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New Product Development Models: A Literature Review From The Perspective Of Independent Inventor

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Abstract:
***Background**: A large number of new products are introduced to the market every year, but most of them are removed from the market prematurely. The reasons for this are usually the lack of adequate knowledge about the new product development (NPD) methodology and its generality and complexity. The aim of this study is to produce an overview of three methods (Design thinking, Lean startup and Stage-Gate processes) to provide scientific information to independent inventors about such models.*
***Materials and Methods**: The methodology consisted of a literature review, analyzing the results obtained.*
***Results**: 71 articles were found (25 analyzed), which were the basis for developing the process flowcharts of the cited models, as well as their analysis.*
***Conclusion:** The results of this study can lead to the conclusion that the existing models failed: or the reasons already known, but also due to their restricted use.*
***Key Word**: Design thinking; Lean startup; Stage-Gate; New product development; Independent inventors; Design engineering.*

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I. Introduction

A huge number of new products are introduced to the market annually, by large, medium and small companies, established enterprises or even startups[7, 15]. There is no academic study that indicates the correct number, but some estimates point to around 300,000 more items each year. However, different authors state that, across all product categories, most of these new products fail (and are removed from the market prematurely); some estimate that this happens 80% of the items, reaching up to 95% of them[7, 15]. These data indicates that there are problems when these products are created, from conception to launch to the consumer, resulting in their failure.

Comparing the estimated number of new products launched with an indicator published by World Intellectual Property Organization (WIPO), but with patents as the theme, in 2022 there were 3,457,400 applications around the world[34]. That is, considering that all product concepts have been patented (with only one patent) and that the number of new products is the same above, the data reveal that only about 10% of the patents filed are transformed into new goods. And comparing the estimate of failure of new products with a published study, also on the subject of patents, but for a specific public and a different period, 21% of the applications found were active[24], tending to confirm the authors' estimate. Another relevant information from this study is that, although the majority of applicants were independent inventors (around 86%), 60% of active applications were filed by companies.

Suggested reasons for the new products fail include an intuition-based approach to new product development (NPD)[15]. The use of NPD team intuition has been emphasized as a critical factor in leveraging team creativity[1] in NPD, but not its exclusive use in designing them. The lack of adequate scientific knowledge about the NPD methodology to achieve high-quality product concepts is other reason indicated[15]. It is necessary to remember at this point that the NPD process (NPDP) is a relatively new concept. The systematization of know-how and how to produce had already begun more than a century ago in some industry fields – Fordism, in manufacturing system, for example –, however, its generalization can be observed from the Second World War and, later, with Schumpeter's theory (which reintroduced the concept of innovation, but in technological terms) and the first NPD models (NPDM).

The NPD is a process based on a series of steps or stages, interpolating mandatory development and evaluation activities and actions, to transform a new idea into a marketable product[16, 32, 33]. This process begins with a product concept that is increasingly refined until it becomes a final product, i.e. separating high-potential inventions from poor ideas[33]. The NPDP is one of the most critical and challenging tasks to manage, since it is a strong strategic decision-making process in which the product must be developed on time, within budget, and in line with customer expectations and needs[32, 33], as well as complying with a series of standards and laws to provide quality and protect consumers from health and safety risks. The NPDP is relevant for any size of company – large companies have already studied the subject[16] – but it should be crucial for smaller companies, due to their characteristics (limited data and resources, including technical, human, and financial) and competitive capacity[8, 25]. This includes independent inventors (individual inventors or small groups of inventors not directly involved with a company).

There are numerous techniques and models for NPD developed by researchers considering their particular characteristics, to understand, improve and support the process[36]. Each one (of the existing models) uses diverse strategies, focus and formulation to enable the process, presenting a high level of generality and complexity, so that no single model can address all problems[15, 36]. Their core is usually concept-problem-launch investigation. NPDM are considered manifestations of NPD best practices, making the process more efficient[12], as they combine the techniques and studies that provide the most prominent results. This also involves organizational factors that can influence the performance of the NDP team, such as strategy, coordination, organizational structures and authority[11, 18]. Therefore, the NPDP must be customized to suit a given purpose[3], the specificities of the enterprise. This means that a NPDM suited to the enterprise must be developed to assist the NDP team in dealing with the planning, execution and evaluation of tactical and operational actions in order to develop the new product.

