be then summarised in a start-up A3 model. PM sets up the Obeya room to include the new project. The last planner lists for 1 week and 6 weeks should be made. Last planner lists and the Obeya room should be updated every Obeya control meeting.

Then, if the PM decides literature research is needed, a knowledge search is carried. Relevant documents and insights are saved in a knowledge database. When PM can develop a series of mixture formulations, then the mixtures are tested in the laboratory, the results analysed, and then the best option, based on its characteristics, costs and commercial potential, is selected. Literature research and hypothesis testing can be done in parallel.

When there is a potential formula for the new product, a small batch of product is produced in the pilot plant. PM and Production agree on a date to perform the test. Based on the tests results of the process and final product control, the decision if the project can proceed to customer's verification or need to redo an IIT is taken.

The client is informed of the realisation of the test, and an agreement on the date is made. The customer performs the industrial test and approves the product. PM and CeramicProvider commercial accompany the test.

Once the PM and the customer approve the product, the NPD project can be closed. To do so, the TTM is calculated, preparation of new product documentation and product sheet are elaborated. For future reference, a closing A3 is done, summarising the main topics of the project and lessons learnt with significant problems and solutions found.

4.2 Ideation process

Ideation process improvement will be based on two workshops: Voice of Customer (VOC) and Breakthrough Ideation (BI). Participants should be all members of the innovation committee. It should allow the techniques to be applied autonomously by the innovation committee in the future.

4.3 Lean Project Management

Project portfolio and capacity management, Stage-Gate Model, Project Initiation, Planning Optimization, Project Tailoring and Obeya Control are the techniques chosen to apply to New Product Development in CeramicProvider, regarding lean project management. The tools tailored to CeramicProvider are presented next.

4.3.1 Project tailoring

CeramicProvider R&D projects' complexity might vary from simple to highly complex projects with research outside the ceramic sector. Therefore, each phase's planning techniques and times must be adapted accordingly. A classification of 5 types of projects is proposed:

- P1 – Raw materials substitution (with similar materials) for existing products
- P2 – Upgrade existing products
- P3 – New product in the ceramic industry
- P4 – New product in the non-ceramic industry
- P5 – Circular Economy / Government financed projects

4.3.2 Project portfolio and capacity management

Project portfolio management should be done by the Innovation Committee, considering the capacity and load of the R&D team, the mix of open projects and the projects in the waiting line. Open projects are reviewed in the Innovation Committee meetings; their progress, costs and results are analysed. Based on this information, the global priority list of the projects can be adjusted. The global priority list inputs are the list of open projects and the pipeline projects to be developed. The final business-case score serves as a guide on where to place the new project within the GPL. However, top management intuition should always have the final say, and the new project should be assigned in accordance with it. The mix of projects open, regarding the number of projects for each type of project and type of product, must comply with the R&D competency matrix and availability.

4.3.3 Stage-Gate model

A stage-gate template is proposed to serve as a basis for planning projects. The template was designed considering a complex project involving all phases described in the process mapping. When doing each project planning, the PM should adapt the template to satisfy the needs of that specific project.

The template, presented in a graphic form in Figure 18: Stage-gate model proposed to CeramicProvider NPD process., is composed of five stages and gates:

- Project Opening

  Review Points:

  - Product Manager assigned
  - Product Goals and Specifications are clear
  - Project Type identified

  - Planning Methodology defined
  - Stage-Gate adaptation completed
  - TTM Estimated
  - Start-up A3
- State of the Art and Industrial Development

  Review Points:
  - Relevant documents are stored in a knowledge database
  - Test results follow the customer requirements
- Internal Industrial Test (IIT)

  Review Points:
  - IIT test results follow the customer requirements
- Customer's Verification of the Prototype

  Review Points:
  - Customer’s Product validation
- Project Closure

  Review Points:
  - TTM calculated
  - Product Datasheet finalized
  - Register summary of problems and solutions from along the project – Lessons Learnt
  - Closing A3

