Analysing Waste in The Development Process of Technological Innovation Projects in a Brazilian Public University

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Abstract: Technological innovation assumes a strategic role in organisational competitiveness. In this sense, it is perceived that universities represent a point of reference for the development of technological projects. The academic innovations arising from these projects are the result of three processes: product development process, business process and technology transfer. During the development of these projects, the team of researchers-entrepreneurs experiences different types of waste. This waste can be studied from the Lean Production Development (LPD) perspective. The LPD constitutes a set of practices capable of mitigating the waste that affects the new product development process (NPD). Aiming to address the scarcity of studies that address incident waste in the NPD of academic projects, this research aims to identify the frequency with which researcher-entrepreneurs experience each category and subcategory of waste during the development of the three processes (technology planning process - TPP; ii) technology transfer planning process - TTPP, and business planning process - BPP), from the perspective of the LPD. These three processes were subdivided into phases: i) initial, ii) intermediate and iii) final. Based on a quali-quantitative approach and using the methodological strategy of multiple case studies, this research analysed the context of nine technological innovation projects developed in a Brazilian federal university. Data were collected using a questionnaire prepared on a Likert scale. Eleven categories and 47 subcategories of waste were analysed in these projects. As a result, it was observed that during NPD, the waste category "waiting" was the most experienced in the different stages of the development of technological innovation, especially the subcategory "unavailability of resources". Regarding business development and technology transfer processes, the "waiting" category was also the most experienced, except in the initial phase when the "defects" category was more significant. However, analysing the 11 categories of waste, it was observed that the category "defect", especially the subcategory "information with insufficient quality" was the most experienced in the phases of technological innovation. From the identification of the different categories and subcategories of waste experienced in the context of technological innovation projects, it is clear that this research provides important elements to help identify LPD practices capable of mitigating the waste experienced during the NPD process in the academic environment.

Keywords: Technological Innovation; Waste; Lean Product Development; Academic Environment; New Product Development.

1. Introduction

Technological innovations in the academic environment involve different viable configurations of business models that allow technologies and products developed in universities to reach the market, through technology transfer to established companies and startups (Menezes *et al.,* 2023; Reis *et al.,* 2022; Elias *et al.,* 2022; Silva *et al.,* 2019; Fernandes, Reis, Serio, 2017). These innovations are the result of integration between technology/product development processes, technology transfer and business development (Reis *et al*., 2022). These processes seek to promote better collaboration between technologies, products, processes, businesses and the market (Reis *et al.,* 2022; Fernandes, Reis, Serio, 2017).

Studies have shown that during the development of these innovations, different types of waste affect the operationalisation of these three processes (technology/product development, technology transfer and business development) (Reis *et al*., 2022; Reis *et al*., 2021). To mitigate this waste, Lean Product Development (LPD) and Lean Startup (LS) practices emerge (Reis *et al*., 2022; Reis, Fernandes, Armellini, 2021; Reis *et al*., 2021). However, it is important to note that during New Product Development (NPD), the focus of LPD practices is not on the physical or manufacturing processes, but on improving the information being processed (Cordeiro et *al.,* 2023a; Cordeiro *et al.*, 2023b; Carvalho de Sá *et al.,* 2022; Reis *et al*., 2021; Dal Forno *et al*., 2016).

The intensity with which entrepreneur-researchers experience different types of waste during the NPD was not observed in the researched literature. So, aiming to overcome the lack of studies that address the waste incident in the process of developing technological innovations, this research aims to identify the frequency with which the development teams of these innovations experience each category/subcategory of waste during the development of the three processes cited, from the perspective of the LDP. It should be noted that these three processes were subdivided into phases: i) initial, ii) intermediate and iii) final.

Considering its contribution to related literature, the research identifies that the incidence of waste in the development of business originates from the wastes experienced during technology development. It was recognised that waste identification could lead to the creation of a prescriptive model of the main practices, for example, one that is related to LPD, which can contribute towards making the process of management of technological innovation, in an academic environment, leaner and free of losses, thus favoring the operationalisation of the development of technology and business through LPD practices (Reis *et al.*, 2023; Reis *et al.*, 2022; Fernandes, Reis, Serio, 2017).

