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Guidelines for Reverse Engineering Process Modeling of Technical Systems

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núcleo de desenvolvimento integrado de produtos

Outline

- Overview
- Literature Review
  - *Conceptual Design of Technical Systems*
  - *Reverse Engineering for Technical Systems Design*
  - *Product Teardown*
  - *Support Methods Related to Reverse Engineering (RE)*
- Technical Visit to a RE Leading Company
- Proposal of the RE Process Modeling
- Guidelines for the RE Model
- Final Considerations

I. Overview

I. Overview

- The process of conceptual design is essential to innovation, because it uncouples the design problem from the known solutions by an abstraction process
- In spite of its importance, this process is not effectively carried out by designers
- Standardized functions should guide the designers in the product functional modeling
- Reverse Engineering (RE) is suggested, as a way to model the processes of identifying, purchasing and modeling design information – functions and design principles – in a continuous and systematic way

II. Literature Review

II. Conception Process of TS

- In the conceptual design phase, the Technical Systems (TS) conceptions are developed by:
  - Functional modeling
  - Design principles and
  - Product conceptions generation
- The main functional modeling approaches are:
  - Functional deployment (Pahl and Beitz)
  - Axiom-based synthesis (Tomiyama *et al*.) and
  - The function-means tree (Tjalve)
- The conceptual design demands:
  - A significant capacity of abstraction
  - An accurate definition of the functions
  - RE supports the acquisition of this information

II. Reverse Engineering for TS Design

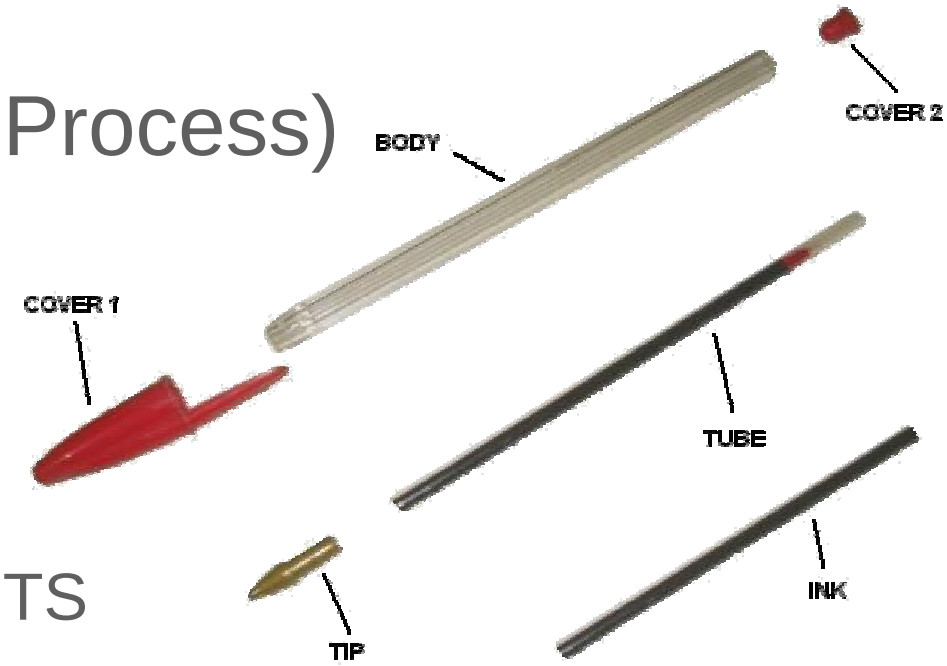
- RE is “a process of information getting and analysis from existent systems, in order to optimize systems being developed”
- RE seeks to understand how a TS works, not copying technical solutions
- RE methodologies have been suggested to formalize the RE process for TS, considering:
  - FAST (Function Analysis System Technique)
  - SOP (Subtract and Operate Procedure)
  - Force Flow
  - Teardown (technical disassembly)

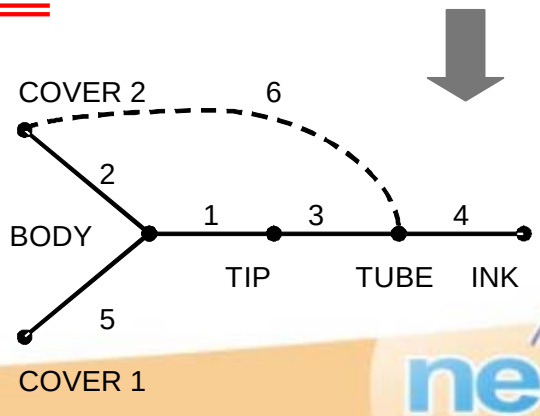
II. Product Teardown

- Teardown is carried out by many companies
  - To verify new technologies in the market
  - Informally, aiming at the solution of specific problems
- Teardown must:
  - Be a formal process of TS disassembling, analyzing each subsystem and component
  - Identify the inter-relationships among them, their functions and design principles
- Methodologies of teardown have been suggested:
  - Otto and Wood (2001): the practical procedure was emphasized but not the functional modeling
  - Abe and Starr (2003): the identification of the TS functions is clear and logical