Some studies have focused in enterprises (large, medium and small), but none have been dedicated to independent inventors, although the data suggests that most failed products were developed by them. The aim of this study is to build an information bank based on theoretical contributions on NPD previously produced and made available by other researchers. The intent is to produce an investigation of Design thinking (DT), Lean startup (LS) and Stage-Gate (SG) processes to provide independent inventors with adequate scientific knowledge about NPDM in order to achieve high-quality product concepts, avoiding the intuition-based approach and reducing generality and the complexity of the process for this audience.

II. Material And Methods

Once the objective of this study and its focus have been defined, a systematic process for conducting the research was established. So, the first step was, for each NPDM listed (MODEL: Design thinking, Lean startup and Stage-Gate), to carry out a search on the electronic platforms Google Scholar using the keywords "MODEL"+"literature review" ("MODEL"+LR).

Inclusion criteria:

1. Scientific articles about a relevant topic after 2020 were included in the database.

Exclusion criteria:

1. Non-scientific articles;
2. Editorial articles;
3. Letters;
4. Newspapers;
5. Citations;
6. Duplications.

Procedure methodology

The articles found were organized by number of citations. The first 10 articles for each keyword were analyzed by reading the article abstracts (full-text review as a second filter); the remaining studies constituted the database. The results were analyzed according to the adopted criteria and the procedure below, as well as the conclusions of the study. If necessary, to meet the objectives, new articles can be added (database or new search). No language criteria have been established. The search was conducted using keywords in the title in an advanced manner. The search was carried out on December 26, 2024. The data obtained was processed in an electronic spreadsheet.

After obtaining the search data, each study was analyzed. The fundamentals and theoretical base of each NPDM were summarized. The information collected aims to design a model flowchart suitable for independent inventors and to verify the following values: Indication (model to create new concepts or improve existing concepts), Idea Protection (patent to protect the value created – Invention or Utility model patent), Consumer contact (how much is necessary to contact the consumer), Strategy (strategy adopted by the model to develop products), Reflection stop (what is necessary to do to use the strategy efficiently), Development (how the product is developed), Customization (if is necessary to customize the model), Gain (what are the benefits of adopting the model), and Loss (what are the losses of adopting the model). If necessary, other values can be created to better describe the results.

III. Result

The search result is shown in Figure no 1; the articles found are arranged by keyword. The search “Stage-Gate”+“literature review” returned only 1 result and the article found was not available. So, a new search was performed removing “literature review” (LR), i.e. only the keyword “Stage-Gate”.

Table no 1: Analyzed studies for each keyword and number of citations (#C).

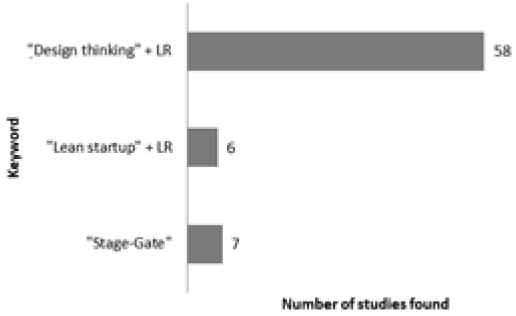
Design Thinking		
Author	Article Title	#C
Rusmann & Ejsing-Duun, 2022	When design thinking goes to school: A literature review of design competences for the K-12 level	63
Wrigley, Mosely & Mosely, 2021	Defining military design thinking: An extensive, critical literature review	34
Kurek *et al*., 2023	Sustainable business models innovation and design thinking: A bibliometric analysis and systematic review of literature	34
Grönman & Lindfors, 2021	The process models of design thinking: A literature review and consideration from the perspective of craft, design and technology education	32
Razali *et al*., 2022	Design thinking approaches in education and their challenges: A systematic literature review	27
Rahman *et al*., 2023	Systematic literature review: TPACK-integrated design thinking in education	26
Arifin & Mahmud, 2021	A systematic literature review of design thinking application in STEM integration	23
Jia, Jalaludin & Rasul, 2023	Design thinking and project-based learning (DT-PBL): A review of the literature	16
Baldassarre *et al.*, 2024	Responsible Design Thinking for Sustainable Development: Critical Literature Review, New Conceptual Framework, and Research Agenda	14
Tekaat, Anacker & Dumitrescu, 2021	The paradigm of design thinking and systems engineering in the design of cyber-physical systems: A systematic literature review	12
Lean startup		
Author	Article Title	#C
Lizarelli *et al*., 2022	Critical success factors and challenges for Lean Startup: a systematic literature review	52
Machado *et al*., 2020	Assessment Models for Evaluating the Combined use of Agile, User-Centered Design and Lean Startup in the Context of Software Development: A Grey Literature Review	3
Gamón-Sanz, Alegre & Chiva, 2024	Industries, frameworks, and key drivers of lean startup: a systematic literature review	1
Stage-Gate		
Author	Article Title	#C
Smolnik & Bergmann, 2020	Structuring and managing the new product development process-review on the evolution of the Stage-Gate® process	33
Aristodemou, Tietze & Shaw, 2020	Stage gate decision making: A scoping review of technology strategic selection criteria for early-stage projects	22
Cocchi, Dosi & Vignoli, 2023	Stage-Gate Hybridization Beyond Agile: Conceptual Review, Synthesis, and Research Agenda	12
Kitsios & Kamariotou, 2020	Stage-gate and agile manufacturing in new product development: a state-of-the art	2
Lim & Kim, 2020	A study on the introduction and operation of stage-gate process for performance management in national R&D projects-focused on the national strategic smart city program	1
Alomrani, 2021	A Review of the Use of an Agile Project Management and Stage-Gate Model	0
Cooper, 2024	Stage-Gate is Not Waterfall… Find Out Why & How.	0