2. Literature review

2.1 Technological Innovation in the academic context

The growing engagement of universities in promoting technological innovation has fostered new developments and technology transfers from the academic environment to the market (Angrisani, Cannavacciuolo, Rippa, 2023). Studies show that industry development strongly depends on scientific research, technological innovation projects developed at universities, research institutes, science and technology, as well as companies with R&D capabilities. (Li, Zhou, Tian, 2023).

To promote technological innovation in the academic environment, there are two mechanisms: technology transfer to startups (Gómez-Baquero, 2023; Papaderos, Bücken, 2023; Reis *et al.*, 2022; Fernandes, Reis, Sério, 2017) or for companies established in the market (Siegel *et al*., 2023).

With a focus on the generation of startups, it is advised that these TTOs together with academic incubators develop policies more focused on providing people with the resources, connections and knowledge they need to create new startups (Gómez-Baquero, 2023). Success in generating startups from universities, the so-called academic spinoffs, depends not only on factors at the micro level, but also factors at the meso and macro levels, such as relationships with parent organisations and regional contexts (Hossinger, Chen, Werner, 2020). Thus, the startup generation is the result of a set of stages, of a technological innovation process that comprises the integration of technologies, products, processes, business and market. (Hossinger, Chen, Werner, 2020; Ndonzuau, Pirnay, Surlemont, 2002).

According to Reis *et al.* (2022), these stages comprise three processes: i) technology planning process (TPP); ii) technology transfer planning process (TTPP), and iii) business planning process (BPP). The technology and product development process (Cooper, 2008) aims to help incorporate technology into a product and bring it closer to the market. The technology transfer process comprises the phases that begin with the development of the technology until its transfer to the market (Boguszewicz-Kreft et al., 2021; Siegel et al., 2004) and the business development process (Majdouline, El Baz e Jebli, 2022), which "corresponds to the phases of business development, which occur in parallel with technology and product development" (Reis *et al.,* 2022).

The integration of the three processes is possible based on three distinct phases. i) World of technology (initial): the researcher seeks to identify theoretical problems with practical applicability in the academic environment; ii) World of transition from technology to product and business (intermediate): the three processes become distinct, and the first approximations with the market begin; iii) Business world (final): represents the insertion of the business in the market through a commercial product (Reis *et al.*, 2022).

To support the operationalisation of these processes, there are several management practices such as those based on lean thinking, representing a way of specifying a value and minimising the efforts applied (Klein et al., 2023; Reis, Fernandes, Armellini, 2021; Reis *et al*., 2021). In this context, the principles of lean thinking applied to NPD can be operationalised by LPD practices. The use of LPD practices allows the processes of technology and product development, technology transfer and business development to be leaner, reduce waste (by identifying and mitigating impacts) and favor the elimination of elements that do not add value to products, business and technology transfer, in the process of generating technological business (Fernandes, Reis, Serio, 2017).

2.2 Classification of Waste from the Perspective of Lean Product Development

Lean Product Development (LPD) is the application of lean principles to product development, with the aim of developing new or improved products that are successful in the marketplace (de Toledo et al., 2023; Belvedere et al., 2019). By focusing on the product development process, LPD increases efficiency and reduces waste in the design of new products, identifying waste that increases costs without adding value to the product (Araujo *et al.* 2023; Reis *et al*., 2021).

Ohno (1988) identified the seven types of waste in Lean Manufacturing which include overproduction, waiting, necessary dependency, transport, overprocessing, defect and inventory. These wastes are applicable to LPD, but were reinterpreted by Bauch (2004), which added three more wastes (reinvention, lack of discipline, and restrictions on information technology resources) to achieve greater consistency and inclusiveness. This research was based on the study by Bauch (2004) as a framework for development. In it, a breakdown of categories and subcategories of losses and an emphasis on the cause-and-effect relationship inherent to each waste was identified. Thus, table 1 presents the categorisation of LPD waste.