II. Support Methods Related to RE

- Value Analysis (VA)
- AHP (Analytic Hierarchy Process)
- Interface Diagrams
  - To identify the connections between the physical components or processes of a TS





- Assembly analysis methods (DFA approach)

III. Technical Visit to a Leading RE Company

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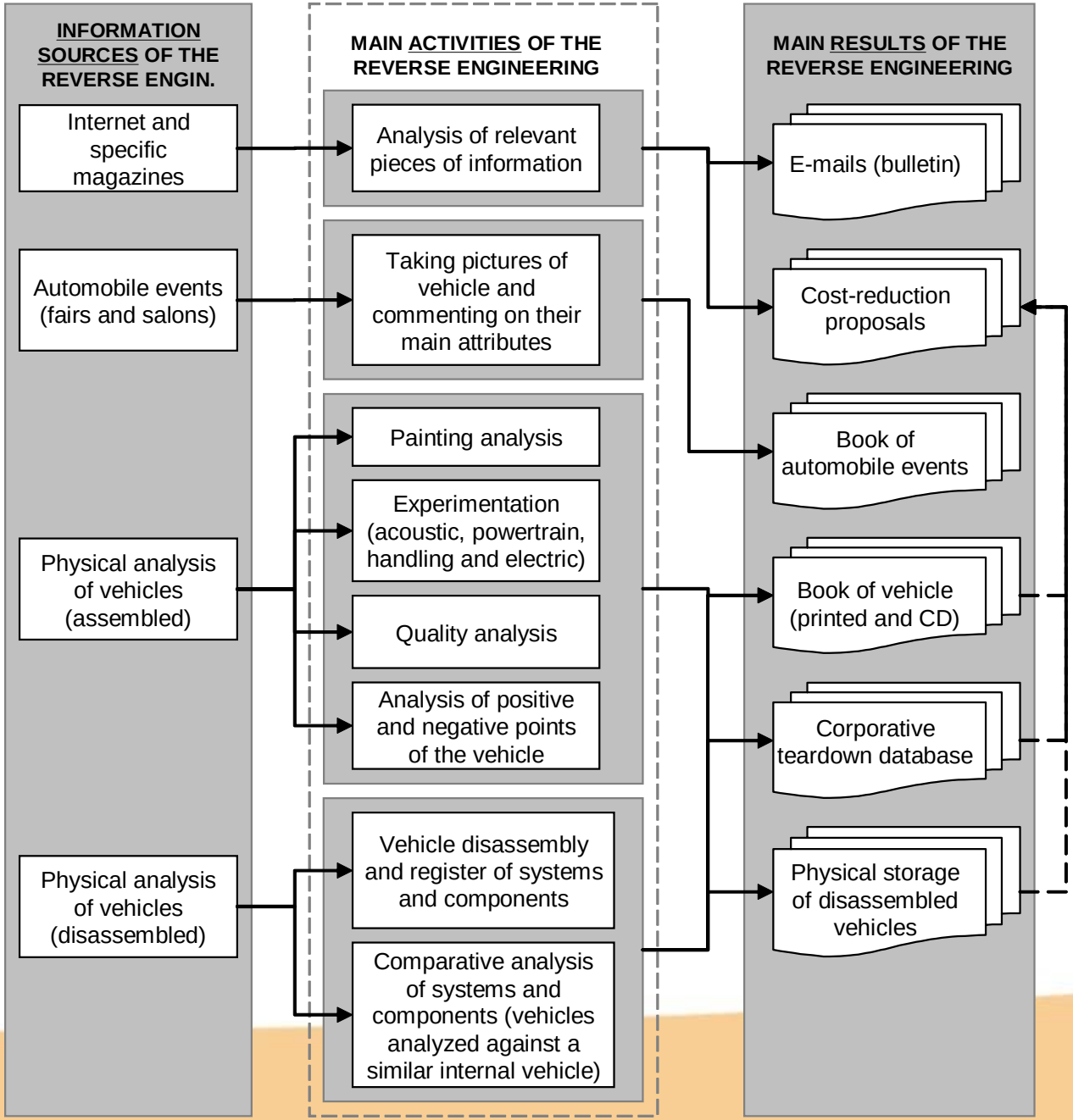


- Company: an automotive assembler (Brazil)
- The European head office designs the new vehicles
- RE sectors: quality, engineering and teardown
- They have a formal and understood procedure of RE, but functions are not focused on

