Model to classify and reduce rework in the production of digital routers in a PIM Company.

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Abstract

Rework has been a challenge for organizations, especially in Brazil, where there is still a lot of waste of resources (IDB, 2018; EMBRAPA, 2018). This case study aims to contribute to improving the classification and rework`s reduction in the sectors involved with the production of digital routers from the company EX da Amazônia (fictitius name), located in the Industrial Pole of Manaus. To this end, bibliographic research and methodology with seven phases, allowed to develop and apply a questionnaire to 71 employees who work in seven sectors involved with the processes of the organization's digital routers. The analysis was carried out with descriptive statistics, which allowed the identification of the best concepts for the term, the main problems, their causes, and effects, as well as reaching the main conclusion that the best model to classify and reduce reworks in the organization, must be developed by senior management, based on an interdepartmental approach, with diagnoses of the situation in each department, as well as the adoption of an annual plan to combat rework, supported by the use of information and communication technologies, awareness campaigns, continuous training, IT tools, quality approaches for improvement projects, audits, standardization, identification and dissemination of good practices, and recognition of employees.

Key-words: Rework; Classification; Conceptual Model;

1. Introduction

An analysis by employees of the Inter-American World Bank (IDB, 2018) pointed out that in terms of fiscal spending, in Brazil and other Latin American countries; there are inefficiencies and waste that could add up to close to 4.4% of GDP. Another study by EMBRAPA with FGV revealed high food waste in Brazil annually, where each Brazilian wastes 41.6 kilos of food (EMBRAPA, 2018).

Waste is something that the consumer does not want to pay (SLACK et al., 2002). In Brazil, this problem is not only present in the public sector, in the rural area or homes, but also in the industries, generally concerning to rework, being considered enemies that affect the competitiveness of any company.

This research is a case study carried out at the company EX da Amazônia located at PIM (Manaus Industrial Pole), with 19 suppliers and 1264 employees. It assembles printed circuit boards in microwave ovens, chargers for notebooks, remote controls, and digital routers, which account for 80% of annual revenue in 2018 and 2019.

In productive terms, the company divides its products into these four families: remote controls, sources, digital routers, and several, which go through two processes, the assembly of printed circuits in automatic insertion and the finishing in the production sector.

The research focuses on the family of digital routers. In nine months (January to September 2019) was identified that they have high cost in rework, with a peak of 30 thousand reworks in a specific product, due to project changes by the supplier, with lost productivity, late deliveries, and customer dissatisfaction. The production of routers, there is a chain of actions that go through various sectors that involve about 284 employees (Table 1).

Table 1: Number of employees involved in the production of routers at EX da Amazônia.

Sector	Number of employees	Sector	Number of employees
Purchasing	3	Automatic Insertion	18
Engineering	3	Manual Insertion	237
Production Planning and Control	2	Quality	11
Warehouse	8	Expedition	2
Total of employees: 284			

Source: EX da Amazônia (2019)

Regarding the production process of digital routers, there are the following steps: the automatic insertion (AI) of surface mount components known as SMD (Surface Mounted Device) and manual insertion (IM), the latter being the one that has registered the higher number of reworks in the company.

1.1 Problem and key question

Each sector related in the production of routers has specific assignments, whose employees may receive or generate dysfunctions in their processes that end up culminating in rework, unnecessary efforts to do again one or more activities performed in the wrong way the first time (LOVE, 2002).

The company has used the Return Merchandise Authorization (RMA) approach to try to manage the rework. Its script starts with a rejection in the production process in which the quality or production identifies the fault, rejects the batch, segregates it to be again reprocessed on the production line, or overhauled elsewhere.

Currently, the company is seeking to computerize processes to improve data management with the areas involved, to reduce losses from rework. So, the research problem lies in the fact that there is no accurate system or conceptual model to classify and monitor reworks to identify the causes and propose solutions aimed at reducing them. Thus, the question of the study "What is the best model for classifying and reducing rework in the sectors of the EX da Amazonia, involved with digital routers?"

1.2 Objectives

The general aim is to contribute for the improvement of the classification and the rework`s reduction in the sectors involved with the production of digital routers in the EX da Amazônia.

The specifics objectives are: a) to identify conceptual models that classify, analyze and help reduce rework; b) to identify the main problems that generate rework with a high impact on the company's costs; c) to identify the effects of rework for the investigated company; d) to propose a conceptual model that allows classifying and reducing rework.

1.3 Importance of Research

The research contributes to helping in the computerization process adopted in the organization. It also helps to reflect on the concepts that involve rework, as well as finding ways to classify and reduce them over time, positively impacting productivity, increasing employee morale, reducing costs, and customer satisfaction, not to mention the environmental benefits.

For the academy, the research adds a case study for teachers who teach related quality management classes, as well as for researchers interested in the topic to conduct new research.

For society, the research contributes to the reduction of environmental problems generated by rework, as well as serving as a benchmark for other companies.

2. Theoretical Reference

2.1 Rework around the world

Several authors have already researched rework. Tables 2, and 3 points out that most of the more systematic studies are developed abroad focused on costs and the civil construction industry.

Table 2: Impact of rework on construction companies in 5 countries

Authors	Abstract
Barber et al. (2000)	In the United Kingdom, costs of quality failures in two overpass construction projects were studied, ranging from 16% to 23%, including the cost related to the delay, if removed, the cost of quality failures would be between 3.6% and 6.6%
Josephson et al. (2002)	A study carried out in Sweden revealed that the costs of the defects identified in 7 building construction projects ranged between 2.3% and 9.3% of the contract value. In another study also in Sweden, the costs of quality failure represented about 6% of the original contract value;
Fayek et al. (2003)	A survey of 108 rework incidence fields in Canada revealed the following cost indices: (a) Engineering and Revision = 61.65%; (b) HR = 20.49%; (c) Materials and Equipment Supply = 14.81%; (d) Construction Planning and Control = 2.61%; and (e) Leadership and Communication = 0.45%;
Rhodes, and Smallwood (2003)	In South Africa, the cost of rework was 13% of the value of the completed work.
Love, and Edwards (2004) Love (2002)	An organization representing the Construction Industry in Australia has identified an average cost of rework of 6.5% compared to the contract value for projects without a quality management system (QMS). On the other hand, they found that the cost of rework for projects with QMS was on average 0.72%; In another study in Australia carried out with 161 projects, it was found that the average costs of direct and indirect rework varied 5.6% and 6.4% of the value of the original contract.

Source: Ekambaram (2006 p. 5.2)

Table 3: % of the cost of reworking construction projects in several countries

Authors	Country	% of Cost
Cusack (1992)		10 *
Borroughs (1993 apud MASTENBROEK, 2010)		5 *
CIDA (1995)		6,5 *
Lomas (1996 apud MASTENBROEK, 2010)	Australia	>1*
Love et al. (1999 apud MASTENBROEK, 2010)		2,4 e 3,15*
Love (2002)		6,4*
Cidb (1989 apud MASTENBROEK, 2010)	Singapore	5 a 10 **
Burati et al. (1992 apud MASTENBROEK, 2010)	USA	12,4 **
Abdul e Rahaman (1993 apud MASTENBROEK, 2010)	England	2,5 a 5 *
Hammarlund et al. (1990 apud MASTENBROEK, 2010)	Sweden	6 **
Josephson e Hammarlund (1990, 1996 apud MASTENBROEK, 2010)	Sweden	2,3 a 9,4 *
Observation: *% of the contract value; **% of project cost		

Source: Mastenbroek (2010)

2.2 Rework in Brazil

No research has been identified on models for classifying and reducing rework in Brazil, and there is little research on the impact of rework on the performance of Brazilian organizations, similar to EX da Amazônia.

However, it is possible to highlight the results of the Federal Government's More Productive Program (P+B), launched in 2016 to stimulate the competitiveness of companies, especially small ones, through consultancies carried out by SENAI professionals in the process of manufacturing to identify and reduce waste through the implementation of lean manufacturing tools.

