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PRIORITY MATRIX TO REDUCE MATERIAL CONSUMPTION DURING REDESIGN PROCESS

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Abstract

Redesign is an important activity performed by several companies. It has been confirmed that most of redesign activities are still based on the experience of the members of the redesign team. Additionally, the lack of more systematic approaches regarding redesign has been identified.

This paper introduces a novel tool, called Priority Matrix - P*Matrix*, for identifying and ranking components and features of a product that offer a better potential to be redesigned in order to provide reduction of material consumption.

The paper also shows a theoretical example of P*Matrix* use, as well as, its application in a case study from an industrial company. The results obtained are discussed, focusing on the consistency of the information produced.

Keywords: Reduction of material consumption, redesign process, redesign tools, priority matrix

1. Introduction

The constant demand to increase the operational efficiency has led industrial companies to look for competitive differences (i.e. generally related to the continuous improvement approach), seeking to secure a convenient market share [1], [2]. In this context, the redesign process is an important subject, which helps in fulfilling customers' new demands and reducing operational costs. As an additional contribution, the redesigned products can have their life cycle extended, which contributes to the business success.

To better understand the redesign process, a preliminary study has been conducted involving 23 Brazilian companies that develop products and which are regarded as having a well-managed life cycle of their products [2]. The results obtained have shown that redesign activities have been occurring more often in the past years, with the average 1,09 redesign cases for each new product that has been developed in the previous 12 months. Additionally, these companies have signalled that one of the main aims of the redesign process is to target the reduction of the material consumption, consequently lowering the costs and helping to preserve the environment (see Figure 1).

Despite the importance of the theme, great part of the redesign activities are still being performed based on the experience of the design team members [1], [2], [3]. Therefore, there is an increasing demand for systematic approaches (i.e. methods and tools) for redesign, which can provide more consistent results than those based on designer's experience only.

Unfortunately, these approaches are rare and almost inexistent when focusing on the redesign aiming at reducing material consumption.

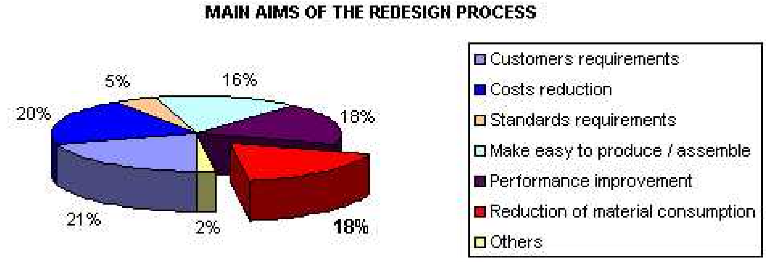


Figure 1. Main aims of the redesign process, according to [2].

This paper aims at presenting the preliminary results of the development of a methodology for guiding the redesign process when targeting the reduction of material consumption (the so called ReRCM), highlighting the use of a novel tool for ordering the redesign actions (i.e. what component to start the process; which feature presents potential to be redesigned) (Priority Matrix or P*Matrix*). The P*Matrix* intends to facilitate the ranking process, employing a methodical approach for diagnosing the redesign needs. Costs and functional aspects are the basic factors considered for indicating those components (and their features) that present the greatest potential for this type of redesign, therefore that should be examined at the first place.

2. Research Approach

An extensive literature review has been conducted aiming at detecting relationships between the design process and redesign process, since the first one is well documented and systematized [2]. Furthermore, it has been tried to identify specific methodologies for redesign that could be used as a framework for this research.

Next, a questionnaire has been sent to 23 companies, which have been identified as conducting redesign activities, with the purpose of gathering information about the best practices in this process. Special attention has been drawn to those practices for reducing material consumption. Following, an *e-brainstorming* has been devised and applied involving 13 members of redesign teams, focusing on what are the best approaches to reduce material consumption.

Finally, seven mechanical and electronic engineers have been interviewed, seeking to clarify the following questions: "*How does emerge the need to redesign a component aiming at reducing material consumption?*" and "*How does start the redesign process?*". A detailed analysis of these information have permitted to better understand the need for a systematic redesign process, as well as, to propose a tool that seeks to guide tasks and define which feature of a component will be dealt firstly during redesign to reduce material consumption.

A theoretical simulation is presented to illustrate the use of the tool. Additionally, a case study with a component from an electrical energy meter is implemented to evaluate the robustness and quality of the information provided.

3. Background Theory

3.1 Importance of redesign

In the present days, industrial organisations are asked to manufacture their products in compliance to stricter customer demands, with compatible costs. Furthermore, the development cycle has to be reduced, so the companies can remain competitive in the market. To achieve these results, the approach adopted by a great number of manufacturers is to implement minor changes and improvements in their products, via redesign [1]. That is whay the number of products with modified designs is increasing.