IV. Proposal for the Reverse Engineering Process Modeling

IV. Proposal for the RE Process Modeling

REVERSE ENGINEERING PROCESS MODELING FOR TECHNICAL SYSTEMS

PLANNING AND PURCHASING	TECHNICAL SYSTEM ANALYSIS	REDESIGN ORIENTATION
- Definition of the RE objectives - Scope definition (market and products of reference) - Project planning (costs, quality, scheduling, etc.) - Purchasing of the Technical System (TS)	- Global evaluation of the TS (use/market) - Testing of the assembled TS - Technical disassembly of TS - Analysis of technical solutions - Analysis of functions and principles - Definition of the function structure	- To define goals and requirements of the redesign process - To compare the function structure and solution principles of a TS (against a similar internal TS) - Function synthesis of the TS - Conceptions generation of the TS
	- Publication analysis (magazines, catalogs, sites, merchandising, etc.) - Events analysis, related to TS market and technologies	

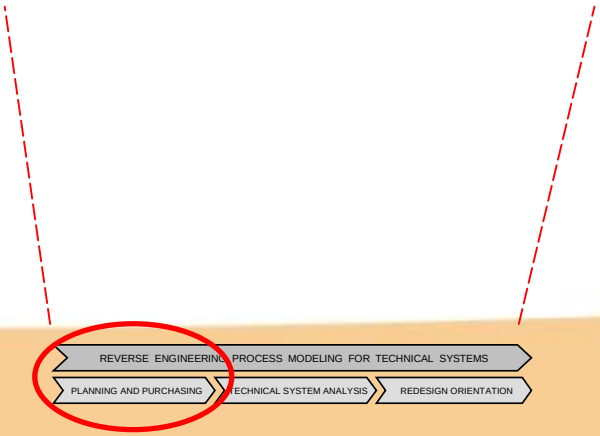
IV. Proposal for the RE Process Modeling

REVERSE ENGINEERI

PLANNING AND PURCHASING

- Definition of the RE objectives
- Scope definition (market and products of reference)
- Project planning (costs, quality, scheduling, etc.)
- Purchasing of the Technical System (TS)

- GOAL: to plan the activities of the RE process, and to orientate the designers to purchase the right TS to be analyzed
- RESULTS: the project plan of the RE process and the TS purchasing