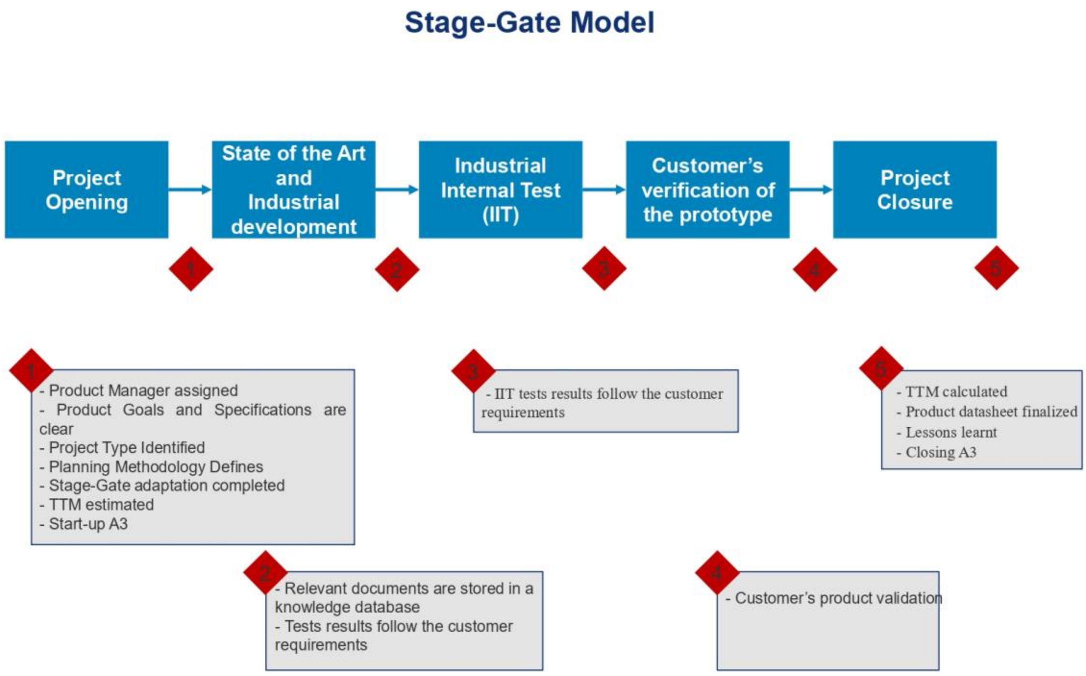

Figure 18: Stage-gate model proposed to CeramicProvider NPD process.

4.3.4 Project initiation

It is necessary to have a developed, clear, and well-defined product concept before beginning a project. Therefore, a thorough definition of the concepts, market research, and profitability analysis is required to determine whether the project has potential and is aligned with the organisation's strategic goals.

A business-case template considering all the referred points is provided to ensure that the member of the innovation committee in charge addresses each item. The template makes it simple to consult each point and determine the final score. A weighted average is used to determine the final score.

After a project is assigned to a PM, the PM, in a workshop with a member of the commercial team and the innovation committee, plan the deliverables by phase, classifies the project type and chooses the methodology accordingly, establishes the critical path, compress the critical path and calculate project buffer, estimate TTM and risk analysis. At the end of this phase, a start-up A3 model is elaborated.

4.3.5 Planning optimization

Initial planning should be done, and then the time required for each task should be adopted to reflect the most probable time when no constraints or problems are found to allow the calculation of time to market and project buffer.

In practical terms, the planning is done using an excel tool where from the final date and the compressed duration of each task, the estimated TTM and Gantt chart are given. The tool considers a percentage of the total time to project buffer as an input.

4.3.6 Obeya Control: Board and meeting agenda

In the weekly quality control meetings for each type of product already are discussed some topics associated with R&D projects: open projects progress and customer insights that can be the source for new product ideas.

The solution proposed suggests integrating the R&D projects Obeya control with the QC weekly meetings. The participants are PMs who manage products of that [IMRF1] type, commercials selling these types of products, production responsible for the factory where these products are produced and R&D team leader.

In order to answer both R&D projects management and quality control themes, the board available in APPENDIX H and presented in Figure 19 was designed. The board is divided by product type, so it can be used in the meetings for each specific type and also allow the visibility of the open projects portfolio.