The methodology was developed by the National Industry Center (CNI), using lean manufacturing tools to reduce overproduction, waiting time, transportation, over-processing, inventory, movement and rework. These gains are for approximately 3000 small and medium companies, operating in the food and beverage, metalworking, furniture, and clothing and footwear sectors.

A report was published in 2018 by the Economic Commission for Latin America and the Caribbean with IPEA (ECLAC, IPEA, 2018), which revealed that:

a) the average reduction in rework was 64.82% in the benefited companies;

b) the industrial sectors with the substantial reductions in rework (Figure 1) were clothing and footwear (Vestuário e calçados = 70%), followed by metal mechanics (66%);

c) small companies had the massive average reduction in rework (71.4%);

d) the states of Rio Grande do Norte, Tocantins, and Acre had the highest rates of average reduction in rework, while Ceará, Amazonas, and DF had the lowest performances (Figure 2).

Another research was developed by De Souza (2018) with eight companies in the IT area, developers of business management systems. Which identified that the resistance of managers, the client, internal conflicts, the poor qualification of the developer professionals, the personal insecurity of the client and employees, the excessive empowerment of the commercial sector, the reactivity of the client's employees, the distance from the professionals, the deficient training and the implementation planning were considered elements that induce rework.

To alleviate these problems, De Souza (2018) recommended approaching designers and service professionals, conflict management, valuing users' opinions, training, selecting the profile of users, and managing project resources.

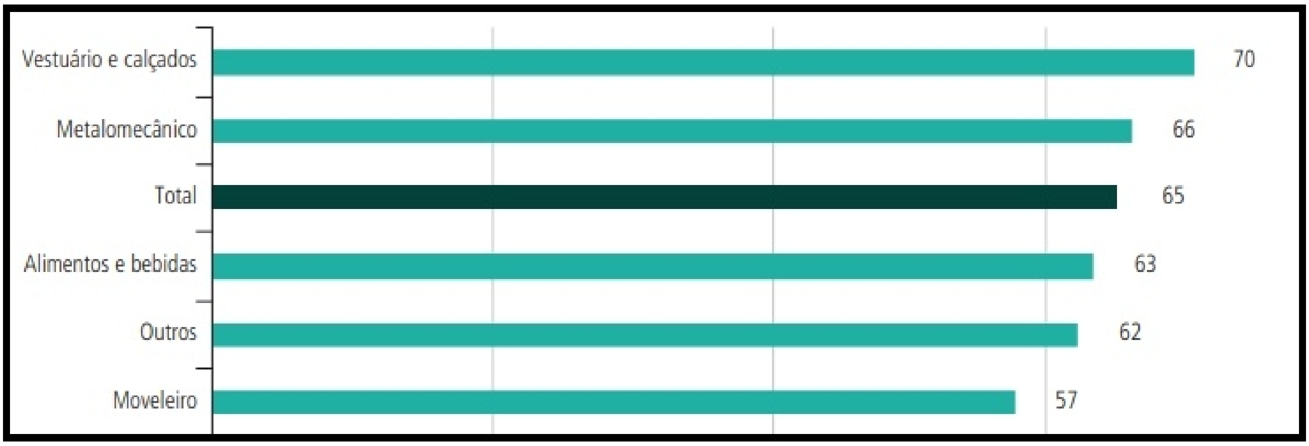

Figure 1: Average reduction (%) of rework by sector
Source: CEPAL and IPEA (2018)

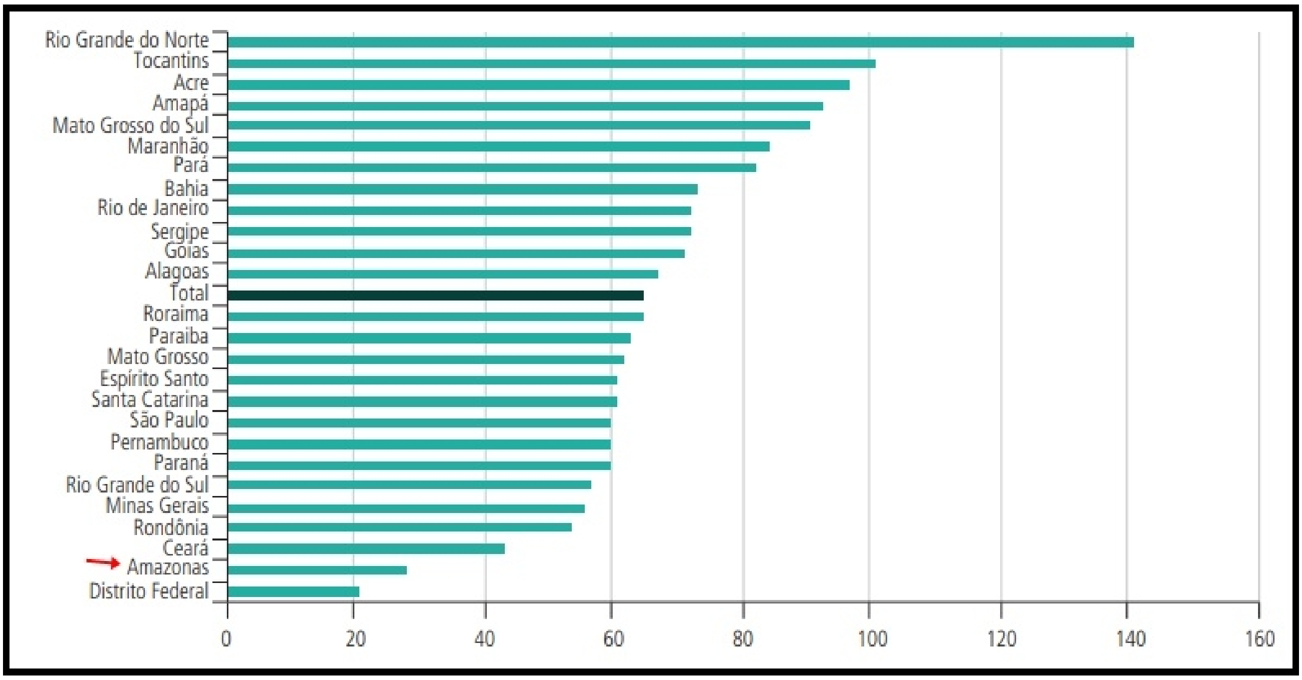

Figure 2: Average reduction (%) of rework by State
Source: CEPAL and IPEA (2018)

2.3 Rework concepts and models for classifying them

Mello et al. (2018) believe that rework is the execution of extra activity to meet a standard that was not achieved in its normal process, where reprocessing is necessary to meet the original requirements of the product, rework is also the correction of imperfection out of quality specifications.

For the authors Hwang et al (2009), rework means that a job must be redone because of not meeting the requirements.

The authors Love and Li (2000) are well known as experts on the subject with several publications, affirms that rework means the effort to redo a process or activity that was implemented incorrectly for the first time.

The authors Josephson, Larsson, and Li (2000) developed a concept that was limited to the construction industry, a rework means an unnecessary effort to correct errors in construction.

Mastenbroek (2010 p. 4) agrees with what was proposed by Love and Li (2000), who used the studies of Farrington (1987) to classify rework in four categories, namely:

Category 1) Change: a targeted action that changes the requirements established;

Category 2) Error: an item or activity in a system that is developed incorrectly;

Category 3) Omission: some part of a system has been forgotten, not executed;

Category 4) Damage: damage caused by employees, contractors, weather conditions, or natural disasters.

To achieve the objectives of his research, Mastenbroek (2010, p.7) proposed a model to try to categorize the sources and consequences of rework (Figure 3).