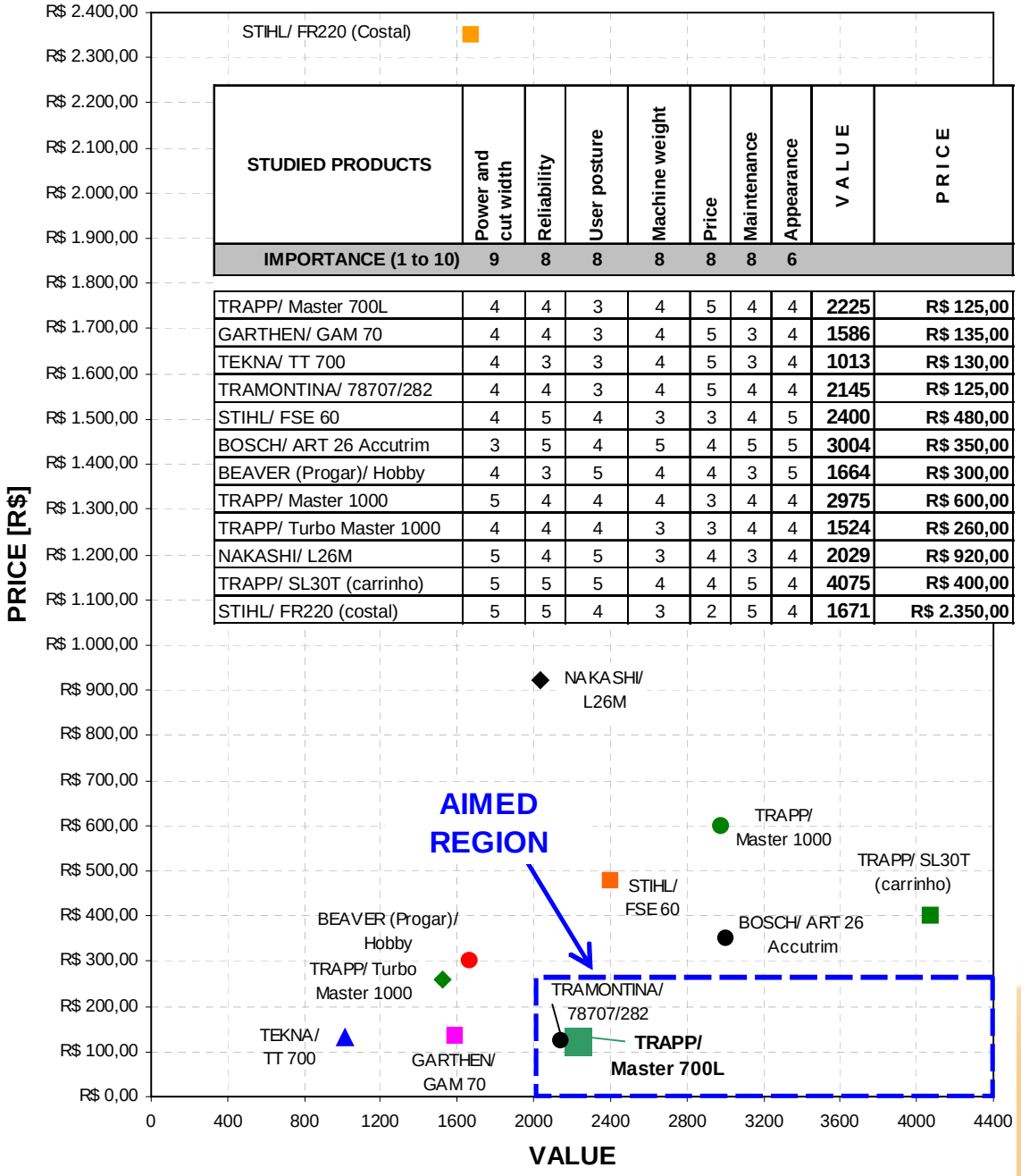


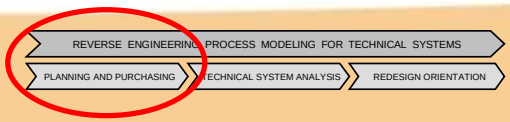
IV. Proposal for the RE Process Modeling

Planning and Purchasing

Map Price x Value

STUDIED PRODUCTS	Power and cut width	Reliability	User posture	Machine weight	Price	Maintenance	Appearance	VALUE	PRICE
IMPORTANCE (1 to 10)	9	8	8	8	8	8	6		
TRAPP/ Master 700L	4	4	3	4	5	4	4	2225	R$ 125,00
GARTHEN/ GAM 70	4	4	3	4	5	3	4	1586	R$ 135,00
TEKNA/ TT 700	4	3	3	4	5	3	4	1013	R$ 130,00
TRAMONTINA/ 78707/282	4	4	3	4	5	4	4	2145	R$ 125,00
STIHL/ FSE 60	4	5	4	3	3	4	5	2400	R$ 480,00
BOSCH/ ART 26 Accutrim	3	5	4	5	4	5	5	3004	R$ 350,00
BEAVER (Progar)/ Hobby	4	3	5	4	4	3	5	1664	R$ 300,00
TRAPP/ Master 1000	5	4	4	4	3	4	4	2975	R$ 600,00
TRAPP/ Turbo Master 1000	4	4	4	3	3	4	4	1524	R$ 260,00
NAKASHI/ L26M	5	4	5	3	4	3	4	2029	R$ 920,00
TRAPP/ SL30T (carrinho)	5	5	5	4	4	5	4	4075	R$ 400,00
STIHL/ FR220 (costal)	5	5	4	3	2	5	4	1671	R$ 2.350,00





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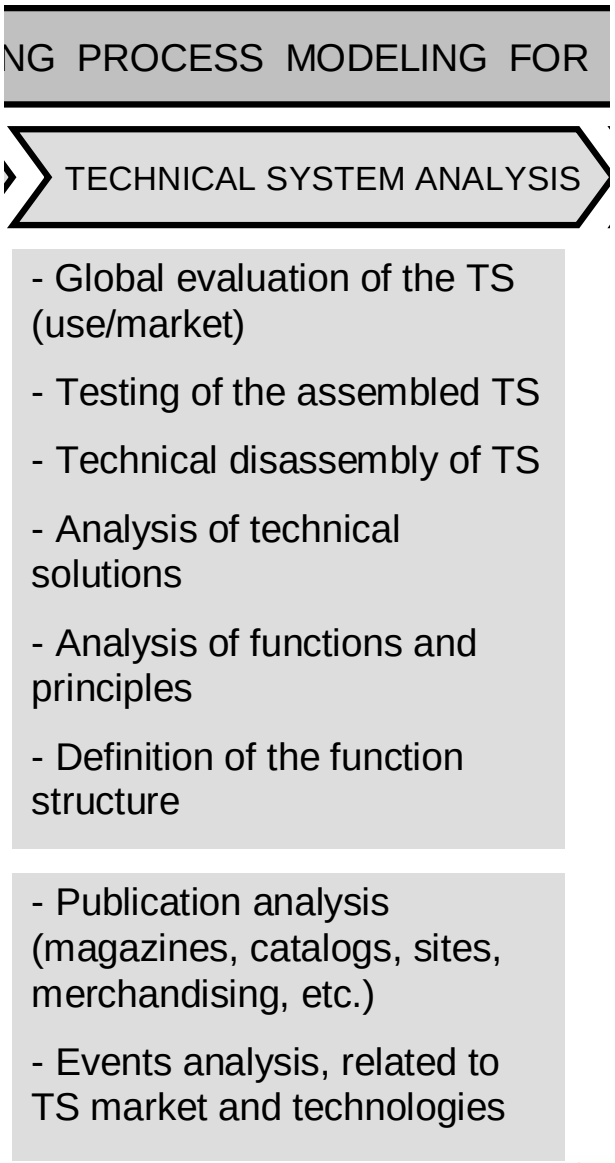