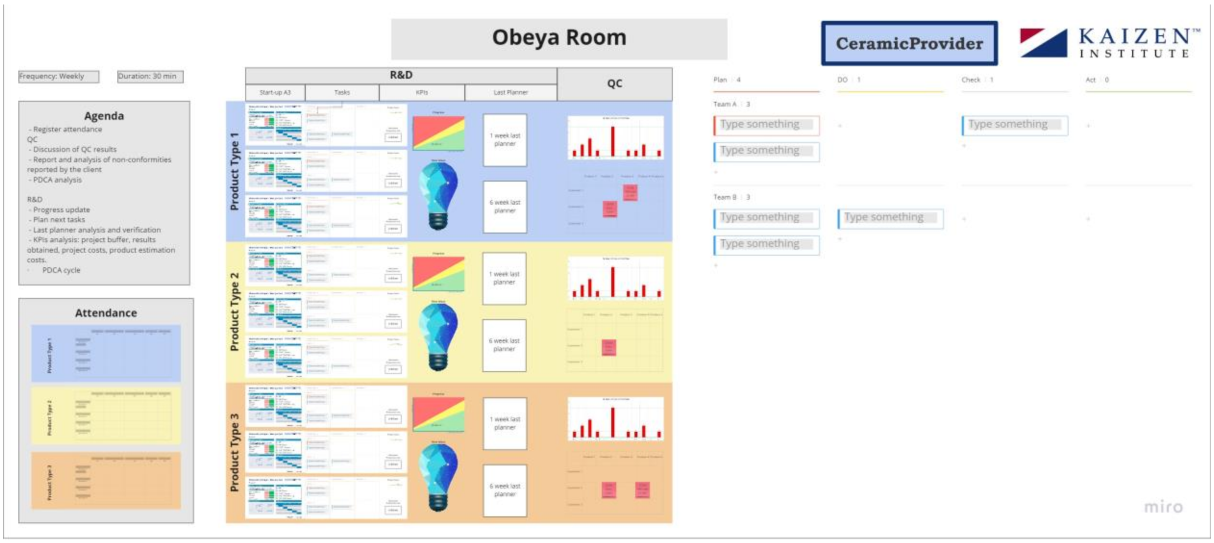

Figure 19: Obeya room board.

On the right side, for QC meetings, there is a matrix with the products' internal CeramicProvider reference rows and customers in columns. The matrix is then populated with the non-conformities reported by each client. An area for KPIs allows a visual representation of the number of non-conformities.

The left part of the board is dedicated to R&D projects and Obeya control. First are placed the start-up A3 for each project, then the planned and unplanned tasks for that project and the tasks planned for the week. Last planners should be updated and checked. KPIs part allows visualizing progress, costs and results of the ongoing project. Graphics and visual elements represent the costs associated with the project's development, the estimated cost of project development and the estimated cost of the final product (if applicable) and the project buffer consumption presented.

Ideas for new products that might arise are placed in a light bulb drawing. Finally, the continuous improvement cycle called PDCA: Plan, Do, Check, and Act is provided so improvement ideas can be registered, implemented and tracked.

The suggested agenda for the meeting follows.

Obeya control meetings Agenda:

Quality Control

- Discussion of QC results
- Report and analysis of non-conformities reported by the client
- PDCA analysis

R&D projects

- Progress update
- Plan next tasks
- Last planner analysis and verification
- KPIs analysis: project buffer, results obtained, project costs, product estimation costs.
- PDCA cycle

4.4 Daily Kaizen Meeting board

Daily Kaizen Meetings create a routine for the team to communicate and plan tasks and actions. For the laboratory team in CeramicProvider, a mock-up for the board to be used is provided in APPENDIX I. It has information on the frequency, duration and agenda of the meeting. Then, a place to register the attendance follows. In the central part, an “R&D this week” field allows to copy the tasks from the Obeya room to allow detailed planning for the week. At this point, quality control tests should also be considered and registered in the planning. Afterwards, KPIs for the team are analysed. Furthermore, a PDCA cycle was added to allow for opening and tracking improvement actions.

4.5 Team Organisation

In CE01, the laboratory team is composed mainly of PMs, professionals who graduated in the ceramic field. The time spent in the laboratory is primarily for routine tests, and the lack of time for R&D is one of the main problems referred to by the team.

To decrease the load of tests for the PMs is suggested to add a laboratory technician to the CE01 team. A CE coordinator should be named to coordinate better all R&D projects, resources, and CQ tasks. Besides coordinating, the coordinator would be in charge of gathering the team's technical knowledge and ensuring it is shared with all members.

To help solving lack of time to R&D in the current state of and the differences in time allocated to NPD, it is suggested to define morning time to develop QC tests, with all members contributing to this end until every control is finished and then allow R&D tasks in the afternoon.

4.6 Process Standards Improvement – standard work in the laboratory

The R&D team spends most of their time on QC tests in the laboratory. Data are being collected to evaluate what are the most time-consuming tasks. Then, these tasks must be standardised to ensure test efficiency and free time for R&D.

5 Conclusions and future works

The present work allowed the investigation and better understanding of lean product development, along with lean project management. After proposing various solutions from different authors, the literature review concluded that there is no consensus or standardization on the definition of some terms. In that way, future research in gathering more visions on the subject and developing a converging definition can be studied.

Regarding the CeramicProvider project, all tools must be validated in the medium term with the functional team (Innovation Committee C, R&D team and Laboratory team) to ensure the right fit for its needs. Easy access and adaptation of the tools must be guaranteed, editable templates, models and boards, so the core can be maintained while changing the elements requiring a change to answer the needs of the team. This aspect was considered for templates, and graphical model representations were done using *Microsoft Excel*, *Microsoft PowerPoint* and *Miro*. However, to allow automatic updates from laboratory test results and project journals, KD board and Obeya board KPIs will be integrated with *PowerBI* in the future.

The team is expected to overcome the initial resistance to change when they start to see results and the outcome of their daily work mirrored in visual KPIs. During the course of the project, there was already a change of attitude in this respect. Initially, the resistance to change was very high, but after some workshop sessions: design of the future vision, games to understand the usefulness and concepts of the tools and discussion of ideas with the team, there was a more predisposed attitude to collaborate, question paradigms and improve. The templates provided to document information and standard communication standard, together with the frequent team meetings, are expected to improve team communication clarity and contribute to team motivation. Regarding NPD tools, with the increase in team maturity, in the future can be integrated more tools referred to in the literature review, such as Production Preparation Process and Set-Based Engineering.