For instance, Pahl & Beitz [4], mention that more than half of the mechanical designs in the German industry are of the adaptive type. In 20% of the cases, there are only minor variations in dimensions and/or configurations. Therefore, the great majority of design situations are in fact, redesign activities.

3.2 Design methodologies and redesign

Due to its importance, it has been realised that the redesign process need to be planned and implemented in a systematic fashion [1], [5], and should not be only based on the designers experience. The application of systematic methods and tools can allow the redesign to be performed more easily and efficiently (i.e. interacting and optimising the use of different resources). The procedures and/or methodologies available for implementing design processes can be used as a framework to guide redesign activities [5], [6].

Generic stages and routine tasks (e.g. "what to do") do exist in design and redesign projects. Additionally, certain tools that help in defining "how to do" can also be applied to both situations [5].

However, despite the existence of relationships between design and redesign, there are several differences [1], [2], which prevent the straightforward use of design methodologies in redesign activities. According to Dufour [1], there are several models to develop products, with considerable differences in their objectives and results.

Thus, it is important to identify what kind of redesign is going to be conducted (e.g. reducing material consumption, ease the manufacturing process), define what are the best practices involved, which will allow to establish the most successful strategy.

3.3 Considerations on redesign approaches

It has not been found in the literature any methodology that encompasses all the redesign activities [2]. This might be due to the fact that are several reasons for starting the redesign process, which generates various needs and approaches to modify products. None of the methodologies and approaches consulted deals with redesign that targets reducing material consumption. However, there are certain approaches that are concerned with costs and environmental topics, so indirectly they discuss reducing material consumption issues. Even so, since they do not target reducing material consumption, there are no clear and efficient guidelines on *what to do* and *how to do* this type of redesign. These guidelines should be understood as methods and practical tools that can provide rapid and reliable solution to the redesign problem being examined.

4. Proposed model for redesign to reduce material consumption

This section presents the model devised, which has been encompassed in a redesign methodology for reducing material consumption, called ReRCM. This methodology, illustrated in Figure 2, proposes to structure in a systematic way the designers' experience (i.e. "means for redesigning"), allied to the theoretical best practices (e.g. process divided into phase, stages and tasks; tools/techniques for each stage) that has been found in the literature, despite the lack of specific redesign approaches. The objective is to facilitate the redesign activities by combining methods and techniques in such a way that the best opportunities for improvement in the product are signalled.

The P*Matrix*, which is the main focus of this paper, is a tool that has to be employed in Phase B (Informational Redesign), of ReRCM. The P*Matrix* approach establishes priorities (components and features) when redesigning to reduce material consumption. Further details about ReRCM can be found in [2].

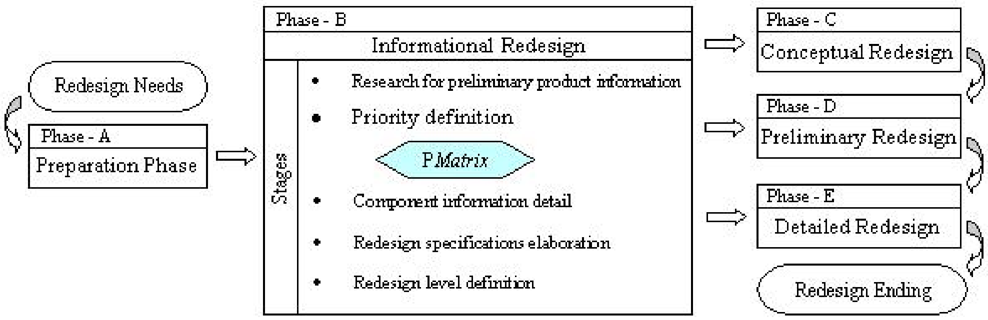


Figure 2. Redesign Process (ReRCM), according to [2].

5. Priority Matrix - P*Matrix*

This section describes the main aspects and benefits of a systematic approach for ranking the redesign actions using a "priority tool" – the P*Matrix*.

The use of P*Matrix* aims at guiding the design team, helping in defining components and features that should be firstly targeted because of their potential (likelihood of successful implementation) in terms of reducing material consumption and consequently, costs.

The P*Matrix* definition has started with the two fundamental questions highlighted in Section 2, which have been formulated to practitioners. From the answers, it has been depicted that one of the triggers for redesigning a component in order to reduce material consumption is: to consider the component "expensive", with considerable material costs involved. Following, it has been realised from "*how to do*" point of view, that the redesign team members perform an intuitive assessment (non-systematic), based on "experience" and "information available" to decide what can be "modified" or even "eliminated". Additionally, it has been noted that the practitioners consider the functional aspects of the component as a criteria in this judgement to implementing the redesign.