Table 1: Categorisation of Lean Product Development Waste

Category	Subcategory	Authors
Waiting	1) People waiting for answers, approvals of test results, decisions, signatures; 2) Information waiting for people; 3) People waiting for available capacity of man or machine	1) Bauch (2004); 2) Bauch (2004); McManus (2005); 3) Bauch (2004)
Transport	1) Excessive information movement; 2) Handoffs - one of the causes of property change which is related to the waste of lack of communication of information; 3) Task Swapping; 4) Ineffective Communication	1) Bauch (2004); 2) Bauch (2004); Kato (2005); Oehmen and Rebentisch (2010); 3) Bauch (2004); 4) Bauch (2004)
Unnecessary movement	1) Lack of direct access; 2) Search for Information; 3) Remote Locations	1) Millard (2001); Bauch (2004); McManus (2005); 2) Bauch (2004); 3) Slack (1998); Bauch
Excessive processing	1) Unnecessary processes and characteristics; 2) Unnecessary precision and detail - "Excessive engineering" where too much detail is specified or exceeds required specifications; 3) Excessive transactions; 4) Inadequate use of skills; 5) Inappropriate use of tools and methods; 6) Excessive Approval	1) Bauch (2004); 2) Bauch (2004); Oehmen and Rebentisch (2010); 3) Bauch (2004); 4) Bauch (2004); 5) Bauch (2004); 6) Millard (2001); Bauch (2004); McManus (2005)
Inventory	1) Excessive data storage - considers the collection, processing, and storage of data that the process participants consider important, whether these are usable or not; 2) Queues in the critical path; 3) Unnecessary testing of equipment and prototypes	1) Bauch (2004); McManus (2005); 2) Bauch (2004); 3) Bauch (2004)
Overproduction (Non-Synchronized Processes)	1) Low timing with respect to content; 2) Low synchronization with respect to time and capacity; 3) Excessive dissemination of information - information is sent to all without the knowledge of what each one really need of ; 4) Redundant Tasks - "perform duplicate work", which may be a consequence of unclear division of labor, and poor communication and misconduct	1) Bauch (2004); 2) Bauch (2004) 3) Millard (2001); Bauch (2004); McManus (2005); 4) Bauch (2004); Oehmen and Rebentisch (2010)
Defects	1) Information deficiency with quality - "lack of quality information" 2) Erroneous information and data - "wrong data, information and reports"; 3) Anxious thinking; 4) Testing the specifications in whose content there are failures; 5) Failed tests and verifications	1) Millard (2001); Bauch (2004); 2) Bauch (2004); McManus (2005); 3) Ward (2000); 4) Ward (2000); 5) Millard (2001); Bauch (2004)
Reinvention	1) Poor reuse of projects; 2) Creativity not used; 3) Knowledge discarded; 4) Useless information; 5) Poor reuse of knowledge	1) Bauch (2004); 2) Liker (2004); 3) Ward (2000); 4) Ward (2000); 5) Bauch (2004)
Lack of discipline	1) Poorly developed objectives; 2) Badly defined roles, responsibilities and rights; 3) Rules not clear; 4) Low discipline regarding compliance with schedules; 5) Insufficient willingness to cooperate; 6) Incompetence/ poor training	1) Bauch (2004); 2) Bauch (2004); 3) Bauch (2004); 4)Bauch (2004); 5) Bauch (2004); 6) Bauch (2004)
IT resource limitation	1) Poor Compatibility; 2) Poor ability; 3) Low Capacity	1) Bauch (2004); 2) Bauch (2004); 3) Bauch (2004)
Correction of Information	1) Repair and Reformulation / Rework; 2) Scrap; 3) External Inspection of Information	1) Oehmen and Rebentisch (2010); 2) Oehmen and Rebentisch (2010); 3) Oehmen and Rebentisch (2010)

Source: The authors.

The studies mentioned above helped to structure a table with 11 categories and 47 subcategories of waste that served as a reference for the construction of a questionnaire, in order to identify the frequency with which researchers experience each category/subcategory of waste from the perspective of the LDP.

3. Methodology

This research is classified as quali-quantitative and the methodological strategy adopted was the case study, in the context of a Brazilian federal university. A case study is a research strategy that involves an in-depth and detailed investigation of one or more cases, with the aim of understanding the phenomena in question (Yin, 2009).

In this context, nine technological projects included in an innovation incentive program were studied. For the collection of project data, interviews were conducted with members of the innovation development teams, in order to build a close connection with the empirical reality, providing the development of a relevant, testable and valid theory (Eisenhardt, 1989).