- GOAL: to obtain information which can be used in future designs and redesigns
- RESULTS: a list of components and materials; TS description; information on technical performance; and the functions identification

IV. Proposal for the RE Process Modeling

NG PROCESS MODELING FOR

TECHNICAL SYSTEM ANALYSIS

- Global evaluation of the TS (use/market)
- Testing of the assembled TS
- Technical disassembly of TS
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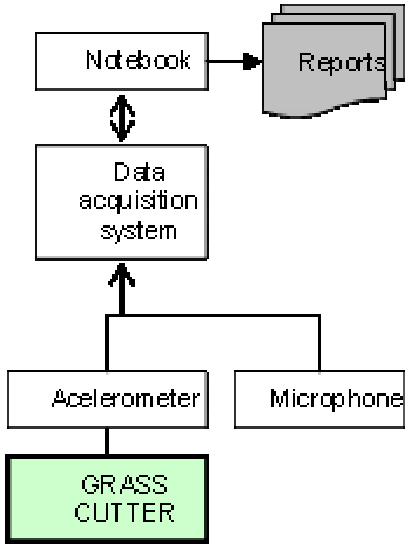
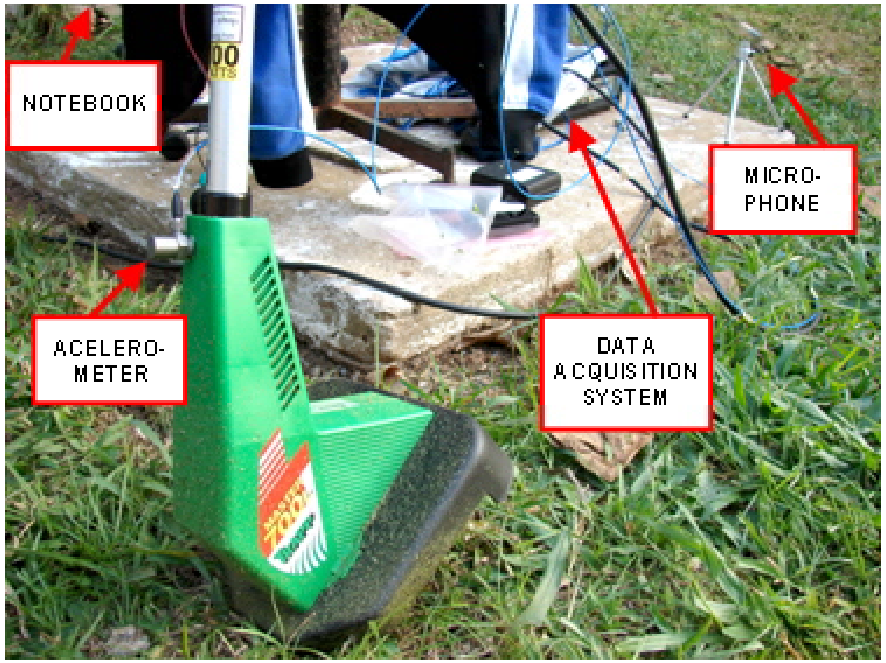
- Analysis of functions and principles
- Definition of the function structure

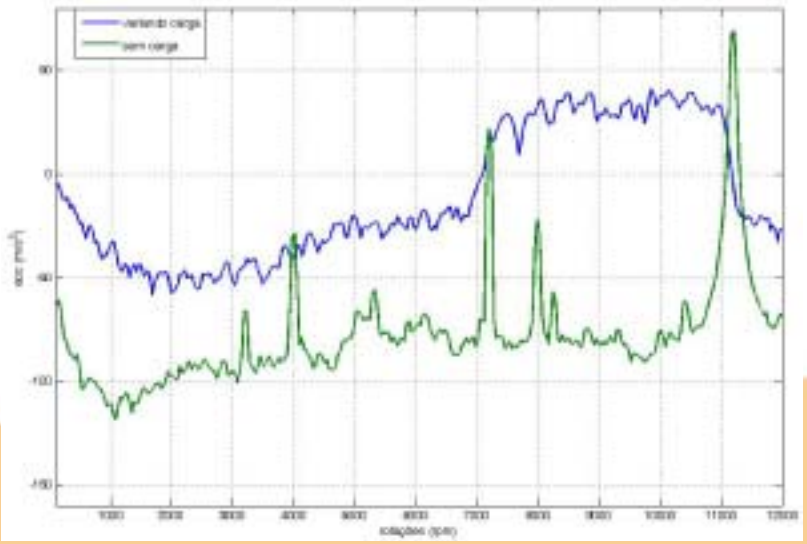
- Publication analysis (magazines, catalogs, sites, merchandising, etc.)
- Events analysis, related to TS market and technologies



a) Data acquisition



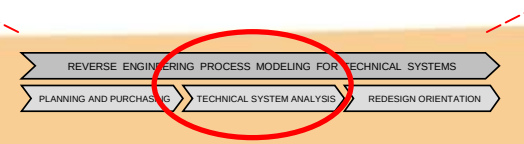
b) Equipments for the frequency measuring