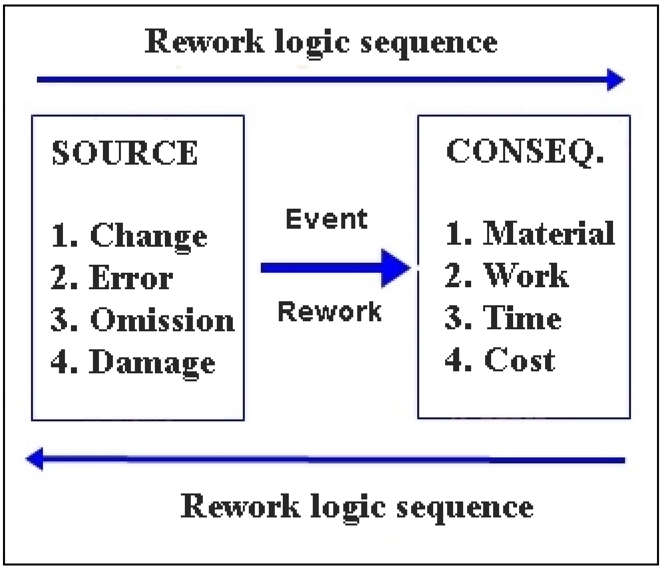

Figure 3: Classification of reworks
Source: Mastenbroek (2010 p. 7)

The sources have the four categories mentioned, while the consequences were classified as indicators, divided into 1. Material; 2. Work; 3. Time; 4. Cost.

Regarding the consequences, Mastenbroek (2010) presented some examples extracted from the literature review. Such as delays in the delivery of projects, extra work, increased costs, increased scraps, stress, fatigue, interdepartmental conflicts, downtime, demotivation, reduced profits, damage to the image of the professional, and even the company, dismissal, dissatisfaction of customers or users, etc.

In summary, this author developed an interesting methodology to measure the costs of rework in the civil construction industry, to identify, classify and analyze 45 causes that generated rework in the design and construction processes, identifying together with the collaborators the most severe and causes impact and proposed improvements to reduce them.

Wasfy (2010) studied two models of rework. The first conceptual model points out the causes of rework and its impacts on the productivity and performance of a project, while the second model classifies the causes of rework.

The first model (Figure 4) used was proposed by Love and Edwards (2004), which consists of three factors that directly and indirectly impact rework. They are the characteristics of a project, the organization's management practices, and project management practices. These factors influence the productivity and performance of the project.

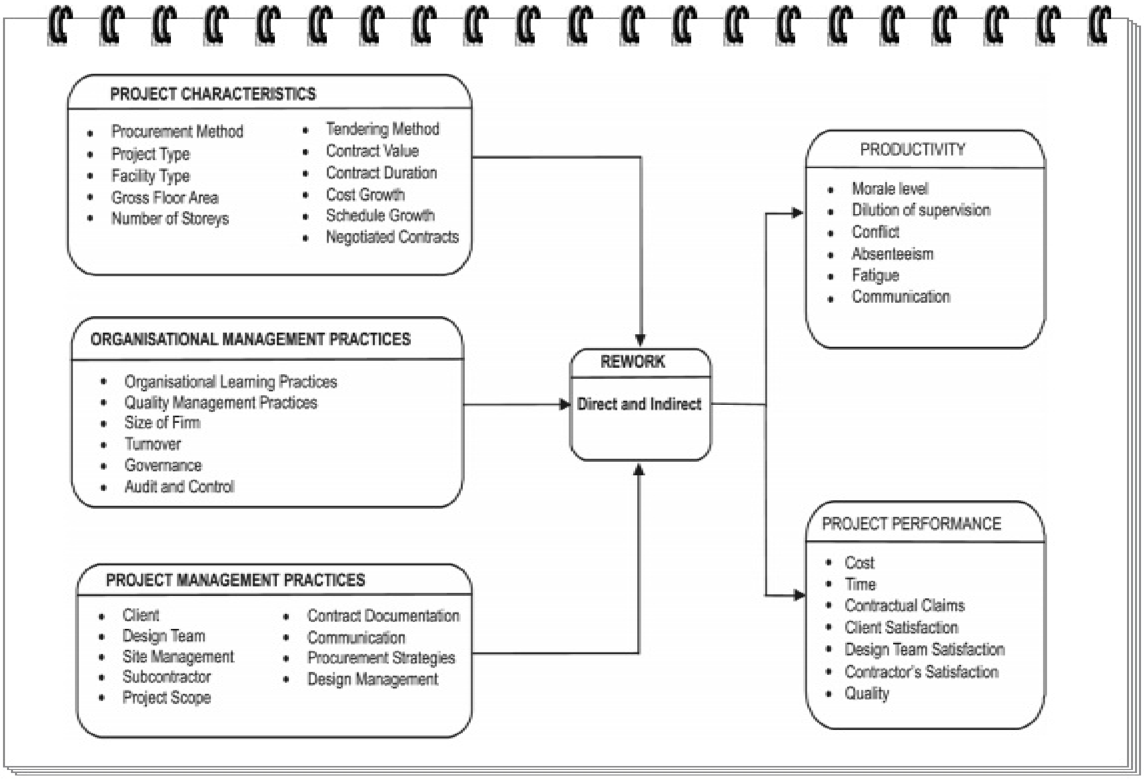

Figure 4: Conceptual Model containing the factors and impacts of Rework

Source: Love and Edwards (2004, p. 261)

In summary, Figure 4 points out that the characteristics of the project, organizational management practices, and project management practices can influence the rework and performance of a project.

Project features include acquisition method, project type, facility type, contract value, contract duration, etc. Among the organization's management practices are organizational learning practices, quality management, company size, turnover, governance, audit, and control.

And concerning project management practices, we can mention the design team, subcontractors, the scope of the project, contractual documentation, communication, project strategies, and design management.

Among the effects of rework on productivity are impacting on employee motivation, conflicts, absenteeism, fatigue, etc. Besides, rework affects not only costs and scheduling, but also has a negative influence on the relationship between departments and the well-being of employees (LOVE and EDWARDS, 2004).

Regarding the effects of rework on project performance, there are impacts on costs, delivery time, contractual dispute and dispute, customer satisfaction, etc.

Another model (Figure 5) studied by Wasfy (2010) was proposed by COAA (2001) to classify the causes of Rework.

This model has five factors that can group the causes of rework:

a) Engineering and Revision: not sufficiently advanced design, changes in scope and design, poor documentation control, errors, and omissions;

b) Human Resources Capabilities: excessive overtime, insufficient skill levels, unclear job specifications, incompetent supervision, and poor work planning;

c) Leadership and Communications: poor communication between the inspector and the builder, lack of security, lack of commitment to quality assurance and/or quality control, inefficient management of the team, etc;

d) Construction Planning and Programming: failure to meet specifications, premature deliveries, materials out of place when needed, etc;

e) Supply of Material and Equipment: unrealistic programming, late entries by the owner, late deliveries, etc.