In order to identify the frequency with which the members of the nine project teams experienced each category and/or subcategory of waste from the perspective of the LPD in the different stages of development of the technological innovation process, (technology and product development processes, transfer of technology and business development and with the integration of these processes from three distinct phases: initial, intermediate and final), a questionnaire was applied containing self-explanatory questions related to each of the categories and subcategories of waste. For each question, respondents indicated the degree of experience of waste in each phase of technological innovation, assigning scores from 1 to 5 (being F1-did not experience it, F2-experienced it rarely, F3-experienced it occasionally, F4-experienced it frequently and F5- experienced very often). The interviews were conducted online, lasting approximately 150 minutes each. The scores were converted into frequencies of occurrence to then perform multivariate analyses.

The analysis of the results was consolidated through Principal Component Analysis (PCA). PCA is a technique that makes it possible to reduce the number of variables, forming new variables that are linear combinations of the original variables (Hair et al., 2014). From these linear combinations, scores are calculated that, when sorted, identify the waste most experienced by members of the innovation development team. To run the PCA, the statistical software Minitab version 16 was used.

An analysis focused on the technology and product development process was carried out, and another on the technology transfer process and business development (analysed concomitantly by the similarity of the context of the processes). For each of the two processes, an analysis was carried out comparing the categories and then the subcategories of the waste considering: i) general analysis of categories and subcategories, regardless of phases (considering the three phases: initial, intermediate, and final); 2) analysis of categories and subcategories for the initial phase; 3) analysis of categories and subcategories for the intermediate phase; and 4) analysis of categories and subcategories for the final phase. With the ACP, it was possible to classify the most experienced categories and subcategories of waste based on the experience of team members.

4. Analysis and Discussion of Results

This section presents a summary of the nine researched technological projects and analyses the results regarding the degree of experience of the categories and subcategories of waste for the three evaluated processes: technology and product development process, technology transfer process and business development process in its initial, intermediate and final phases.

4.1 Project Presentation

Table 2 was constructed to detail the technological projects studied, and contains a brief description of them and their market profile. Cases 1 and 5 are focused on the pharmaceutical area, with the first focusing on the development of a drug that seeks to increase the number and quality of male reproductive cells, and the second is responsible for the development of software that increases the quality of cytological analyses. Case 3 is focused on mobile and cloud computing. Cases 2, 4, 7, and 9 focus on the mechanical areas, on the development of machines capable of optimising processes, generating energy, and monitoring possible non-compliance. Finally, cases 6 and 8 are aimed at the food industry, in order to contribute to the quality and monitoring of food.

By the end of this research, most projects were still focused on technology and product development, with no conviction about the decision to transfer to an established company or a new company. Other projects, for example, which had the intention of transferring technology to technology-based companies, were still in the initial and intermediate stages of business development, with significant immaturity, which challenged the understanding of the frequency with which researchers- entrepreneurs experienced different types of waste.

Therefore, the researchers answered questionnaires considering their individual experience in technological projects and accounted for the uncertainties experienced in ongoing projects, in order to make predictions and design the path to be followed, based on the technology transfer and development phases of the business.

Table 2: Description of Analysed Projects

Projects	Knowledge area	Description
Case 1	Pharmaceuticals	Medication based on a species of plant that changes male behavior and induces an increase in the number of spermatozoa produced by it, in addition to an improvement in semen quality.
Case 2	Mechanics and organic chemistry	Polymer printing machine that allows you to mold objects from polymers (plastic). This equipment aims for the production of a detailed object with volume and depth, obtained by overlapping several layers of polymers, layer by layer, giving the final shape.
Case 3	Mobile and cloud computing	The technology developed was born from a concept called "information management in the agent life cycle" (IMALC), which consists of a new paradigm of information and document management.
Case 4	Applied mechanics	The purpose of the technology is to detect deterioration of the geometry of the rails and the appearance of its fractures. The process for obtaining the data is done by producing a stimulus on one end of the sleepers with a hammer or similar tool.
Case 5	Computation and cytology	Analysis of cervical cell samples by imaging treatment. It is intended to create a high-performance semiautomatic computational tool capable of identifying and quantifying cellular components.
Case 6	Food and chemistry	Sensor of the chemical type the verification of the pH alteration of foods. It undergoes a change of color (light pink to violet) when in the presence of compounds released from the metabolism of decaying bacteria. The technology contributes to reducing the excess of meat waste in Brazil caused by bad conditions.
Case 7	Electrical	Generation of electrical energy by means of the waterfall of the residential or building reservoir. It works in a similar way to a hydroelectric plant.
Case 8	Food and chemistry	The research studies a way to incorporate the extract (Brazilian fruit isolates) of antimicrobial action in cellulosic film, in which the extract would be released from the same on the packaged food product. In addition to economic benefits, it can reduce losses and reduce intoxications and other problems related to food consumption.
Case 9	Blockbuster Games	Simple and innovative equipment, which integrates two technologies that already exist in the market, and enables the creation of games with sounds, through a virtual 3D environment, making its use viable for the visually impaired.