Rotation *[rpm]* x Acceleration *[m/s^2]*

GREEN = without load

BLUE = with load



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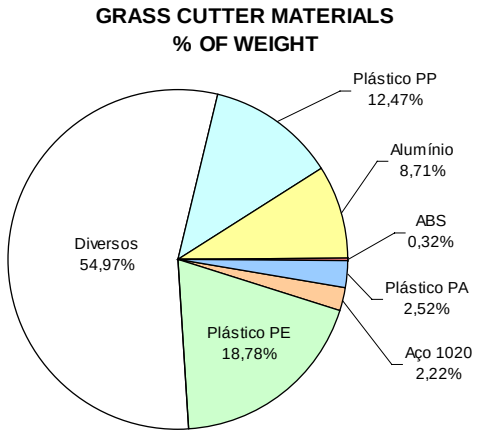
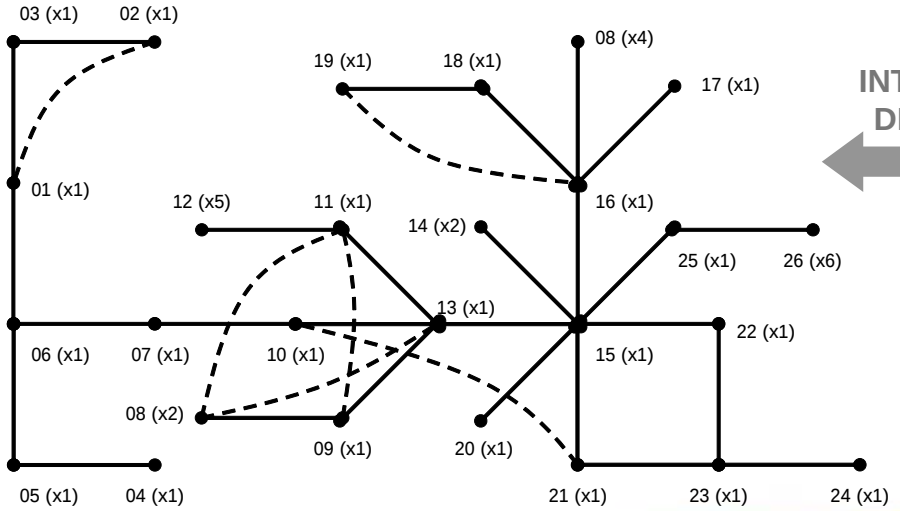
CÓD.	COMPONENT	QTD.	MATERIAL AND DIMENSIONS	WEIGHT UNIT. (g)	WEIGHT ITEM (g)	% WEIGHT ITEM	PART TYPE
26	Parafuso 4 x 20mm	6	Aço 1020	1,42	8,52	0,42%	B
25	Punho direito	1	Plástico PE/ 235 x 110 x 15mm	57,06	57,06	2,81%	B
24	Cabo elétrico com plug - 2 x 1 x 320mm	1	Diversos	41,02	41,02	2,02%	A
23	Botão de acionamento (gatinho) sem trava	1	Diversos/ 47 x 29 x 15 mm	18,54	18,54	0,91%	A
22	Punho esquerdo	1	Plástico PE/ 235 x 110 x 25 mm	63,59	63,59	3,14%	A
21	Cabo elétrico inferior - 2 x 1 x 1180mm	1	Diversos	47,72	47,72	2,35%	A
20	Adesivo com instruções	1	Vinil/ 190 x 30 mm			0,00%	B
19	Borboleta de fixação	1	Diversos/ 25 x 25 x 27 mm M8	14,00	14,00	0,69%	B
18	Porca da borboleta	1	Aço 1020/ 13 x 19 x M8	6,90	6,90	0,34%	B
17	Punho ajustável traseiro	1	Plástico PP/ 142 x 110 x 45 mm	38,08	38,08	1,88%	B
16	Punho ajustável dianteiro	1	Plástico PP/ 142 x 110 x 75 mm	60,76	60,76	3,00%	A
15	Tubo de alumínio	1	Alumínio/ 900 x ø25 mm x1	176,69	176,69	8,71%	A
14	Anel trava	2	ABS/ ø33 x 11 mm	3,23	6,46	0,32%	B
13	Capa lateral direita	1	Plástico PE/ 250 x 170 x 45 mm	128,76	128,76	6,35%	A
12	Parafuso 4 x 30mm	5	Aço 1020	2,06	10,30	0,51%	B
11	Capa lateral esquerda	1	Plástico PE/ 250 x 170 x 45 mm	131,54	131,54	6,49%	A
10	Motor 700W – 220V	1	Diversos/ 160 x 70 x 60 mm	956,77	956,77	47,17%	A
9	Saia de proteção	1	Plástico PP/ 230 x 200 x 55 mm	154,16	154,16	7,60%	A
8	Parafuso 4 x 16mm	6	Aço 1020	1,29	7,74	0,38%	B
7	Pino trava de transmissão	1	Aço 1020 – ø3 x 13mm	0,94	0,94	0,05%	A
6	Tampa superior do carretel	1	Plástico PA/ ø79 x 21 mm	24,00	24,00	1,18%	A
5	Arruela da porca sextavada	1	Aço 1020 – 5/16" x 1mm	0,68	0,68	0,03%	B
4	Porca sextavada com inserto de nylon	1	Aço 1020 – 5/16"	6,51	6,51	0,32%	B
3	Mola do carretel	1	Aço 1020/ ø11,5 x 35 x ø1,3 mm x 8 espiras	3,39	3,39	0,17%	A
2	Carretel/ refil	1	Diversos/ ø47 x 44 mm	36,89	36,89	1,82%	A
1	Tampa inferior do carretel	1	Plástico PA (nylon)/ ø71 x 40 mm	27,11	27,11	1,34%	A
	TOTAL =	41	Componentes		2028,13 g		