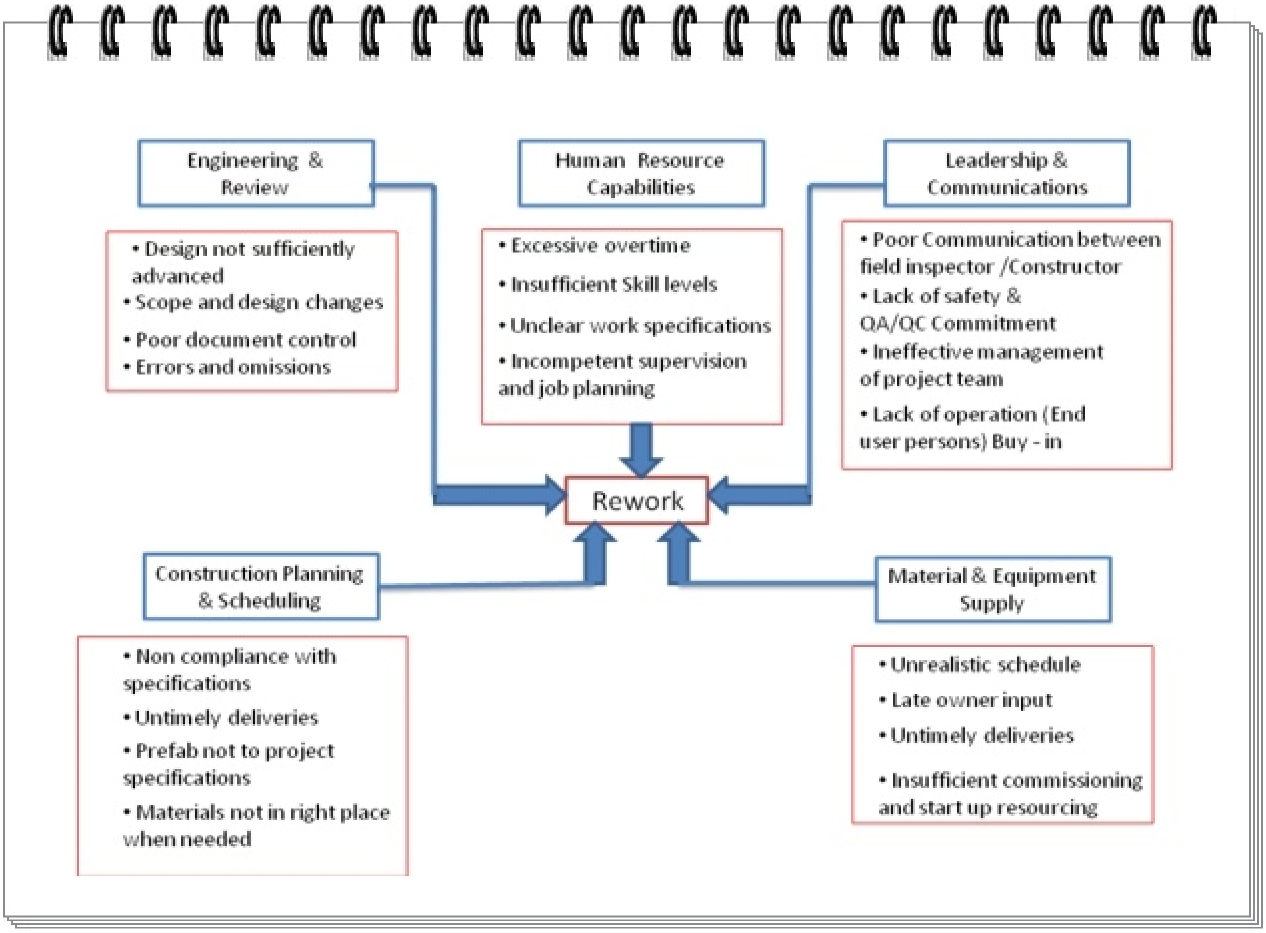

Figure 5: Model for Classifying the Causes of Rework
Source: COAA (2001)

Based on these two models, as well as on his experience, Wasfy (2010) suggested the model proposed in Figure 6 to classify the causes of rework.

The model proposed by Wasfy (2010) classified the causes in two categories. The first contains the causes of rework that occurred indirectly, involving the inadequate selection of the subcontractor, inadequate work protection, lack of coordination, as well as an inadequate sequence of work.

The category containing the direct causes of rework: insufficient and incompetent supervision, inadequate labor, incorrect material, defective material, errors, and omissions in the drawing, etc.

Several issues need to be considered to reduce or minimize the occurrence of rework in construction projects, such as changes, the use of information technologies, the training of supervisors, the quality control plan, the inspection project, etc. (WASFY, 2010, p. 31).

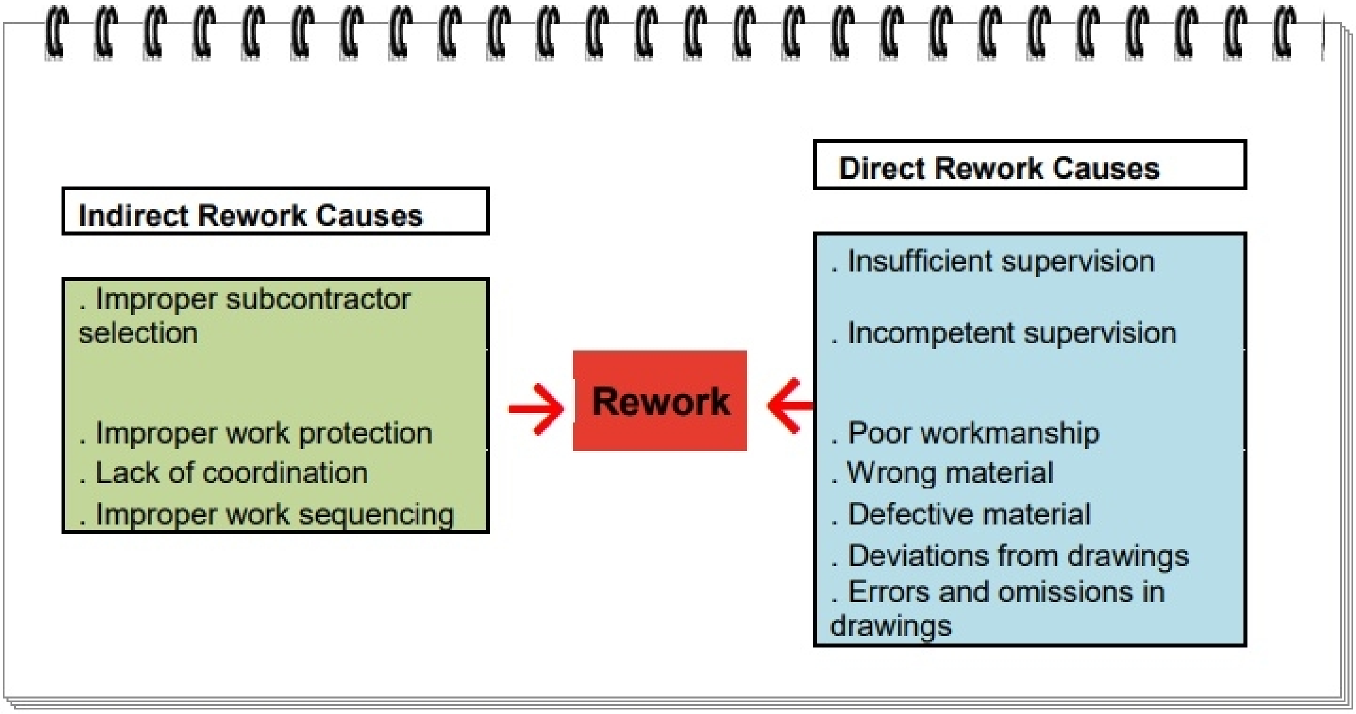

Figure 6: Model for classifying indirect and direct causes of rework

Source: Wasfy (2010 p. 28)

Other authors frequently cited in research to classify rework in the construction field are Fayek et al. (2004) that conducted a study to establish great practices and indicators for construction companies to reduce overwork in Canada. These authors were also inspired by the model in Figure 5 to develop the methodology presented in Figure 7 to collect data, generate indicators, and monitor events related to rework.

To facilitate data collection, they developed a system called the Field Rework Data Collection System (FRDCS), using Microsoft Access 2000 software together with the Microsoft Visual Basic 6.0 interface.

This system allows the elaboration of several graphs, through which it is possible to analyze the trend of rework, which impacts on costs and deadlines, to develop strategies to reduce the problem. The details of the study carried out by Fayek et al (2004) in Canada can be seen in the Research Report published by COAA (2003).

In short, the methodology begins when an incident is identified in the field, which involves something to be redone over time. The professionals who identify these incidents can be operators, supervisors, technicians, engineers, Quality Control employees, etc.

Depending on the type of incident, they can report the matter to their respective bosses to obtain instructions, which can be classified into two categories, or the job is redone or accepted as it stands.