Source: The authors

4.2 Analysis and discussion of the results within the scope of the technology/product development process

To analyse the waste in the technological planning process, comparative analyses were carried out between the categories and subcategories of waste in each of the three phases (initial, intermediate and final) and, then, those with the highest level of experience were identified for the nine analysed cases. Interpreting the Minitab software output for waste categories regardless of phase, the first principal component Y1, for example, showed a variance of 0.020836, explaining 64.5% of the total variability of the original variables. In this way, the principal component can be described according to expression 1:

$$Y_1 = -0.693\ (F1) - 0.325\ (F2) + 0.451\ (F3)\ + 0.124\ (F4) + 0.443\ (F5) \tag{1}$$

Table 3: Ranking of waste experienced during the technological planning process

Categories of Waste	F1	F2	F3	F4	F5	Score	Ranking
Wait	0,2222	0,0494	0,2346	0,2469	0,2469	0,0757	1
Inventory	0,222	0,370	0,204	0,204	0,000	-0,157	2
Unnecessary movement	0,324	0,259	0,093	0,222	0,102	-0,194	3
Transport	0,333	0,296	0,126	0,156	0,089	-0,212	4
IT resources Limitation	0,389	0,315	0,093	0,176	0,028	-0,296	5
Excessive Processing	0,402	0,365	0,079	0,111	0,042	-0,329	6
Defects	0,407	0,348	0,081	0,163	0,000	-0,338	7
Reinvention	0,469	0,272	0,025	0,235	0,000	-0,373	9
Lack of discipline	0,494	0,241	0,037	0,210	0,019	-0,369	8
Overproduction	0,519	0,267	0,059	0,133	0,022	-0,393	10
Correction of informatior	0,543	0,235	0,012	0,210	0,000	-0,421	11

Source: Drawn from Minitab 16 output.

The coefficients of the equation indicate the relative weight of each variable in the component. A higher absolute value of the coefficient means the importance of the corresponding variable in the construction of the component. As the variables F1 and F2 have negative factors (represent the frequency of projects that had no or little waste), the categories of waste with low Y1 have a greater proportion of these scores, and are considered categories of waste little experienced, and may not even experience waste. Thus, the interviewees' scores for component 1 helped to create a ranking of the relevance of waste experienced during the technology/product development process (Table 3). The resulting Table 3 indicates that the higher the value of the principal component, the stronger the experience of waste.

Conducting an evaluation of the technological planning process, it was concluded that the most common subcategories (Table 4) were "type of waiting C" and "type of movement C", both with a score of 0.172. The "waiting" category was the most frequent due to the unavailability of resources, being classified as the most experienced waste, with a score of 0.076. The incidence of "type of wait B" was also observed, with a score of 0.134, representing the wait for information, results, signatures, and decisions.