All Articles found for the keyword "Stage-Gate" were available. Of the 58 studies found for the keyword "Design thinking" + LR, 9 were not available to read, 3 were only citations and 1 was on another subject, finally resulting in 45 studies found with this keyword. Of the 6 studies found for the keyword "Lean startup" + LR, 2 were not available to read and 1 was a non-scientific article, finally resulting in 3 studies found with this keyword. The articles which were analyzed (the first 10 articles for each keyword) are shown in Table no 1, organized by keyword and number of citations (#C).

Observations:

1. According to methodology, the studies Zamakhsyari & Fatwanto (2023) and Syaflita, Efendi & Azhar (2024), both for the keyword "Design thinking" + LR , were added from database;
2. Although this study sought to seek the contributions of each NPDM individually, some articles investigated hybrid models. This was not the scope of this study. Therefore, the author's research on the other NPDM researched (other than the keywords) will be considered in the respective model, but the hybrid model created will not be mentioned;
3. If the NPDM has evolved since its introduction, the most recent version of the model will be presented instead of the original.

Figure no 1: Search result by keyword.



IV. Discussion

Design thinking (DT)

The concept of DT initially emerged in the 1960s, in the design community, and has been discussed by academia for over 30 years, assuming several definitions with different interpretations and areas of application[14, 17, 31]. Therefore, there is not a single process flowchart for DT, but rather a flowchart for each model developed. Most authors refer to DT as an user-centered or a human-centered systematic innovation process to solve complex problems (real-world challenges) based on customer needs, analyzing their demands, identifying them and generating ideas by combination of analytical and intuitive thinking[4, 6, 20,26, 30, 37]. Others authors consider DT a learning or teaching strategy[9, 28, 30] or cognitive and multi-disciplinary process[27]. It is also considered that DT emphasizes aspects such as observation, collaboration, rapid learning, idea visualization, rapid prototyping and simultaneous business analysis[4]. Then, DT is used as a tool for NDP as well as for service, education, military and social fields, according to the subjects of the found articles.

The authors also emphasize the use of empathy (focusing on consumers to observe their needs). For many, this is the key to generating new high-value ideas in DT and transforming them into quality products (solution to a problem). This is due to a deep understanding promoted by the contextual problem (through the model process) and the acceptance of failure as a learning opportunity, enabling a diversity of solutions (which accelerate the innovation process) and delivering adjusted requirements. Therefore, it results in the creation of desirable, feasible and viable solutions[4, 6, 31].

Most authors did not present a DT process as a sequence of phases. Some presented a framework of themes or core capabilities as model development phases with three to five steps. It was highlighted the 3-I's Model (Inspiration-Ideation-Implementation), the Human-Centered Design, HCD (Hear-Create-Deliver), and the Double Diamond model (Discover-Define-Develop-Deliver)[14, 37]. The Design Thinking model (Empathize-Define-Ideate-Prototype-Test) and the Kees Dorst model (Formulating-Representation-Moves-Evaluation-Managing) were also presented[37]. According to the general understanding of the methodology, the process flowchart presented in Figure no 2 illustrates a sequence of activities to develop a product based on the DT method for independent inventors.