If it is decided to rework, managers need to provide resources, instructions on the processes and set a deadline for completion. Besides, there was a concern to create a database to register the characteristics of rework, involving causes, classification, indicators, etc.

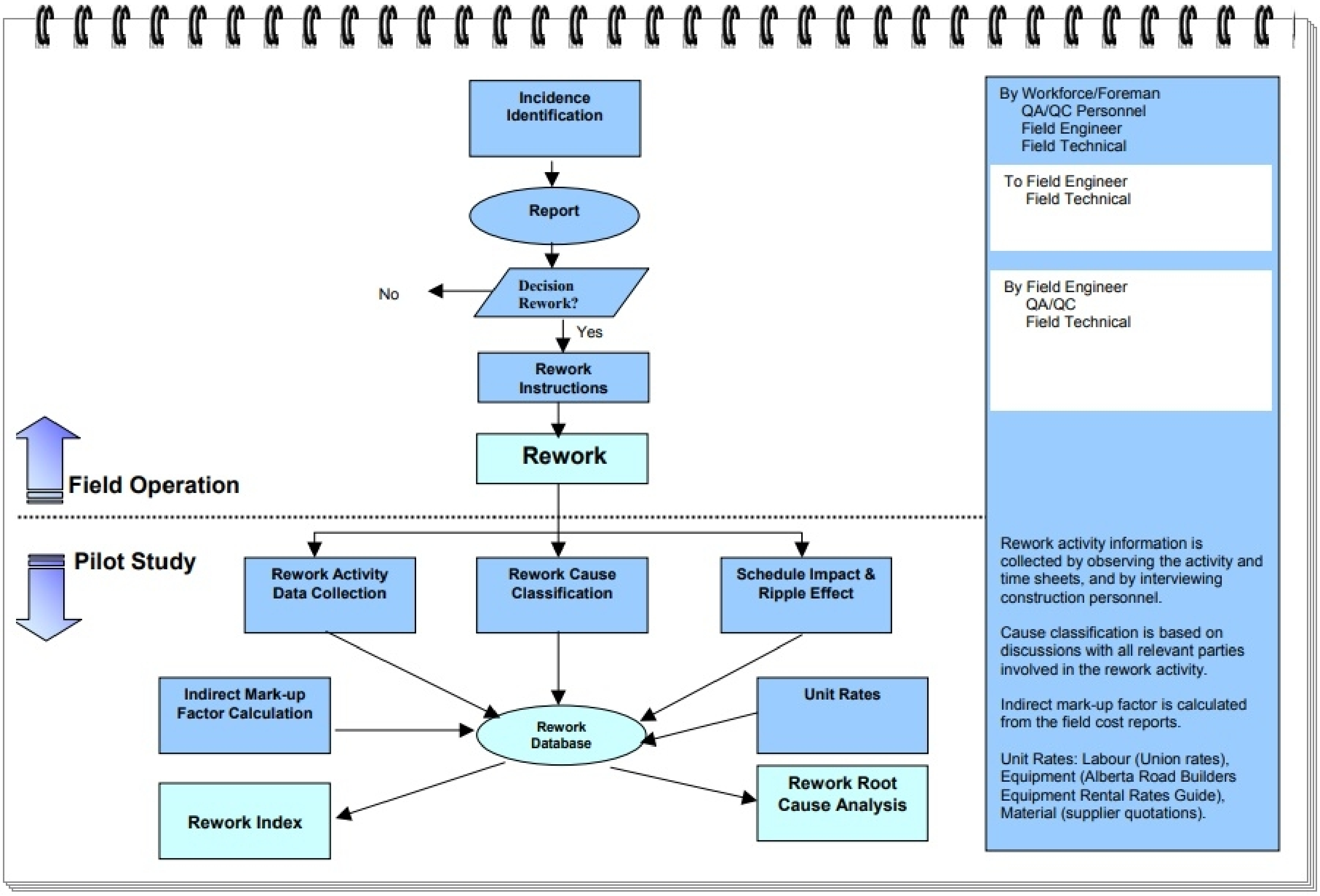

Figure 7: Methodology proposed by Fayek et al (2004) to collect data on Rework

Source: COAA (2003, p. 21)

3. Methodology

The research is of an applied nature since it will offer practical contributions to the EX da Amazônia company to face rework over time.

As for the objectives, the research is descriptive since it will study and describe the characteristics of rework, its causes, and consequences in the organization.

Regarding the way the information was collected and analyzed, the combined approach (qualitative and quantitative) with procedures involving bibliographic research of articles, dissertations, theses were used, aiming at the formulation of the conceptual model and its tools, as well as a case study, the latter being an empirical investigation that investigates the contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and the context are not clearly defined (YIN, 2005 p.32).

Also, for data collection, a questionnaire was developed and applied to the main employees in the sectors involved with the planning and production process of digital routers.

For data analysis, an electronic spreadsheet, descriptive statistics, PDCA (Plan, Do Check and Action), and SCORE Matrix were used, as detailed in the research steps.

The research steps are:

1st) to state of the art review: until December 20, 2019

2nd) to meet managers at the company to obtain support and explain the project: 11/27/19;

3rd) to develop the data collection instrument: 27 to 29 November 2019;

A questionnaire with 19 questions was developed using part of the models of the aforementioned authors, whose structure and content can be viewed on the Typeform platform <https://bit.ly/30Xyc64>, which can be answered digitally through QR Code with the possibility of a reply via cell phone, tablet, computer or another electronic device.

Besides, the printed questionnaire was delivered to members of the sectors, considered the most experienced and accessible.

4th) to define the type of sampling and data collection strategies: 11/13/2019

Due to the 284 employees involved with digital routers being very busy professionals, it was carry out sampling for convenience, where the researcher selects more accessible members of the population (SCHIFFMAN, L. & KANUK, 2000), prioritizing experienced employees and their availability to participate in the research.

As a result, a confidence interval or margin of error was not adopted.

5th) to apply the pilot test: November, 29 to December 3, 2019

The pilot test was carried out using the electronic questionnaire applied to 5 employees, where it was possible to make changes to some questions to make the survey easier to understand and answer.

6th) to improve the questionnaire and apply the definitive test: 04 to 12/20/2019

7th) to verify, type, and analyze data by using a spreadsheet and descriptive analysis: 12/04/19 to 03/30/20

8th) to present partial results: 12/17/19

9th) to elaborate the model and article: January, 5 to August 15, 2020

10th) to defend, improve, and deliver the final version of the article: 08/23 to 09/10/20

11th) to translate the article into English and submit for publication: 1 to 15 September, 2020.

4. Discussion

4.1 Respondents profile

Seventy-one employees correctly completed the questionnaire, which represents 25% of the 284 employees involved in various processes of the digital routers.

Regarding the position of the respondents' position, it was observed that the majority (49; 69%) act in operational level positions, a little more than a fifth (16; 22.53%) act in a tactical level, and only 6 (8.4%) work in strategic level positions.

Concerning the department where they work, two work in the Production Planning and Control, for work in Purchasing, 3 in Engineering, 4 in the Warehouse, 46 work in Manual Insertion, 7 are in Automatic Insertion, 3 in Quality, and two are in Expedition.

4.2 Choice of the rework concept to be adopted in the Company

Question 1 presents four concepts of rework and asks the respondent to choose one that would best help in standardizing the term in the company.

The results in Table 4 show that the two most prominent concepts were “Redo something that was done incorrectly in the first time” with 48% of the votes and “Action to correct changes, errors, omissions or damages” with 32% of the answers. These two concepts stand out in all sectors when compared to the others.

Table 4: Rework concepts to standardize in the Company

Rework Concepts	Warehouse	Purchasing	Eng.	Exp.	AI	MI	PPC	Qual.	Total	%
Redo something that was done incorrectly for the first time	1	0	2	0	3	26	1	1	34	48
Action to correct changes, errors, omissions or damage	3	3	0	0	1	14	1	1	23	32
Correct imperfections (out the quality specifications)	0	1	1	0	2	3	0	1	8	11
Work to be redone for not meeting the requirements	0	0	0	2	1	3	0	0	6	8
Total →	4	4	3	2	7	46	2	3	71	100

Source: Author (2020)

4.3 Problem identification

To identify the sector with the greatest number of problems, it was asked “which major problem has had a strong impact on the company's costs?”.