Table 4: Ranking of waste experienced during the technological planning process

Subcategories of Waste	Score	Ranking	Subcategories of Waste	Score	Ranking	Subcategories of Waste	Score	Ranking
Type of Wait C	0,172	1	Type of Process E	-0,260	15	Type of Process F	-0,350	30
Type of movement C	0,172	1	Type of Defect A	-0,265	16	Type of Reinvention A	-0,355	31
Type of Wait B	0,134	2	Type of Inventory A	-0,266	17	Type of Limitation B	-0,361	32
Type of Limitation D	0,030	3	Type of Process G	-0,268	18	Type of Overproduction A	-0,364	33
Type of transport C	-0,012	4	Type of Defect E	-0,270	19	Type of movement A	-0,380	34
Type of Overproduction C	-0,014	5	Type of transport E	-0,280	20	Type of Defect D	-0,397	35
Type of Wait A	-0,015	6	Type of Fault F	-0,283	21	Type of Correction C	-0,416	36
Type of Inventory B	-0,027	7	Type of Fault B	-0,289	22	Type of Fault C	-0,419	37
Type of Fault D	-0,040	8	Type of Limitation A	-0,299	23	Type of Overproduction B	-0,426	38
Type of Correction A	-0,112	9	Type of Process D	-0,303	24	Type of Overproduction E	-0,434	39
Type of movement B	-0,188	10	Type of Defect C	-0,309	25	Type of Limitation C	-0,442	40
Type of transport D	-0,206	11	Type of transport A	-0,318	26	Type of Fault E	-0,490	41
Type of transport B	-0,208	12	Type of Process C	-0,318	26	Type of Correction B	-0,524	42
Type of Reinvention B	-0,221	13	Type of Defect B	-0,321	27	Type of Process B	-0,533	43
Type of movement D	-0,238	14	Type of Fault A	-0,329	28	Type of Overproduction D	-0,573	44
Type of Process A	-0,260	15	Type of Reinvention C	-0,335	29			

Source: Minitab 16 Score Analysis. The categorisation of waste types was based on the information available in table 1.

The "inventory" category ranked second (score -0.157), standing out in the technological and product planning phase due to the occurrence of situations in which queues are caused by bottlenecks or critical paths, such as case 7, which caused delays in the product development stage.

The "unnecessary movement" category was the third most frequent (-0.194), and "type C" was classified as the most experienced waste subcategory, with emphasis on case 9, which had many displacements in the validation of its steps. Waste of "transport" (Score -0.212) ranked fourth, evidenced in complex projects, as in case 5. The category "limitations of IT resources" ranked fifth, with "type of limitation D" evidenced in cases 2 and 4. "Excessive processing" was classified in sixth place (Score -0.329) and addressed the excess of work throughout the technology transfer process, to achieve the results. The "defect" category ranked seventh, which is one of the major causes of rework in new projects.

In eighth place is the waste generated by the “lack of discipline” category (Score -0.369), evidenced in the “type D” subcategory, characterised by the lack of meeting deadlines during technological and product planning, demotivating team members and leading to the abandonment of the project, as an example of case 9. The ninth position is occupied by "reinvention" (Score -0.373), characterised by the non-use of knowledge acquired in previous projects, which could contribute to several stages of development, experienced in case two. The "overproduction" category occupied the penultimate position (Score -0.393), due to an excessive disclosure of information and redundancy of tasks, mainly in the subcategory "type of overproduction D". Finally, “information correction” was in the tenth position of waste (Score -0.421), in which the need for rework is seen as inherent to the technological planning process.

A comprehensive waste assessment was carried out in the context of the nine projects, where the experience of waste was evaluated in a broad context throughout the technological planning process. Waste categories and subcategories were classified, considering simultaneously the initial, intermediate and final phases of the technological business planning process of all technological projects. The adoption of this procedure helped us to understand waste and its ramifications and allowed us to identify the most frequent wastes in the development of technologies and products.

Analysing the collected data, the "waiting" category was the most frequent, due to the delay caused by the lack of resources and qualified personnel. In the initial phase, the most experienced subcategory was the excessive search for information. It is observed that the subcategory "type of overproduction D" was less experienced in the intermediate and final phases. The subcategory "type of correction C" originated from the category "correction of information" and was less frequent, which contributed to identifying that, in the initial phases of project development, information was significantly scrapped in the initial phases due to the high degree of uncertainty involved in the development of the project.

4.3 Analysis and discussion of results within the scope of the technology transfer process and business development process

Similar to the method developed in section 4.2, wastes were jointly analysed for the technology transfer planning process and the business planning process. This analysis applied the answers to the questionnaires used in the nine technological projects.

In order to create rankings for the frequency with which a given waste was experienced during the technology transfer planning process and business planning process, through the PCA, the scores of the first component were calculated based on the responses of the researcher-entrepreneurs of the nine projects. The results show that when the score value is higher (score), more waste was experienced (Table 5).