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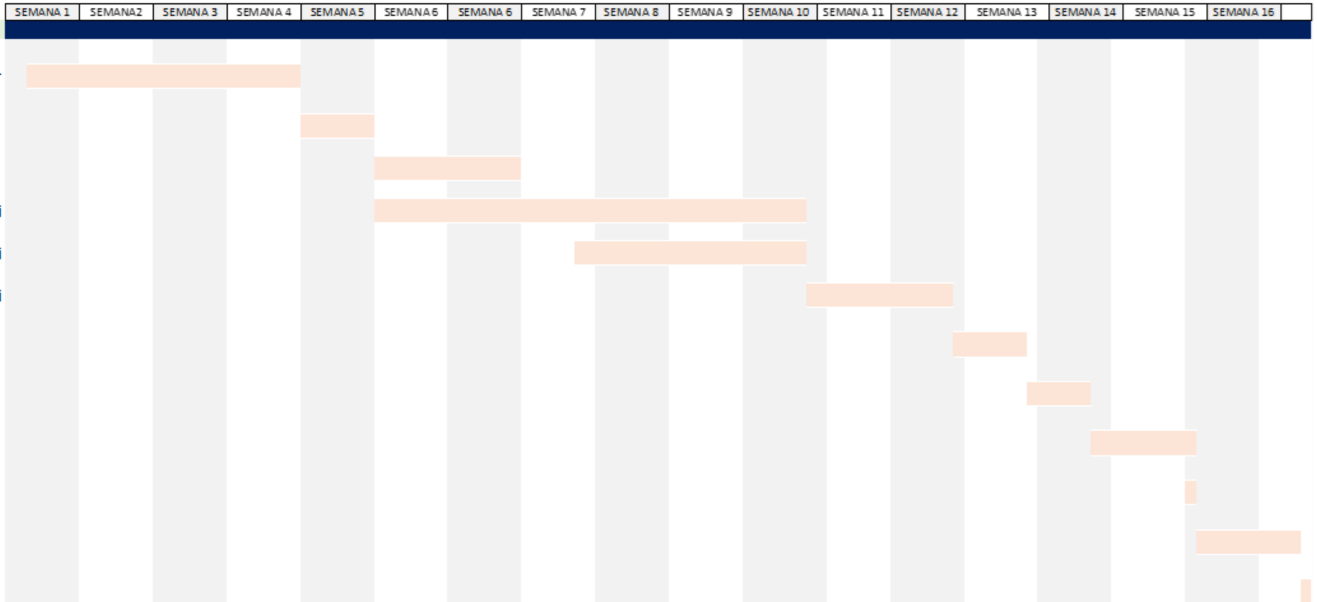
APPENDIX A: Gantt chart

Figure 20: Gantt chart.

DURAÇÃO	TAREFAS	PROGRESSO	INICIO	FIM
25	Conhecer o projeto e pesquisar	Em curso	2/mar	27/mar
6	Introdução		28/mar	3/abr
13	Estado Atual (AS IS)		4/abr	17/abr
40	Estado da Arte		4/abr	14/mai
21	Metodologia e soluções propostas		23/abr	14/mai
13	Resultados e discussão de resultados		15/mai	28/mai
6	Conclusões e trabalhos futuros		29/mai	4/jun
5	Resumo e abstract		5/jun	10/jun
9	Revisão		11/jun	20/jun
0	Entrega ao orientador da FEUP		20/jun	20/jun
9	Revisão		21/jun	30/jun
0	Entrega no SIGARRA		1/jul	1/jul



APPENDIX B: Business-case template

Figure 21: Business-case template (Mascitelli 2011).

Product Business-Case Brief	Date First Submitted:	Submitted By:
Product Designation:	Revision Number:	Prepared By:

Description of Opportunity

1 What specific customer problem(s) does the new product solve?

2 Description of target customers / market segments.

3 Key differentiating features / performance levels.
1
2
3

4 Critical physical characteristics (weight / dimensions / etc.).

5 Critical performance requirements / features.

6 Other critical requirements / mandates for competitive parity

Financial / Risk Analysis

1 Market forecast:

Sales Volumes -	Minimum	"Most Likely"	Optimistic		
Year 1				Target Market Price =	
Year 2				Target Mfg. Cost =	
Year 3				Target Entry Date =	

2 Risk Analysis:

	Risk Impact (1-5)	Description of Critical Risk(s)
Market Risk -		
Technical Risk -		
Schedule Risk -		
Cost / Quality Risk -		