As a result, all 71 responded, generating a total of 41 problems, of which, these 39 problems were validated and organized in descending order:

Wrong component feeding (7; 10.4%), damaged bosa (7; 10.4%), missing components (5; 7.5%), broken led (4; 6%), tall components, damaged components, blurred label, failed tests, lack of engineering maintenance, lack of trained labor, insufficient welding, duplicated MAC and design change each appears with two votes (3%) of the respondents.

Finally, each of the following problems was mentioned only once (1.4%):

Stained bosa, an employee in training, standing component (tombstone), displaced components, foreign body, old equipment, recording error in the IC, design error sent by Supplier, label with wrong information, false failure, process failures, lack of daily maintenance of the welding machine, incorrect planning or customer information, displaced LEDs, non-standard SMD materials, poor quality material, change in firmware, not following the IGTs of the processes, production order with wrong structure, a plate with graphite problem, damaged plates, finished product rejects, retests, RMA, testing and exchange of labels and components.

4.4 Identification of sectors, classification, causes and prioritization of problems

Other questions were asked to identify the sectors that detect the problems, their origin, their classification, the root causes, as well as to verify the impact, the ease of elimination, the level of investment required, and the tendency of a resurgence, to try to prioritize the problems by the SCORE matrix. The questions were:

3a "What sector do you work in?”

3b "What is the number one problem that has generated the reoccurrence of rework with a strong impact on costs in the short term?”

3c "Which category would you rate the Problem in?"

3d "What root cause is contributing to the problem?”

3e "If nothing is done to face the problem, what negative impact on the Sector's Image (Seriousness = S)"

3f "How Easy is it to eliminate or reduce the problem (Resolution)”

3g "If a budget was released to face the problem, what is the level of investment needed (Very high budget = 1; Medium = 3; Low = 5)

3h "If nothing is done, what is the tendency of the Problem to reappear over time (Evolution takes time to appear = 1; to appear in up to 1 month = 3; to appear soon = 5”

3i Usually the problem has origin in which sector? ”.

Regarding the SCORE Matrix, it was developed by Silva (2018) to prioritize each problem using a Likert scale from 1 to 5 (Seriousness, Cost, Budget=Orçamento, Resolution, and Evolution), the product of these values generates the SCORE of the problem, allowing its sorting in the order of priority. And Chart 1 presents the profile of the 39 problems in order of SCORE prioritization, and the five considered as priorities are:

First) IC recording error (2500 points), with the root cause being the failure to comply with the procedure;

Second) tall components (2025 points), the root causes are lack of skill or misalignment of the welding machine;

Third) lack of engineering maintenance (2025 points), root causes are test failures or inefficient maintenance management;

Fourth) production order with wrong structure (1600 points), the root cause is system structure not updated according to BOM;

Fifth) blurred label (1280 dots), the root cause is an oscillation in the printer.

The sector where most problems were detected is Manual Insertion (63%), followed by Automatic Insertion (10%), Warehouse (6%), Purchasing (6%), Engineering (4%), Quality (4%), PPC (3%) and Expedition (3%). The sector that causes problems are: Manual Insertion (37%), followed by Automatic Insertion (16%), Other (16%), Supplier (9%), PPC (6%), Warehouse (6%), Client (4 %), Expedition (3%) and Quality (1%).

Regarding the question “3.c What root cause is contributing to the problem?” about 35 potential root causes have been identified, of which the most frequently cited are non-compliance with the procedure (mentioned eight times out of 50; 16%), inattention (mentioned five times out of 50; 10%), lack of components (appear two times; 4%), lack of skill (mentioned two times; 4%), lack of maintenance in the tests (mentioned two times; 4%), inadequate maintenance on the machine (mentioned two times; 4%), etc.

Regarding the classification of problems, most were considered Error (44%), followed by Change (24%), Omission (20%), and Damage (12%).

Problems	**Detected**	**Origin**	**Classification**	**Root causes**	**SCORE**
IC recording error	Warehouse	Other	Change	Non-compliance with the procedure	2500
Tall components	MI	MI and other	Error or Omission	Lack of skill or mishandling of the welding machine	2025
Lack of engineering maintenance	MI	MI	Omission	Testing failures or inefficient maintenance management	2025
Production order with wrong structure	PPC	PPC	Omission	System structure not updated according to BOM	1600
Blurred label	AI and MI	Warehouse	Error	Oscillating printer	1280
Employee in training	MI	MI	Omission	Lack of skill	1200
Damaged components	MI	MI	Error	Incorrect handling	1200
Lack of trained labor	MI	MI	Error or Omission	Lack of follow-up	1139
Incorrect planning or customer information	EXP	Other	Change	Change in what was initially agreed or change in customer demand	1125
Low quality material	Purchasing	Other	Damage	New supplier failure	1125
Graphite problem board	Quality	Other	Error	The temperature of the welding machine is incompatible. The plate was not developed for welding by the machine, but manual	1125
Tests failed	MI	MI and Other	Error or Omission	Lack of testing maintenance	1050
Offset components	IM	IM	Change	Inadequate maintenance on the welding machine	1000
Label with wrong information	ENG	Other	Omission	Communication failure	1000
Non-standard SMD materials ex: out of tape	Warehouse	Oher	Error	Supplier sends material out of specifications	1000
Damaged plates	MI	MI	Error	Change in production cycle time	960
Insufficient welding	MI	AI	Change	Non-compliance with the procedure	945
Strange body	MI	MI	Error	Non-compliance with the procedure	800
Failure to follow the IGT's of the processes	Quality	Other	Error	Indiscipline	800
Firmware change	ENG	Other	Omission	Failed to implement the new product version	750

Continuation of Chart 1.

Problems	Detected	Origin	Classification	Root causes	SCORE
Finished product waste	Purchasing	MI	Error	Inattention	750
Missing components	MI	AI, MI and other	Error, Change or Omission	Inattention	657
Duplicate Mac	Warehouse (Exp)	MI and Exp	Error	Labeling and reading error	608
Process failures	Quality	Other	Error	Lack of information for the employee and insufficient training.	540
Broken led	MI	AI and MI	Damage, Error or Change	Non-compliance with the procedure	482
Wrong component feeding	AI and MI	Warehouse, AI and Other	Error, Change or Omission	Inattention	456
False failure	MI	Other	Error	Lack of maintenance during the tests	450
Offset LEDs	MI	AI	Change	Misfit machine	450
Damaged bosa	MI	MI, Quality and Other	Damage, Error or Change	Inattention	445
Changing in the Project	Purchasing and MI	PPC and other	Change	Engineering does not act effectively	391
Label and component exchange	PPC	Other	Error	Labels with internal validation problems out of date, supplier error component wrong indication	300
Standing component	AI	AI	Error	Oven profile failure	200
Lack of daily maintenance of the welding machine	MI	PPC	Change	Inefficient maintenance management	180
Spotted bosa	MI	other	Change	Non-compliance with the procedure	150
Old equipments	ENG	PPC	Error	Demotivation or Devaluation	120
Design error from Supplier	Purchasing	Other	Error	Wrong Product Development.	75
Retests	MI	MI	Error	Insufficient soldering on the plates	60
Test	MI	MI	Omission	System error	30
RMA	Warehouse	MI	Damage	Inattention	25

Chart 1: Profile of problems that generate rework in the processes of digital routers.

Source: Author (2020)

4.5 Serious consequences for the organization and partners

To identify the consequences of the problems generating rework in the organization or the partners, the following question was asked, containing six options:

3i) In addition to the cost, the selected problem has generated more consequences in which category? a) Employees; b) In the Material; c) In Time; d) In the Management of Directors; e) Relationship with Suppliers; f) In the Relationship with Internal Customers; g) I don't know.