Table 5: Ranking dos desperdícios vivenciados durante processo de transferência da tecnologia e processo de desenvolvimento do negócio

Categories of Waste	F1	F2	F3	F4	F5	Score	Ranking
Wait	0,6670	0,0740	0,0250	0,1230	0,1110	-0,0790	1
Inventory	0,689	0,096	0,015	0,111	0,089	-0,115	4
Unnecessary movement	0,630	0,093	0,065	0,130	0,083	-0,088	3
Transport	0,688	0,143	0,037	0,116	0,016	-0,167	7
IT resources Limitation	0,648	0,148	0,037	0,167	0,000	-0,141	6
Excessive Processing	0,711	0,133	0,044	0,022	0,089	-0,193	8
Defects	0,607	0,119	0,030	0,178	0,067	-0,085	2
Reinvention	0,728	0,198	0,000	0,074	0,000	-0,247	10
Lack of discipline	0,716	0,099	0,006	0,130	0,049	-0,124	5
Overproduction	0,657	0,324	0,019	0,000	0,000	-0,367	11
Correction of informatior	0,753	0,160	0,012	0,037	0,037	-0,232	9

Source: Analysis of Minitab 16 scores.

By analysing the frequency tables and processing the data, a small reduction in waste was observed during the technology transfer planning and business planning process, compared to the technology planning process. Most waste came from the literature on technology and product development. However, waste typologies were common in business development processes, emphasising the need for evaluation in this area of study. Detailed results of the waste subcategories can be found in Table 6. Among the categories of waste, "waiting" took first place (-0.079), justified by the lack of technical resources and people capable of providing the necessary market guidance. In second place, the category "defect" (-0.085) stood out, in which the "types of defect B" (-0.710) and "type of defect E" (-0.741) were the most common, indicating an execution of work with insufficient quality of information. The category "necessary movement" (-0.088) evidenced the loss of time and resources with the necessary displacements of people to access information that could be transmitted through more efficient electronic communication.

"Transport" (-0.115) gained prominence due to excessive movement of information, and "lack of discipline" (-0.124) was characterised by poor management of goals, objectives and responsibilities, which generate lack a of motivation in teams and non-compliance with scheduled activities.

The "inventory" category (-0.141) generated delays in the business development stages mainly caused by slowness in the decision-making process and waiting for information. "Excessive processing" (-0.167) was experienced by the use of advanced tools and methods and by excessive approvals for executed processes, overloading the team. The "overproduction" category (-0.193) was characterised by the lack of experience of those involved and the excessive generation of inaccurate information. "Information correction" has also been experienced, due to failures of external organs. For example, the lack of monitoring and verification procedures by the bodies, considering the way in which the projects were being carried out, exposed a certain amateurism in supporting technological projects. The "reinvention" category had little experience across multiple projects, receiving a score of -0.247. The "Limited IT Resources" category came in last, with a score of -0.367, demonstrating that it was not a significant barrier in the business planning process.

Table 6: Result after general analysis of the waste subcategories in the context of the technology transfer planning process and business planning process

Subcategories of Waste	Score	Ranking	Subcategories of Waste	Score	Ranking	Subcategories of Waste	Score	Ranking
Type of Defect B	-0,710	1	Type of Overproduction C	-1,536	13	Type of Wait A	-1,859	24
Type of Defect E	-0,741	2	Type of Defect C	-1,536	13	Type of transport A	-1,859	24
Type of movement c	-0,836	3	Type of Fault A	-1,536	13	Type of transport E	-1,867	25
Type of Process A	-0,877	4	Type of Reinvention B	-1,557	14	Type of Limitation B	-1,880	26
Type of Wait C	-1,155	5	Type of Process D	-1,562	15	Type of Process E	-1,899	27
Type of movement D	-1,266	6	Type of Inventory A	-1,576	16	Type of Reinvention A	-1,899	27
Type of Fault B	-1,291	7	Type of Fault E	-1,576	16	Type of Reinvention C	-1,899	27
Type of Inventory B	-1,352	8	Type of Overproduction D	-1,584	17	Type of Fault C	-1,899	27
Type of transport C	-1,395	9	Type of Fault D	-1,584	17	Type of Correction A	-1,899	27
Type of Limitation A	-1,436	10	Type of Overproduction E	-1,624	18	Type of Overproduction A	-1,947	28
Type of Limitation D	-1,436	10	Type of movement A	-1,684	19	Type of Overproduction B	-1,948	29
Type of transport B	-1,447	11	Type of Correction B	-1,759	20	Type of Correction C	-1,948	29
Type of transport D	-1,447	11	Type of Limitation C	-1,773	21	Type of Process B	-1,988	30
Type of Process G	-1,447	11	Type of Defect D	-1,778	22	Type of Process C	-1,988	30
Type of Process F	-1,535	12	Type of movement B	-1,811	23	Type of Fault F	-2,223	31
Type of Wait B	-1,536	13	Type of Defect A	-1,811	23			