3 Investment: Total Non-Recurring Investment (Capital and Labor) =

4 Profitability Calculation:
Net Present Value (NPV) = (Based on 3-Year "Most Likely" Sales)
Risk-Adjusted NPV = (NPV / Max. Risk Impact)

Strategic Assessment

Description of Strategic Alignment:

Assessment of Strategic Impact (1 - 10 Scale):

1	Supports Retention of Existing Customers -	
2	Contributes to Growth of Market Share -	
3	Encourages Pull-Through of Other Products -	
4	Supports Development of New Markets -	
5	Contributes to Product Line Cost Reduction -	
6	Contributes to Image of Firm in Marketplace -	
7	Increases "Mindshare" Among Customers -	
8	Enables Implementation of New Technologies -	
9	Supports Development of Core Competencies -	
10	Supports Overall Strategic Roadmap -	
	Total Strategic Score =	

Opportunity Assessment

Step 1 - Estimate the no. of design / development hours required to commercialize the new product.
Non-Recurring Engineering (NRE) =

Step 2 - Calculate the "Productivity Metric" for the proposed new product.
(Risk-Adjusted NPV / Est. NRE)
Project Productivity Metric =

Step 3 - Calculate Overall Project Rating .
(Productivity Metric x Total Strategic Score)
Overall Project Rating =

Notes and Comments:

APPENDIX C: Project tailoring rating method

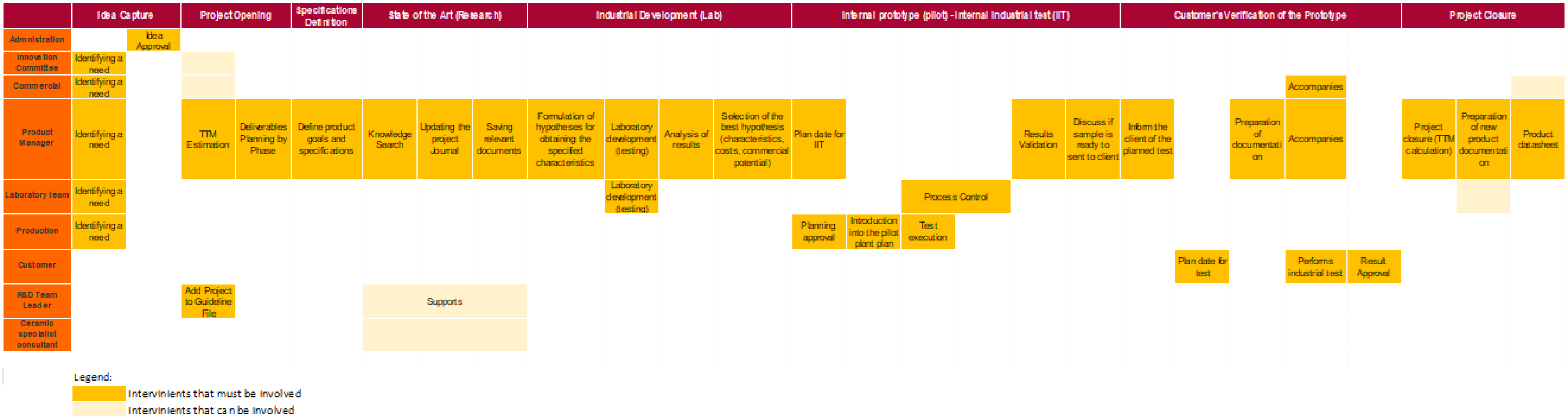
Figure 22. Project tailoring rating method (Kaizen Institute Portugal n.d.).

				CLASSIFICAÇÃO					
				1	2	3			
Dimensão	% Ponderação	Parâmetro	% Ponderação	Baixa	Média	Avançada	Ponderação Final	Inserir Classificação	
Inovação	25%	Necessidade de prova de conceito	50%	1 Parâmetro	2 Parâmetros	3 ou mais parâmetros	13%	1	0%
		Tipologia	45%	Nova Funcionalidade	Novo Produto	Nova Gama	11%	1	0%
		Necessidade de avaliar concorrência	5%	Não	Sim	Sim	1%	1	0%
Criticidade	10%	Data Limite/*Time to Market*	25%	> 12 Meses	3 a 12 Meses	< 3 Meses	3%	1	0%
		Visibilidade no mercado	25%	Sem impacto nos media	Com impacto em alguns media	Com impacto em todos os media	3%	1	0%
		Novas Normas Legais	10%	0	1	2 ou mais	1%	2	50%
		Impacto em caso de falha	40%	Impacto na produtividade	Perda de Lucros	Perda de Reputação	4%	2	50%
Cliente	5%	Interno ou externo?	5%	Interno	Interno com implicação de externo	Externo	0%	2	50%
		Impacto nas Vendas €	55%	< 100k	1000 k a 1M	> 1 M	3%	1	0%
		Alinhamento estratégico U.N	40%	*Could Have*	*Nice to Have*	Must Have	2%	1	0%
Complexidade	60%	Duração estimada	50%	Até 1 mês	1 a 6 Meses	Mais de 6 meses	30%	2	50%
		Tipo de Mudanças	35%	1	2	3 ou mais	21%	1	0%
		Recursos Necessários	5%	Sem equipa a tempo inteiro	Sem equipa a tempo inteiro	Pelo menos uma equipa a tempo inteiro	3%	1	0%
		% do projeto executada por	10%	0%	Até 50%	Mais de 50%	6%	1	
Total	**100%**					**RESULTADO:**	**100%**	Baixa	18%