As a result, 18 (25.4%) employees stated that they did not know how to answer, 53 (74.6%) pointed out that external Customers (58%, 5), Time (13.2%), Material (9.4 %), and Employees (7.5%) are the categories most affected, as shown in Table 5.

Table 5: Categories most affected by the problems that generate rework

Affected categories	Total	%
Relation with External Customers	31	58.5
Time	7	13.2
No Material	5	9.4
Employees (HR)	4	7.5
Management of Administrators	3	5.7
Relationship with Suppliers	3	5.7
Total →	53	100

Souce: Author (2020)

4.6 Serious effects on Employees

The analysis of this section involves questioning the effect of the problem on employees, and these eight options were presented:

a) absenteeism (lack of employees); b) Conflicts between sectors; c) Fatigue (tiredness); d) Demotivation; e) Stress; f) Dissatisfaction; g) Fear of being fired; h) It worsens the professional image of those involved.

The majority (69; 97.18%) answered the question correctly and the results show that rework affects employees with:

1st) demotivation (21; 29.6%); 2nd) absenteeism (10; 14.1%); 3rd) conflicts between sectors (9; 12.7%); 4th) stress (9; 12.7%); 5th) the worsening of the professional image of those involved (7; 9.9%); 6th) dissatisfaction (6; 8.4%); 7th) the fear of being fired (5; 7.0%); 8th) fatigue (4; 5.6%).

4.7 Consequences on the Categories, and Employees

The Table 6 shows the consequencies of the problems that generated rework on the categories, as well as on employees.

In short, the result showed that:

First) the relationship with External Customers (yellow column) is the category most affected and the main problems that generate rework and seriously affect this category are: broken led (Led Quebrado = 4; 13%), missing components (Componentes Faltando = 3; 9.7%), wrong component feeding (Alimentação errada do componente = 2; 6.5%), damaged bosa (Bosa danificada = 2; 6.5%), project changing

(Mudança de Projeto = 2; 6.5%), defected components (Componentes danificados = 2; 6.5%), lack of trained labor (Falta de mão de obra treinada), duplicate Mac (MAC duplicado), lack of engineering maintenance (Falta de manutenção de Engenharia), finished product rejected (Rejeito do produto acabado), recording error in the IC (Erro de gravação do IC), each with a vote (3.2%).

Second) concerning the effects of rework on employees, demotivation (clear pink column) was highlighted, due to: broken led (Led quebrado = 2; 9.5%), components missing (Componentes faltando = 2; 9.5%), damaged bosa (Bosa danificada = 2; 9.5%), damaged components (Componentes danificados = 2; 9.5%), wrong component feeding, lack of trained labor, and change of project (4.8%).

Table 6: Problems that generated rework and affect the categories and employees

PROBLEMA NÚMERO 1	Total	CONSEQUENCIAS SOBRE AS CATEGORIAS						EFEITOS SOBRE OS COLABORADORES							
		Adm.	Clientes	Fornec.	Material	Tempo	RH	Abs.	Conf.Set.	Desm.	Estresse	Fadiga	Ins.	MedoDesp	ImagProf.
Led Quebrado →	4	.	4	.	.	.	.	1	.	2	.	.	.	.	1
Componentes Faltando →	4	1	3	.	.	.	.	1	.	2	2	.	.	.	.
Alimentação errada do componente →	4	.	1	1	2	.	.	.	.	1	.	1	.	3	2
Bosa Danificada →	2	.	2	.	.	.	.	2	.	2	1	1	1	.	.
Falta de Mão de Obra Treinada →	2	.	1	1	.	.	.	.	.	1	.	.	1	.	.
Mac Duplicado →	2	.	1	.	.	1	.	.	1	.	.	.	1	.	.
Etiqueta Borrada →	2	.	1	.	.	.	1	1	.	.	.	.	1	.	.
Mudança de Projeto →	2	.	2	.	.	.	.	.	.	1	1	.	.	.	.
Componentes Danificados →	2	.	2	.	.	.	.	.	.	2	.	.	.	.	.
Falta de Manutenção de Engenharia →	1	.	1	.	.	.	.	.	.	.	.	.	.	1	1
Rejeito De Produto Acabado →	1	.	1	.	.	.	.	.	.	.	.	.	.	.	1
Erro de Gravação do IC →	1	.	1	.	.	.	.	.	.	.	.	.	.	1	.
Inf. Incorreta/Incompleta do Plan/Clientes →	1	.	.	.	.	1	.	.	.	.	.	1	.	.	.
Mudança de Firmware →	1	.	1	.	.	.	.	.	.	.	.	1	.	.	.
Não Seguimento das IGT's dos Processos →	1	.	.	.	.	1	.	.	.	.	1	.	.	.	.
Material Com Baixa Qualidade →	1	.	.	.	1	.	.	.	.	.	1	.	.	.	.
RMA →	1	.	.	.	1	.	.	.	.	.	1	.	.	.	.
Falha Falsa →	1	.	1	.	.	.	.	.	.	.	1	.	.	.	.
Outros problemas citados →	18	.	8	.	1	4	.	5	8	10	1	.	.	.	2
Sub total →	**51**	**3**	30	**2**	**5**	**7**	**4**	**10**	**9**	**21**	**9**	**4**	**4**	**5**	**7**
% →	**100**	**5,9%**	**58,8%**	**3,9%**	**9,8%**	**13,7%**	**7,8%**	**14,5%**	**13,0%**	**30,4%**	**13,0%**	**5,8%**	**5,8%**	**7,2%**	**10,1%**

Source: Author (2020)

4.8 Proposed conceptual model to classify and reduce rework

When analyzing the models identified in the theoretical framework, as well as the results obtained in the company's sectors, a conceptual model was proposed for top management to reflect, adapt and use, as shown in Figure 8.

The conceptual model is based on 5 stages of the Organizational Learning Cycle PECAV (Plan, Execute, Check, Act and Value), an improved variation of the old PDCA Cycle (Plan, Do, Check, and Action).

Rework is a non-conformity linked to quality. There must be a political decision, determined by the top management of the organization (DEMING, 2000). The model is for managers, with the following recommendations:

<u>Step 1) To Plan (Strategic Level)</u>

1) to analyze this article, its results, and the proposed model;

2) If the model is useful (adapted to the reality of the organization), incorporate it into the company's strategic planning;

3) to create an interdisciplinary committee, composed of representatives from each sector that was

studied; define assignments for the commission, some of which are: define the concept of rework; study the article; prioritize the problems that were identified in the research; prepare, approve, launch, monitor and evaluate the Annual Plan to Combat Rework (APCR);

4) to allocate resources to the APCR;

5) to support the improvement of a robust database containing information about the APCR, improvement projects, indicators;