As mentioned above, the DT method has been applied in different knowledge fields. Many subjects of the found articles were about DT in education and how the method could contribute in solving problems; few presented a full process, i.e. a process to create the idea and transform it into a product. Based on the information exposed by the authors, an analysis of the DT method for independent inventors is presented in Table no 2.

Figure no 2: Process flowchart for DT method.

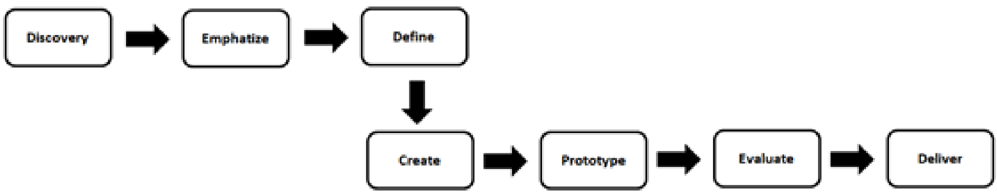


Table no 2: DT method analysis for independent inventors.

Value	Analysis
Indication:	Create/Improve ideas
Idea Protection:	Utility Model Patent/Invention Patent
Consumer contact:	Intense

Strategy:	Empathy focus on consumers to understand their needs
Reflection stop:	Existence of a representative target audience to base the process
Development:	Linear
Customization:	Adaptable
Gain:	Reduce uncertainties
Loss:	Consumer Dependence

Lean startup (LS)

The LS is a software development process considered a scientific method applied to startups, but not limited to them only[13]. LS was inspired by the principles of Lean Manufacturing (related to the Toyota Production System) that considers the optimization of resource expenditure and, adopting the perspective of the customers, emphasizes that if a feature does not add value to them, it is considered a waste[13, 22]. This “added value” is achieved through strategic experimentation[23], using an iterative product development and a validated learning strategy: a combination of hypothesis-driven experimentation (which aims achieve product fit) instead of a business plan that is driven by implementation[22].

The main priority of the method is to ensure early and continuous delivery of the product to the customer, quickly creating a minimum prototype of functionalities or a minimum viable product (MVP) to validate ideas (customer feedback) and avoid wasting resources[13, 22, 23]. Then, the hypotheses (idea) about the prototype can be tested, the knowledge and understanding of customer needs observed and the deviation to failure can be identified[22], a “Customer Development”. Customer feedback is analyzed and interpreted to draw conclusions that validate the hypotheses or initiate a pivot (a change in one or more hypotheses that are being tested through MVP), when the new hypotheses are tested again[13, 22], resulting a Build-Measure-Learn feedback loop[22]. According to this understanding, the process flowchart presented in Figure no 3 illustrates a sequence of activities to develop a product based on LS method for independent inventors.

This process allows you to reduce market risks in product development and in the creation of business models, avoiding investing time in an idea (which may not be effective) and avoiding expenses where the result is uncertain[22]. The LS method can be applied outside the software field – such as agriculture, automotive, libraries, biopharmaceutical, biotechnology, public research centers and universities, cinema, construction and energy efficiency, consultancy, local development, electric power distribution, consumer electronics, social entrepreneurship, education, tire manufacturing, financial, governmental, industry 4.0, Living Labs, advanced materials, health, social work, tourism, and clothing retail - but significant customization of the methodology is required[13].

LS shares similarities with SG and DT[13]. Although LS and SG have sequential and well-defined development stages (as will be detailed), in LS the decision to continue or not a feature is made during the development phase, not at the end of the stage or project, as in SG. And observing the process kick off, the development process in LS usually starts from an existing idea, while DT includes idea generation in its process. Based on the information exposed by the authors, an analysis of the LS method for independent inventors is presented in Table no 3.

Figure no 3: Process flowchart for LS method.

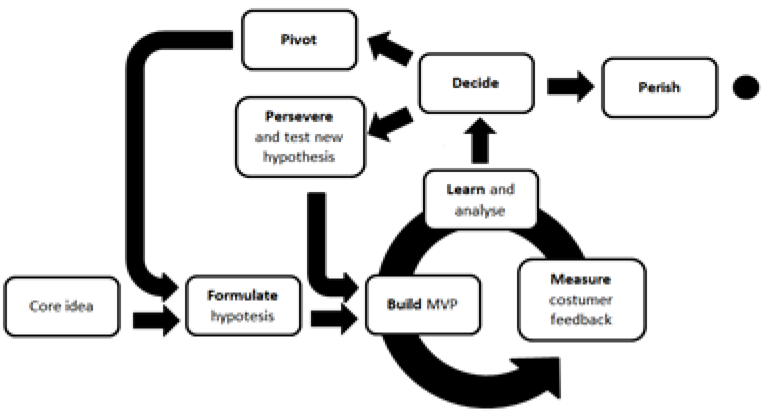


Table no 3: LS method analysis for independent inventors.