Therefore, it is possible to conclude that for redesigning components aiming at reducing material consumption, experienced designers considered firstly, the costs involved, and next, functions implemented.

This set of information has provided fundamental guidelines for developing this tool that could provide a more systematic approach for eliciting components and features to be redesigned, and in the end, to ensure better and faster results.

The proposed matrices integrating the P*Matrix* approach are going to be illustrated and detailed via a hypothetical case study (the Brace case), presented in the next sections.

5.1 Selecting the components to be redesigned

As the first step of ranking process, the team should provide the Bill of Materials (BOM) for the product (with the costs of its components and subassemblies), in order to fill the chart *Cost Structure*, shown in Table 1. This example considers only 2 parts of a complete product as an illustration. The redesign team should elicit only the most cost significant parts to be considered in the process.

Table 1. Chart ***Cost Structure*** (case: Brace).

Product Cost Element		Element Code	Unitary Cost	Qty / Product	% of Product Final Cost
1	Shaft	38.001.013	$5.26	1	11.3%
2	Brace assembly	38.001.715	$8.33	1	17.9%

Following, the cost elements (each component or subassembly) should be deployed in order to obtain the percentage of: material costs (%MAT); direct labour costs (%MOD); manufacturing indirect costs (%CIF).

Table 2. Chart ***Cost Elements' Deployment*** (case: Brace).

Elem. N#	Components	Part Number	Unitary Cost	Qty / Prod.	% of Product Final Cost	Cost Composition		
						% MAT	% MOD	% CIF
1	Shaft	38.001.013	$5.26	1	11.3%	57%	24%	19%
2	Brace	38.001.001	$7.30	1	15.7%	52%	30%	18%
	Screw	38.001.002	$1.03	1	2.2%	14%	35%	51%

The natural decision on which component to perform redesign focusing on reducing material consumption, is to choose the one that presents the highest value of material rate, i.e. *% of Product Final Cost * %MAT*. In the case, the chosen component has been the *Brace* (0,157 * 0,52 = 0,0816 or 8,16%).

5.2 Priority definition

Once a component has been selected to be redesigned from costs point of view, the next stage is to *rank the redesign actions*. This is defined based on the amount of material and functional implementation of each *feature* that forms the component. In this paper, a feature has been defined as being each part of a component with a physical volume and mass, which implements one or more functions. The sum of the each feature mass represents the component mass. Figure 3 illustrates the hypothetical case of a component called *Brace* (a). This component has been separated in portions, called *features* (b) (i.e. in this case four features, represented by a different colour).

a/ Component: Brace. b/ Features that define the component: Brace.

Figure 3. Example of a component and its features.

The next step involves providing information to fulfil the chart *Feature Definition* presented in Table 3. This includes: a/ defining each *feature*; b/ quantifying the masses (for each feature and component); c/ establishing the functions implemented by each feature; d/ classifying the features - firstly, in: wished (+1) and unwished (-1); secondly, defining the functions' relative importance: main, secondary (SEC) or auxiliary (AUX). In order to illustrate the procedures involved, Table 3 contains details related to the case Brace.

Table 3. Chart ***Feature Definition*** (case: Brace).

Code	Feature Description	Mass (g)	Function Description	Function Classification				
				Wished	Unwished	MAIN	SEC	AUX
A	Brace body	50	Compress shaft	X		+1		
			guide shaft	X		+1		
			support features	X			+1	
			facilitate handling	X				+1
			waste material		X			-1
B	Support	10	support screw	X		+1		
			guide screw	X				+1
C	Threaded Support	14	resist force	X		+1		
			attach screw	X			+1	
			facilitate assembly	X				+1
D	Ring	26	prop brace	X		+1		
4	**Brace**	**100**						

Following, the next stage is to derive the information that is presented in the chart Priority Matrix, pictured in Table 4. For this, the subsequent guidelines should be observed: a/ transfer the names of each feature and component; b/ obtain the values for each function (MAIN, SEC, AUX), considering the relative importance of all functions implemented by each *feature* and respective weights (5, 3 or 1, according to a scale proposed in [2]). For instance: the feature *body* implements two main functions, whose weight is 5 (+1+1*5=10); c/ obtain the figures in the column *ΣFUNC FEAT*; d/ indicate in percentage the values in the column %MAT (for the same example *body*: 50g / 100g = 50%); e/ compute REF1 = *ΣTOTALFUNC/number of features* (for the Brace case REF1 = 33 / 4 = 8,25); f/ compute REF2 = *100/number of features* (for the Brace case REF2 = 100% / 4 = 25%); g/ compare the values of *ΣFUNC FEAT e %MAT* defined for each feature with REF1 and REF2, respectively; h/ indicate in the columns SIGNAL FUNC and SIGNAL MAT, the respective symbols according to the following convention:

↑ - when the considered value is bigger than the reference (REF1 or REF2);

↓ - when the considered value is smaller than the reference (REF1 or REF2);

The last step is to evaluate the results produced and obtain the rank for the column *POT* (potential), following the convention presented in Table 5. According to each situation, it would be necessary to run more iterations (*IT* cell – iterations number) in order to obtain the final results. This is because features could present equal POT values. For additional detail can be obtained from [2].

Table 4. Chart ***Priority Matrix*** (case: Brace).

COMPONENT		**FUNCTION**				**MATERIAL**	**PRIORITY**		
Brace		**MAIN**	**SEC**	**AUX**	**Σ FUNC**	**% MAT**	**SIGNAL**		**POT**
Code	**FEATURE**	**(X5)**	**(X3)**	**(X1)**	**FEAT.**		**FUNC**	**MAT**	
A	Brace body	+10	+3	0	+13	50%	↑	↑	**2**
B	Support	+5	0	+1	+6	10%	↓	↓	**3**
C	Threaded sup.	+5	+3	+1	+9	14%	↑	↓	**4**
D	Ring	+5	0	0	+5	26%	↓	↑	**1**
4	**Brace**	**+25**	**+6**	**+2**	**+33**	**100%**	**8,25**	**25%**	**1**

ELECT FEATURE **REF1** **REF2** **IT**

Table 5. Chart ***Priority Scale***.

PRIORITY			**ANALYSIS**
POT	**SIGNAL**		
	FUNC	**MAT**	
1	↓	↑	These features contain little functional value and use considerable quantity of material to implement the function(s). Therefore, presents the greatest potential to reduce material consumption via redesign.
2	↑	↑	Despite demanding great quantity of material, this feature implements important functions. Thus, the redesign activities should also pay attention to this feature in order not to degrade the overall performance.
3	↓	↓	Despite implementing few functions, this feature still uses small amounts of material. Thus the potential to reduce material consumption is remote.
4	↑	↓	This feature should be the last one to be tackled. It implements a great deal of functions using small amounts of material.

It has to be emphasised that the priority definition is a relative evaluation, assessing different aspects from those features that define the component.

The P*Matrix* for the case *Brace* indicates coherent results, electing the feature *Ring* as the first one to be redesign cause its potential. So, the redesign team should start to look for means to modify the feature regarding the question *"how to transform its potential in material consumption savings?"*.

6. Case Study

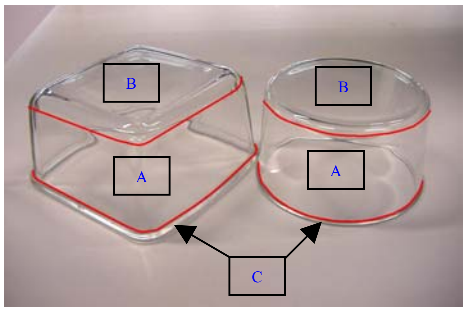
Siemens Metering Ltda (SIEMET) is a multinational company that produces and trades electrical energy meters in Curitiba, Brazil. Aiming at reducing manufacturing costs and increasing the market share in South America, SIEMET has identified the need to redesign one of its products, the electrical energy meter LGI21 (original version). The first step adopted by the design team was to evaluate the individual components of the meter by their weights, seeking for opportunities to reduce material consumption. The redesign team was formed by engineers from SIEMET (know-how of the product) and by members of Federal

Centre for Technological Education-PR (CEFET-PR) (know-how on tools and techniques for product development). The final results obtained in this redesign project for reducing material consumption were: new meter, called F21 (redesigned version), released in January 2003; with average reduction of 37,3% in the weight of the external components and 13,5% in their acquisition costs involved. As a successful case, the redesign of LGI21 has been selected as a reference for validating the P*Matrix* tool. The strategy employed has been called the reverse validation, since the redesign project had already been finished. The criteria considered for choosing LGI21 were: a/ one of the main objectives was to reduce material consumption and costs; b/ the redesign process has been conducted by an experienced and qualified team, providing successful cases as a reference; c/ the design history was documented, allowing comparative evaluations; d/ LGI21 contains components with low complexity features, which can facilitate the understanding and validation process.