Avaliação	Ponderação
1	**0%**
2	**50%**
3	**100%**

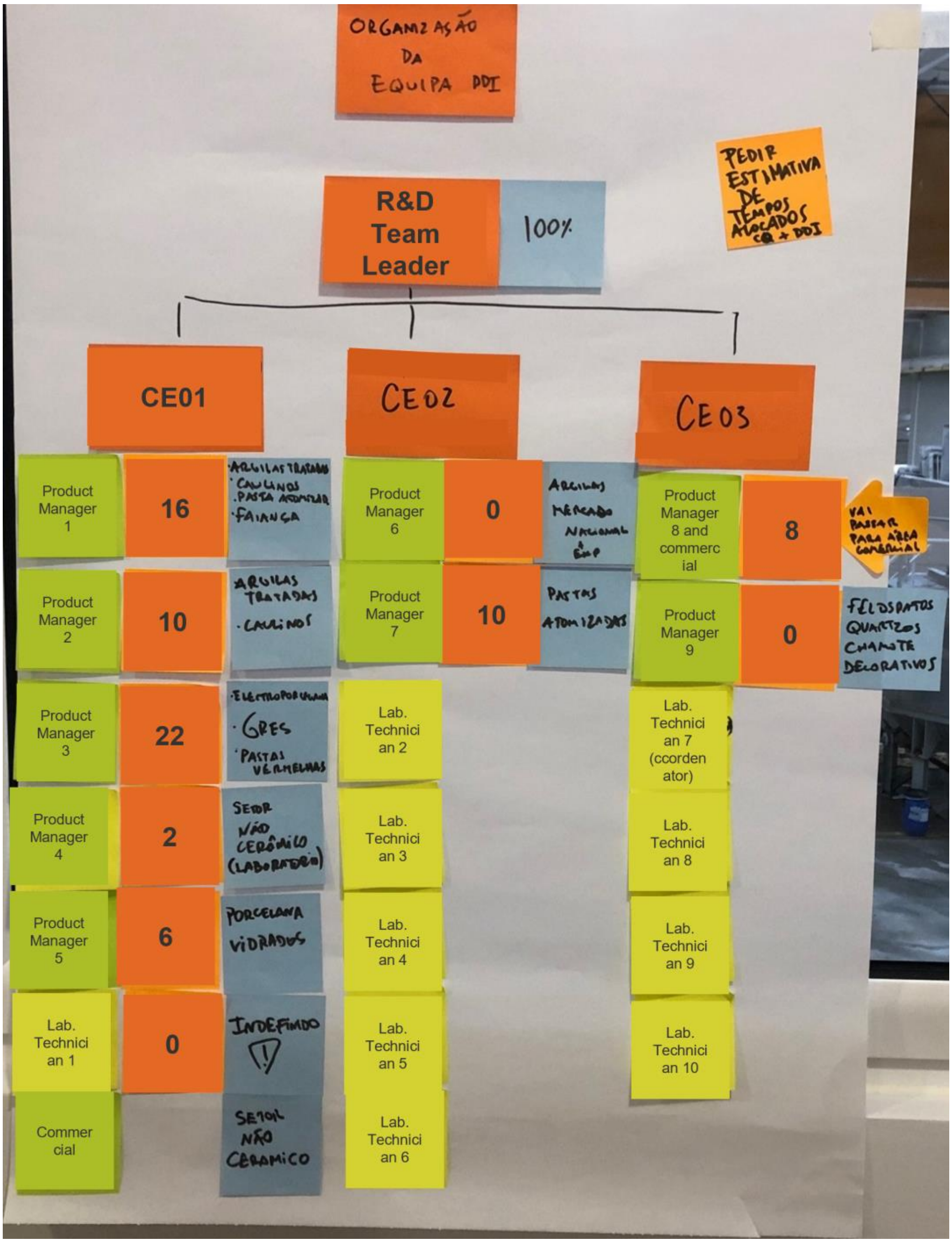
APPENDIX D: Process Mapping AS IS

Figure 23: Process mapping AS IS.