Value	Analysis
Indication:	Improve ideas/existing product
Idea Protection:	Utility Model Patent (occasionally Invention Patent)
Consumer contact:	Intense

Strategy:	MVP- hypothesis test - validation
Reflection stop:	Possibility of dividing the product into subsystems
Development:	Incremental cycle
Customization:	Significant
Gain:	Reduce uncertainties
Loss:	Consumer Dependence

Stage-Gate (SG)

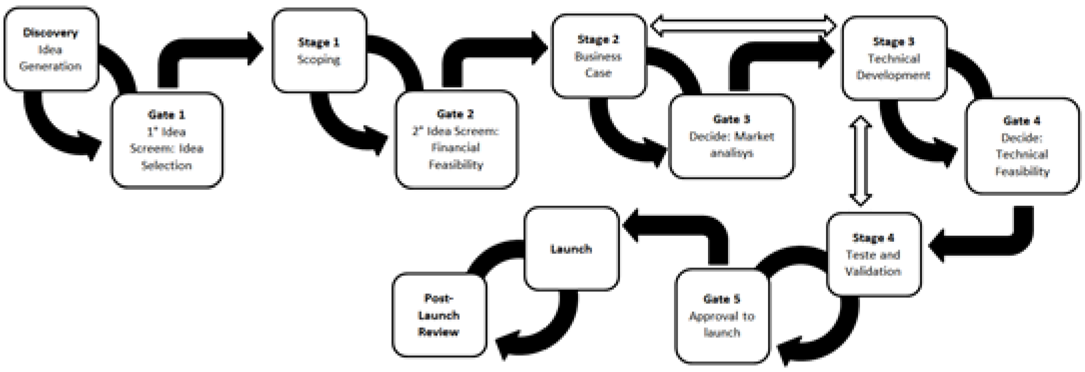
The SG process was developed in the 1980s, designed specifically for NPD and innovation, becoming the basis of most NPDP used in industry[9, 10, 29]. Decades after its introduction, SG remains the most widely adopted model and significantly influences the working methods of organizations[9, 13]. The original model consists of dividing the NPDP into distinct stages and gates, each stage with defined tasks and deliverables, and each gate with a decision criterion to advance to the next stage or to discontinue the project, covering product innovation from idea generation (Discovery) to product launch and beyond – Post-Launch review[9, 10, 13, 19, 29].

Thus, the model works as a roadmap, facilitating the understanding of project progress[21]. The stages contain a set of necessary best practice activities, divided into several small units for collecting information (the deliverables), which are analyzed acting as input to the gate[5, 10, 21]. The gates are decision points, based on a defined set of business criteria, intended to eliminate bad projects or those that compromise resources for the next stage of the project[5, 10, 29].

Initial activities contain idea generation tasks to determine unmet customer needs – Voice of the Customer, VoC[10] –, and reduce uncertainty (fuzzy front-end). The intermediate stages can be classified into "homework" phases[29], that is, searching for information about the market, the consumer and the product, to improve the quality of the project. The initial stages do not involve substantial expenses, however the phases after technical development (the back-end phases) require serious financial commitments[29]. Thus, reducing uncertainty in the fuzzy front-end means a better chance of product success, reducing the total project investment and meeting consumer desires.

Since the original model, introduced in the 1980s, the SG process has evolved, including modern NPD practices[10]. Some of them were introduced by other models, such as iteration loops between phases, giving more flexibility to the process by allowing iterations within or to previous stages or even overlapping stages. However, the author states that many companies still use outdated versions of the SG. According to the understanding of the methodology, the process flowchart presented in Figure no 4 illustrates a sequence of activities to develop a product based on the SG method (the most recent version) for independent inventors.

Figure no 4: Process flowchart for SG method (the most recent version).