INTERFACE DIAGRAM

IV. Proposal for the RE Process Modeling

NG PROCESS MODELING FOR

TECHNICAL SYSTEM ANALYSIS

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FUNCTION STRUCTURE:

USING **SOP** (SUBTRACT AND OPERATE PROCEDURE) AND

FAST (FUNCTION ANALYSIS AND SYNTHESIS TECHNIQUE)

IV. Proposal for the RE Process Modeling

TECHNICAL SYSTEMS

REDESIGN ORIENTATION

- To define goals and requirements of the redesign process
- To compare the function structure and solution principles of a TS (against a similar internal TS)
- Function synthesis of the TS
- Conceptions generation of the TS

- GOAL: the goals and requirements of the TS redesign are defined, indicating which subsystems should be optimized
- RESULTS: the redesign of goals, a comparative analysis of the function structures, the optimized function structure and the attributes of the new versions of the TS conceptions

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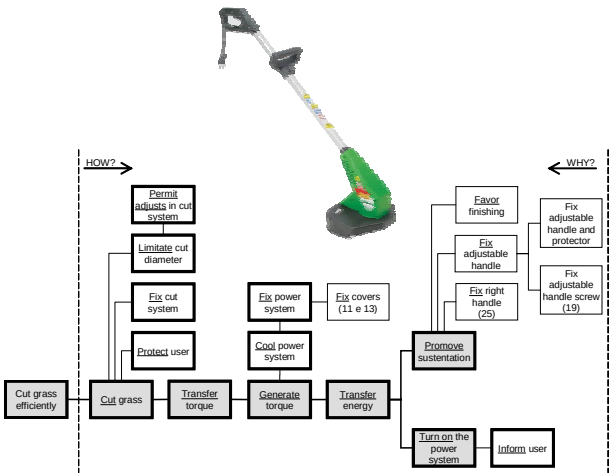
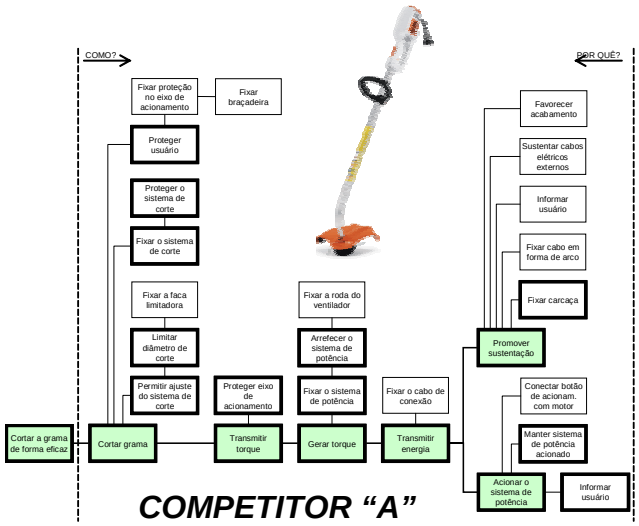
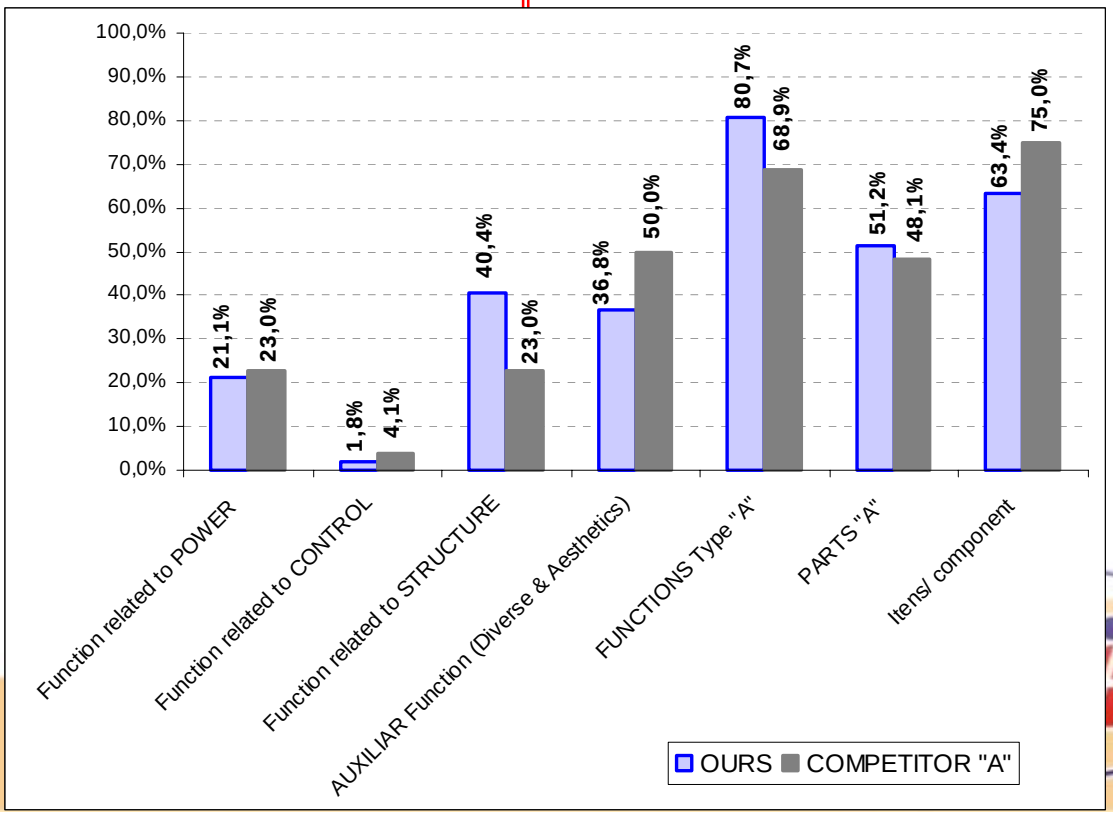