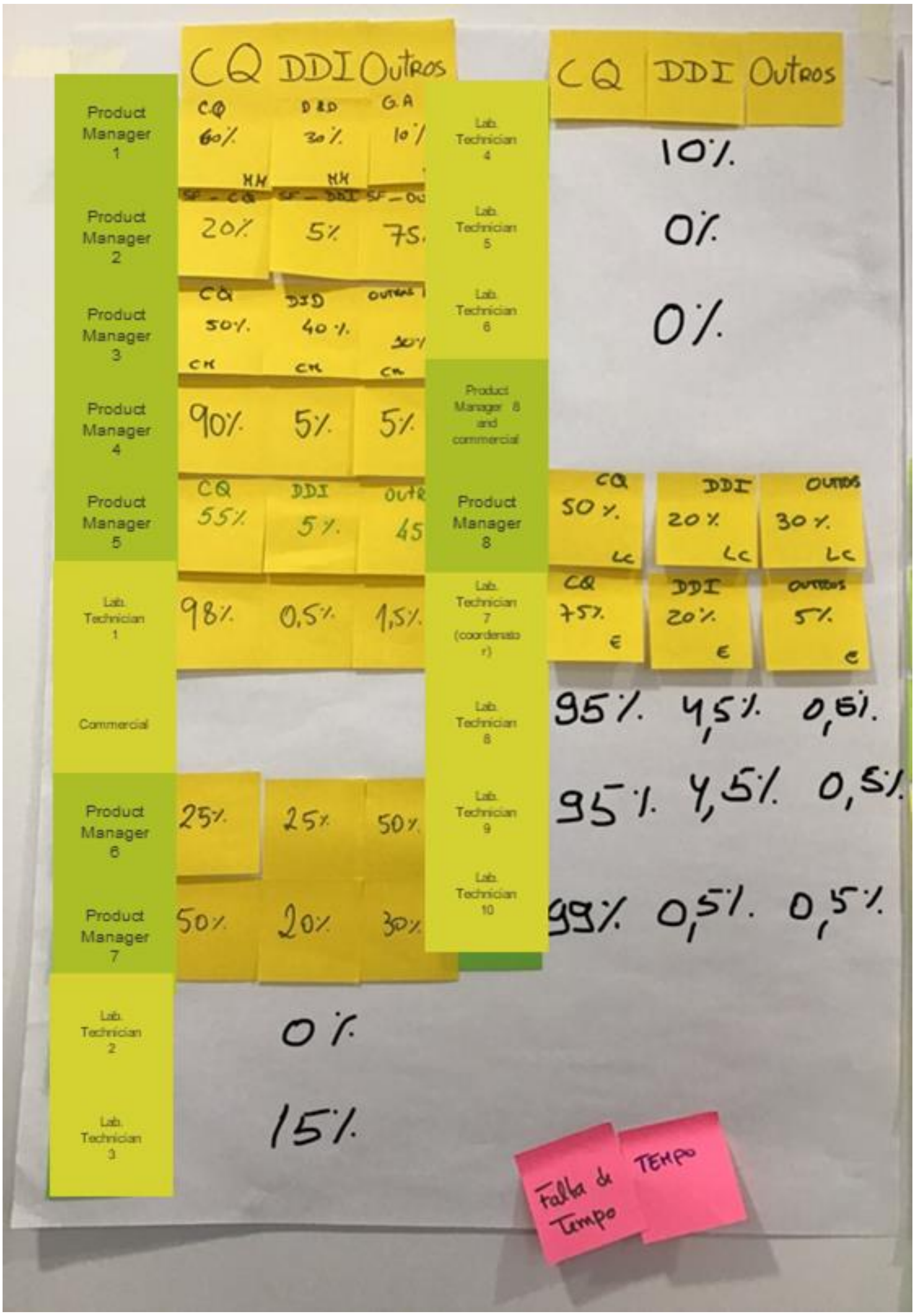
APPENDIX E: R&D Team organization and projects assigned

Figure 24: R&D Team organization and projects assigned.



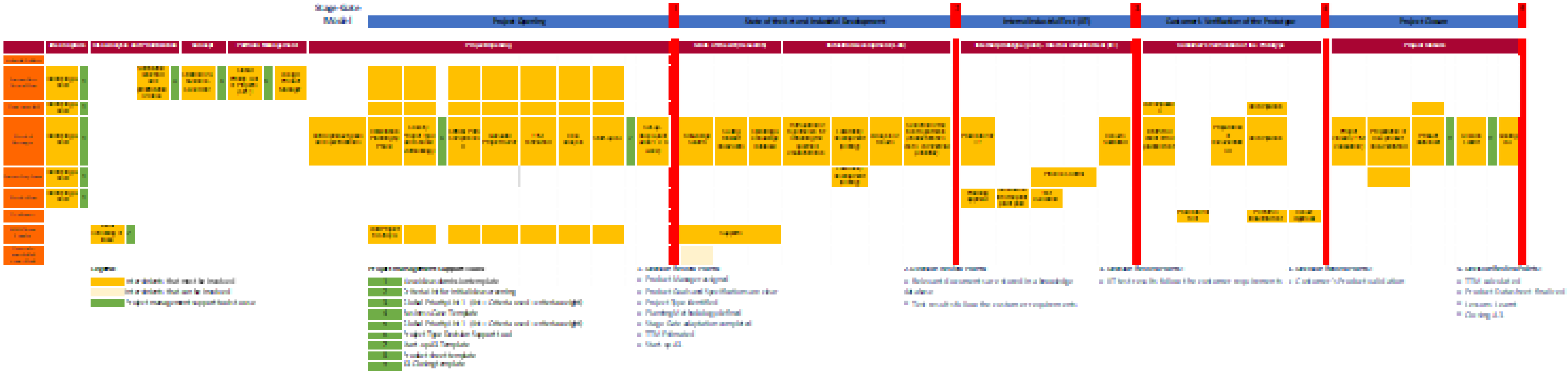
APPENDIX F: Laboratory team time allocated for QC, R&D and others tasks