As mentioned above, the SG method has been applied in different areas by companies in various fields. Companies usually adapt a scalable and context-based implementation for specific projects to manage NPDP effectively and efficiently[9, 29]. That is, depending on the size of the project, they can adopt the “full” model (large projects), or a “light” version (for moderate-risk projects), or even an “express” version with only one gate (for smaller projects). There are still, as mentioned before, studies for hybrid models, using SG, combining the roadmap (SG process) with the agility of other proposed models, often software development models. This makes SG the basis of most NPDP used, the most influential and the most widely adopted in the industry. Based on the information exposed by the authors, an analysis of the SG method for independent inventors is presented in Table no 4.

Table no 4: SG method analysis for independent inventors.

Value	Analysis
Indication:	Create/Improve ideas
Idea Protection:	Utility Model Patent/Invention Patent
Consumer contact:	Front-end phase/Moderate
Strategy:	Systematic roadmap evaluated by deliverables
Reflection stop:	Existence of sufficient technical knowledge for effective application (interdisciplinary support) and possibility of subsequent development of similar products to minimize investment in information collection
Development:	Linear
Customization:	Adaptable and scalable
Gain:	Protection against project errors
Loss:	Planning/information Dependence

V. Conclusion

Independent inventors can be great potential users of the NDPM. In the specific case, they represented the majority of the patent applicants[24], but not of active patents. That is, the created ideas could not evolve into a new product, they failure. Then, the NDPM can be a good guide for them.

The number of articles found in the search can be considered small. However, they represent a good sample, as the authors used in their database different studies – since the articles were literature reviews –, improving the efficiency of this study. So, all articles used to analysis and models flowcharts were from the search database. The search only for DT, LS and SG processes could be too restrictive, at first, however – with the exception of "Agile process" (in which DT and LS are included) –, many articles cited these three NPDM in their studies.

Firstly, for the DT process, the analysis revealed it as a method indicated for creating or improving ideas, reducing front-end uncertainties, not for developing products; independent inventors can get lost in the sequence of activities to transform their idea into a product, as can be noted in the flowchart presented. This created idea is the core of a Utility Model Patent/Invention Patent application, but the intense contact with the consumer to refine it until it meets their needs can greatly depend on the existence of a representative contact base and be a problem. And this can be extremely critical when not even the consumer knows what their needs are (this is not unusual). The DT flowchart presented is a summarization of the understanding of all the models found, containing the core theory, but some customization is necessary.

The LS process was considered a method to improve existing ideas or an existing product, in an incremental development path, not for creating it (occasionally a new idea can be created, but is not the focus of the model, as noted in the flowchart). This provides the core to a Utility Model Patent to protect the creation, however, again, consumer dependence can be a difficulty (perhaps because both methods derive from Agile process and are for developing software). The process allows the NPD, but the inventor needs to know how to break the product process down into subsystems to properly use the MVP-hypothesis test-validation strategy. Another observation is that the process seems to be an endless development: the inventor must be able to know when the MVP is the product. The significant customization (again perhaps due to the origin of the software development) can be another difficulty.

The SG process, however, was considered a method for developing new products (the purpose for which it was originally developed), for improving existing ideas or an existing product, not for creating new ideas, although its creator claimed the opposite. Its idea generation tasks suggest it is more of a refinement method than a creation stage, seeking information from the market, consumers and the product as a "homework" to avoid introducing items that tend to fail. The SG front-end phase seems to be a filter to get a better chance of product success, not to create it, protecting companies from project errors. The strategy to use a systematic adaptable and scalable roadmap with deliverables to be analyzed before continuing the process requires the existence of sufficient technical knowledge for its effective application. No deliverables are presented in the model, they will depend on customization. Then, this could be a solution for companies that have already developed similar products and have had some information collection. Product success tends to depend on correct planning; following it, the new product can be developed.

Although focused on DT, LS and SG process, this study presented that there are numerous techniques and NPDM; however, as also was mentioned, a huge number of products still fail. This and the results of this study can lead to the conclusion that the existing models failed: due to their complexity or their generality[15, 36] – and can be noted in the flowcharts presented –, or even due to their restricted use (the lack of adequate scientific knowledge about the NPD methodology[15]). Therefore, the NPDM cannot be accessed by the most potential users (independent inventors), as concluded above, and even large companies can use outdated versions[10], which may be due to failure in accessing NPDM. So, as products like these NPDM are also and being launched to the market, they failed (in being accessed, understood, consumed, and delivering what their consumer needs: to develop new products). Then, without a basis to follow, an exclusively intuition-based approach[15] remains as the method to be used, which may result in the estimated numbers presented at the beginning of this study. As future work, expand the NPDM study by including hybrid models, investigating and comparing them from the perspective of independent inventors.

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