OURS



COMPETITOR "A"



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TECHNICAL SYSTEMS

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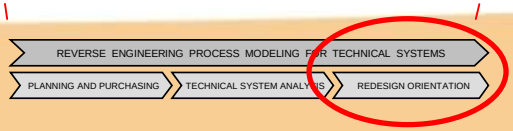
TOP SEVEN FUNCTIONS OF OUR PRODUCT

NO.	ITEM	FUNCTION	DESIGN PRINCIPLES				
01	19 (A)	Cut grass	TR-02. Refil	Grass scissors	Helicoidal blade	Rotative blade	Knife
02	10 (A)	Generate torque	TR-10. Motor 700W – 220V	Hydraulic motor	Pneumatic motor	Crank	Torsion spring
03	16 (B)	Cool power system	TR-06. Refil top cover	Cooler (computer)	Blower	Heat exchanger	Peltier's plate
04	15 (B)	Transfer torque	TR-07. Transmission locker pin	Gib	Groove	Driveshaft	Strap
05	03 (B)	Turn on power system	TR-23. Button without locker	Button type on-off	Connect cables (without button)		
06	02 (B)	Transfer energy	TR-24. Electric cable with plug 2 x 1 x 320mm	TR-21. Down electric cable 2 x 1 x 1180mm	Wireless (without cables)	Pipes	
07	04 (B)	Promove Sustentation	TR-25. Right handler	TR-22. Left handler	TR-17. Back adjustable handler	TR-16. Front adjustable handler	TR-15. Aluminum tube



V. Guidelines for the RE Model

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- To study processes of functional modeling, in order to define the information structure needed to describe the TS functions, considering the function deployment levels and the right technical language
- To develop a method for the comparative analysis of TS function structures, considering the functions of each subsystem, the interaction among functions, types of flows, types of transformations, etc.
- To develop a database, who will permit the comparison of similar functions, as well as the registration of functions and solution principles from many areas – mechanical, electrical, optical, bionic (analogy with nature), and others – to satisfy the design needs

VI. Final Considerations

VI. Final considerations

- The RE process formalizing supports the identification of TS functions and solution principles
- A comparative analysis between the studied TS and an internal TS can favor an improvement in the TS
- By utilizing the RE process as a source of knowledge for innovations in TS, companies can develop TS solutions in a faster way and with less uncertainties, in relation to a project without comparison parameters
- However, our methodology is currently being developed. For this reason, practical results in companies have still not been obtained, but they will be reported before the end of this year.

Contacts

Guidelines for Reverse Engineering Process Modeling of Technical Systems

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