Figure 25: Laboratory team time allocated for QC, R&D and others tasks.



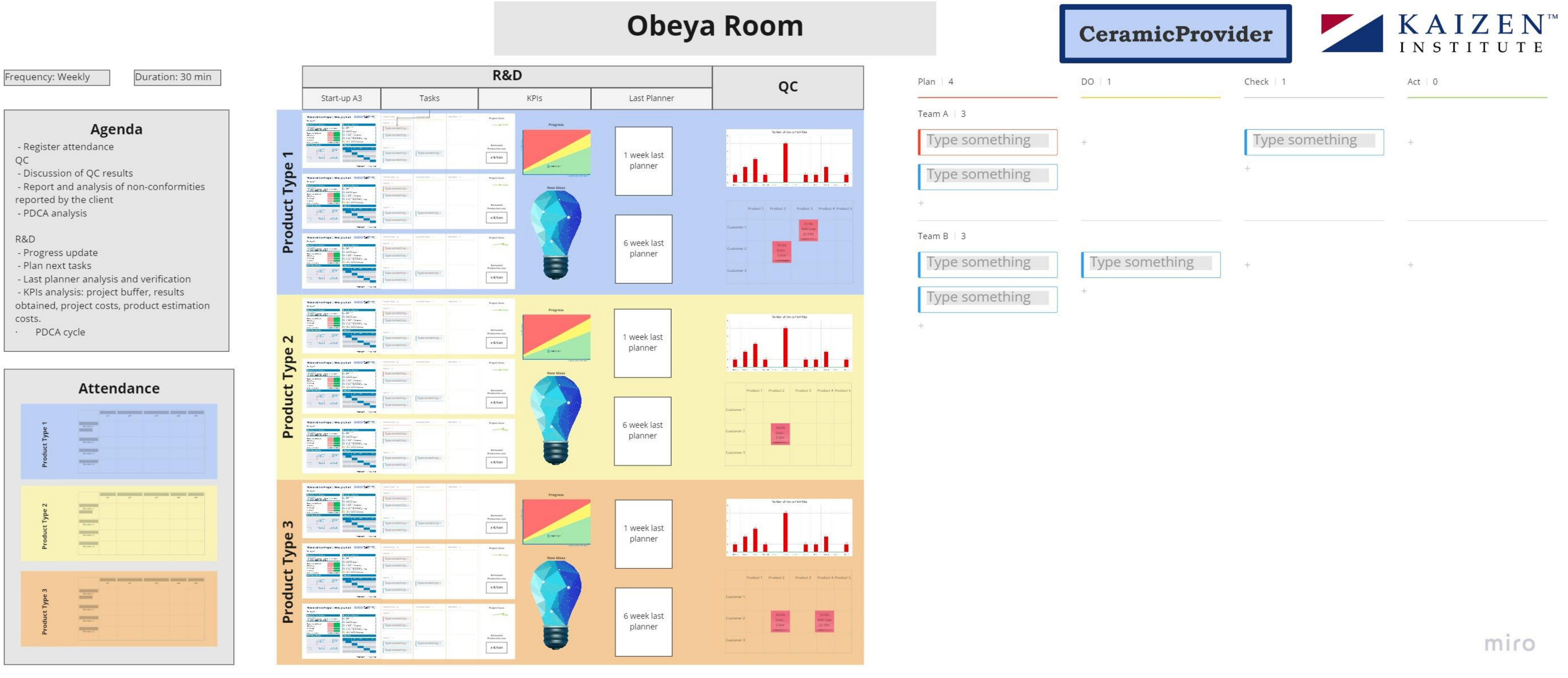
APPENDIX G: Process mapping TO BE

Figure 26: Process mapping TO BE.



APPENDIX H: Obeya room board

Figure 27: Obeya room board.



APPENDIX I: Laboratory daily kaizen board

Figure 28: Laboratory daily kaizen board.