Source: Minitab 16 Score Analysis.

The evaluation process considered each phase of the technology transfer process and business development process, with the "waiting" category being the most experienced in the protected and final phase. In the preserved phase, the lack of knowledge in management led the researchers to seek external help, increasing the waste of "waiting". In the final phase, the market feedback time contributed to the high degree of "waiting" waste. In the initial phase, the "defect" waste was the most experienced. The least experienced category of waste was "limitation of IT resources". The most experienced subcategory was "type B defect", while the least experienced subcategory was "type F fault". The subcategories "types of processes B and C" were the least experienced in the intermediate and final phases, related to waste from "excessive processing" that does not add value to business development.

5. Conclusion

Technological planning faces losses and waste, just like in other organisations. In this context, this study highlights the importance of assessing the frequency of waste occurring during technology, product and business development. From the data analysis it is possible to infer that the adoption of lean product development tools throughout the process can contribute to reducing waste. Comparing LPD practices with the contributions arising from the waste analysis can improve processes and rationalise the use of resources in technological projects and startup companies. Table 7 summarises the plus (+) and minus (-) waste categories experienced at different stages of the process.

It is observed that the "waiting" category is the most experienced in all three phases of the technology and product development process (TPP), as well as in the intermediate and final phases of the technology transfer planning process (TTPP) and business planning process (BPP). Regarding the waste subcategories, at least three positions are occupied by some type of waste related to waiting in the technology and product development process, while all four positions are occupied by "type B defect" in the transfer planning process of technology and business planning process.

Table 7: Summary of categories and subcategories of waste experienced throughout the development of technological innovations

	General		Inicial		Intermediate		Final	
	Category	Subcategory	Category	Subcategory	Category	Subcategory	Category	Subcategory
TPP	(+) Waiting (-) Correction of information	1 (+) Type of wait C (-) Type of overproduction D	(+) Waiting (-) Reinvention	2 (+) Type of movement C (-) Type of correction C	(+) Waiting (-) Correction of information	3 (+) Type of wait B (-) Type of overproduction D	(+) Waiting (-) Correction of information	4 (+) Type of wait C (-) Type of overproduction D
TTPP/BPP	(+) Waiting (-) IT resource limitation	5 (+) Type of defect B (-) Type of fault F	(+) Defeitos (-) IT resource limitation	6 (+) Type of defect B (-) Type of fault F	(+) Waiting (-) IT resource limitation	7 (+) Type of defect B (-) Type of limitation B and C, type of process B and C, transport E	(+) Waiting (-) IT resource limitation	8 (+) Type of defect B (-) Type of process B and C

Source: The authors

This research's theoretical contribution focused on identifying the main wastes experienced in the three processes (TPP, TTPP, and BPP). In relation to the theory, it was possible to expand the scope of the table presented on wastes (Table 1). In parallel, new findings were added. Initially, the framework proposed by Bauch (2004) had 10 categories and 37 subcategories of waste. This research enriches the literature with another structure containing 11 categories and 47 subcategories of waste. From the analysis of this new table of residues, it is possible to understand the ways in which a type of residue can be identified in the PDP. In this way, it is possible to analyse each subcategory of waste and understand the extent to which the different wastes impact the PDP.

The empirical contribution will be centered on the identification of a practice or a set of practices capable of assisting researchers-entrepreneurs in each phase (initial/intermediate/final) to mitigate the waste experienced by those involved during the development of technologies, products, and business.

A limitation is the lack of evaluation to confirm the direct influence of this waste on the development and success of technological projects. Future developments of this research may include the creation of a prescriptive model that integrates LPD with wasteful practices and LPD practices with the different phases of the three processes.

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