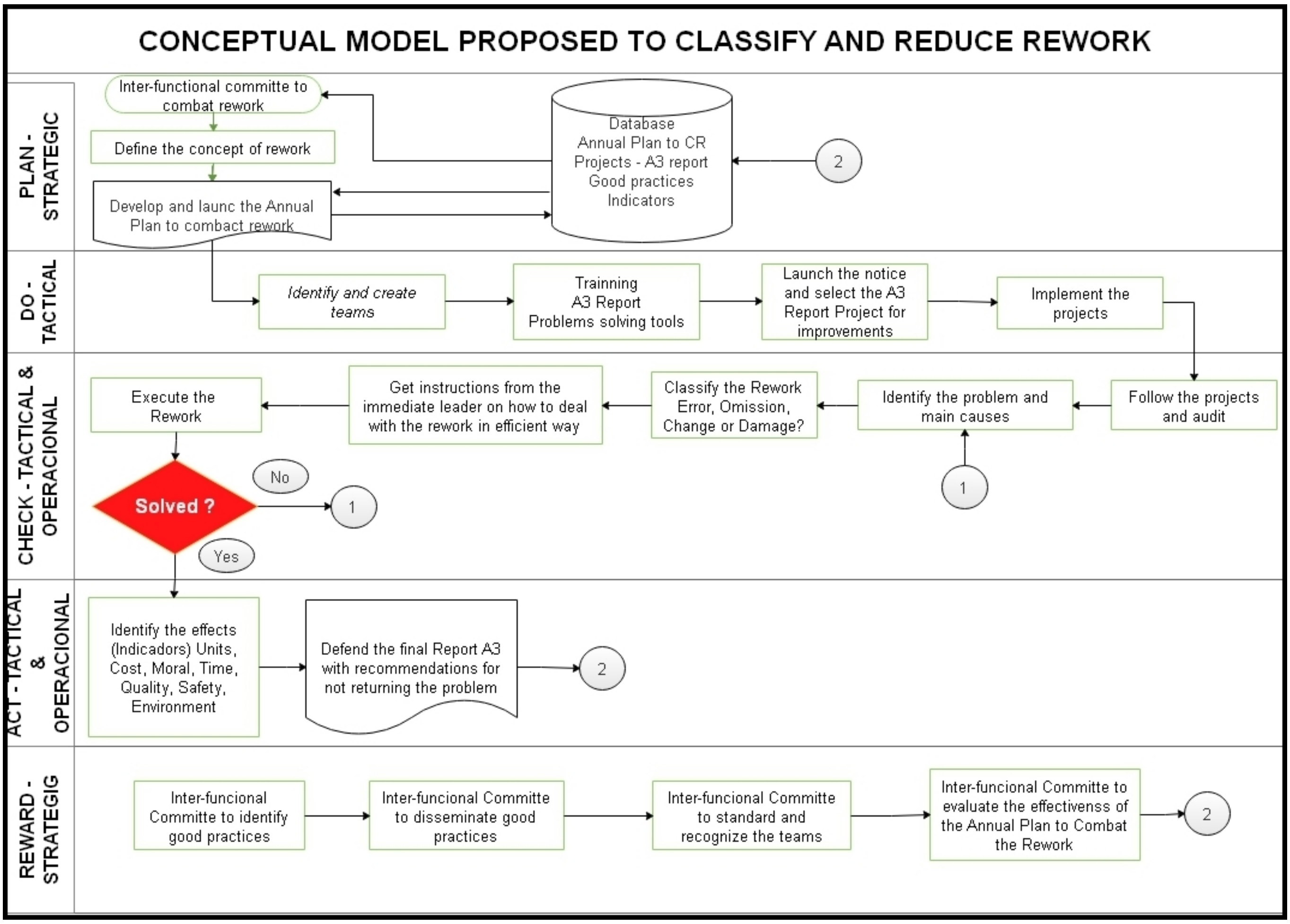

Figure 8: Conceptual model proposed to classify and reduce rework

Source: Author (2020)

<u>Step 2) Execute (Tactical Level) in partnership with the managers of the sectors involved</u>

6) to identify and form teams;

7) to conduct training for team members to improve skills to identify and solve problems that generate rework.

Seventy-one employees answered if they were interested in participating in this type of training, the majority (60; 84.5%) reported that yes, nine (12.7%) responded negatively, while two (2.8%) did not respond. Table 7 shows the respondents' interest in the techniques offered.

According to the results in Table 7, some of the techniques/tools that aroused interest in employees are: Decisory Star (43.3%), Objectives and Challenges Trees (38.3%), PDCA (36.7%), SCORE Matrix

(36.7%), MASP (33.3%), Vertical Flowchart (31.7%), A3 Report (28.3%) and Rich Picture (26.7%).

Table 7: Techniques or Tools that 60 respondents would like to receive training

SECTOR	Objectives and Challenges Trees	Decisory Star	Rich Picture	Vertical Flowchart	MASP	SCORE Matrix	PDCA	A3 Report
Warehouse	1	1	1	1	2	1	1	2
Purchasing	0	2	0	0	0	0	1	0
Engineering	0	0	0	0	1	0	1	0
Expedition	1	1	1	1	2	1	1	1
AI	0	2	0	1	1	1	2	1
MI	20	18	13	15	12	17	14	12
PPC	1	2	1	1	1	1	1	1
Quality	0	0	0	0	1	1	1	0
Subtotal →	23	26	16	19	20	22	22	17
% →	38.3	43.3	26.7	31.7	33.3	36.7	36.7	28.3

Source: Author (2020)

8) to Launch a public notice and select proposals for development projects to reduce rework, using the A3 Report model in conjunction with other techniques/tools;

9) the teams execute the projects;

Step 3) to Check (Tactical and Operational Levels)

10) to create or mobilize an audit team to monitor and support the development of projects, involving the correct identification of the problem, analysis of the root causes, classification of rework, obtaining guidance from the immediate leadership, execution of Rework, analysis of the rework resolution and corrective actions, if necessary, return to the first actions;

Step 4) to Act (Tactical and Operational Levels)

11) to identify the Effects (Indicators) of Rework;

12) to prepare and defend the Final Report A3, containing proactive recommendations to avoid reoccurrence of rework;

13) to constantly supply the Database with all the key information of the project involving rework;

Step 5) to Value (Strategic Level) involving the Interdisciplinary Committee

14) to identify good practices;

15) to support the dissemination of Good Practices;

16) to standardize Good Practices with the Database;

17) to recognize the teams;

18) to assess the effectiveness of the APCR with recommendations for the next annual plan;

19) to update the Database.

5. Conclusions and recommendations

The general objective of the research is to contribute for the improvement of the classification and the rework`s reduction in the sectors involved with the production of digital routers from EX da Amazônia.

After studying a theoretical framework on rework, involving five identified models, as well as applying a questionnaire to 71 company employees, the data analysis allows us to conclude that:

a) rework is a challenge faced in several countries, and a good part of the research identified in articles was carried out in the civil construction industry, all five models identified came from this economic branch, which is why it is recommended to approach the academy for expansion of research in other types of companies, especially those with more expressive participation at the Manaus Industrial Pole, such as electronic electronics, computer goods, two wheels, thermoplastic, metallurgical, mechanical and others;

b) Rework is a non-conformity linked to quality, to face it, there must be a political decision, determined and supported by the top management of the organization (DEMING, 2000), because of this, the best model to classify and reduce reworks of EX da Amazônia, must be developed by senior management, based on an interdepartmental approach, with diagnoses of the situation in each department, as well as the adoption of an annual plan to combat rework, supported by the adoption of information and communication technologies, awareness, continuous training, quality tools, approaches for improvement projects, audits, standardization, identification and dissemination of good practices, and recognition of employees;

c) “Redo something that was done incorrectly the first time” and “Action to correct changes, errors, omissions or damages” are the concepts of rework most chosen by employees in the investigated sectors, being recommended for managers, to standardize and disseminate to employees, external customers, and suppliers;

d) rework brings more serious consequences on the Relationship with Clients, Time, Material and HR, with the most effects on employees being: 1st) demotivation; 2nd) absenteeism; 3rd) conflicts between sectors; 4th) stress; 5) and worsening the professional image of those involved. In general, it can be seen that External and Internal Customers are strongly affected by the effects of rework, worsening the image of the organization over time, reason by which the implementation of an annual plan, implemented in partnership with the employees and partners can help to systematically reduce problems, as well as to start a proactive culture to prevent such problems from recurring;

e) the proposed conceptual model can be incorporated into the strategic planning of the organization, has five phases, with 19 recommendations that can be improved with the existing expertise, accompanied by strong training of employees, with the following techniques/tools being recommended: Decisorial Star, Trees Objectives and Challenges, PDCA, SCORE Matrix, MASP, Vertical Flowchart, A3 Report, and Rich Picture. New research can be done to assess the necessary budget, as well as the impact of the implementation of this model on the organization.

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