The validation process has started with the study of LGI21 and its components. Next, the LGI21 external components have been highlighted as having potential to reduce material consumption (by the P*Matrix* selecting proceeds). A careful analysis has indicated that the glass cover (Figure 4-a), could be used to test the proposed tool, since it had been redesigned and presented low complexity features. The glass cover implements the following functions, according to the redesign team members: to protect and seal the meter; to allow seeing through to read the energy consumption in the metering mechanism.

a/ Glass cover for LGI21 (original version).

b/ Glass cover for F21 (redesigned version).



c/ Detected features in the case: glass cover.

Figure 4. The case study: glass cover.

Next, the glass cover has been divided in characteristic features, which would implement the component's functions. Figure 4-c presents the obtained results that are: side cover (A); front cover (B); and edge ring (C). The mass for each feature has been measured, which has given data to fulfil the chart Feature Definition (Table 6).

Table 6. Chart ***Feature Definition*** (case: Glass cover).

Code	**Feature Description**	**Mass (g)**	**Function Description**	**Function Classification**				
				Wished	**Unwished**	**MAIN**	**SEC**	**AUX**
A	Side cover	310	support front cover	X			+1	
			support edge ring	X			+1	
			seal / protect side	X		+1		
			waste material		X			-1
B	Front cover	123	see inside	X		+1		
			seal / protect front	X		+1		
C	Edge ring	59	seal meter	X		+1		
			secure main ring	X			+1	
3	**Glass cover**	**492**						

The P*Matrix* results obtained are presented in Table 7, according to feature' sequence for redesigning: side cover (A: POT = 2), edge ring (C: POT = 3) and front cover (B: POT = 4).

Table 7. Chart ***Priority Matrix*** (case: Glass cover).

COMPONENT		FUNCTION				MATERIAL	PRIORITY		
LGI21 Glass cover		MAIN	SEC	AUX	Σ FUNC FEAT.	% MAT	SINAL		POT
Code	FEATURE	(X5)	(X3)	(X1)			FUNC	MAT	
A	Side cover	+5	+6	-1	+10	63%	↑	↑	2
B	Front cover	+10	0	0	+10	25%	↑	↓	4
C	Edge ring	+5	+3	0	+8	12%	↓	↓	3
3	**Glass cover**	**+20**	**+9**	**-1**	**+28**	**100%**	**9,33**	**33,33**	**1**

For the redesigned glass cover (Figure 4-b), similar features have been identified. Here, the objective has been to verify if the feature highlighted in the chart *Priority Matrix* (side cover) as having the highest potential to reduce material consumption, had been addressed by the redesign team. Therefore, the features for F21'glass cover have been weighted. The differences for each feature in the original version and redesigned can be seen in Table 8. The mass reduction for each feature originates a sequence of gains that is equal to the rank suggested by the P*Matrix* (Table 7). Thus, at first place if the figures produced by the P*Matrix* are equivalent to those proposed by a qualified redesign team, it is possible to infer that the proposed approach is supplying reliable information.

Table 8. Comparison between the weights of the original and redesigned glass cover.

Feature	Description	Mass (g)		Mass reduction		POT	Sequence of mass reduction gain
		LGI21	F21	Value	%		
A	Side cover	310	160	150	68	2 (1º)	1º
B	Front cover	123	96	27	12	4 (3º)	3º
C	Edge ring	59	15	44	20	3 (2º)	2º
3	Glass cover	492	271	221	100	OK	OK

7. Discussion

The P*Matrix* have been tested firstly in a theoretical case (Brace). The proposed Priority Scale has produced coherent results (i.e. priority 1 stands for a feature that has a high quantity of material and little functional importance. Thus, this feature presents an opportunity for being redesigned).

After that, the P*Matrix* has been used in a reverse validation method (the LGI21 meter glass cover case). The results have been considered satisfactory compared with those of the real case. These results have been presented to the original redesign team, whose members demonstrated interest in knowing more about a tool that indicates the features with a better potential to reduce material consumption, rather than depending only on their experience. Furthermore, it is also expected that via a more systematic approach better results can be achieved, saving costs and time.

It is important to emphasize that the proposed approach highlights which components and features should be targeted, and not how to redesign them.

8. Conclusions

This investigation has shown that redesign is an important activity, performed by a great deal of companies developing products. Additionally, a literature review and field research have exposed the lack of systematic methods and tools for conducting the redesign activities. It has been observed that one of the most important issues to start a redesign process is to reduce material consumption in a product.

The information collected from several sources has provided a better understanding of the redesign process aiming at reducing material consumption. A preliminary structure for a redesign methodology (ReRCM) has been proposed [2], aiming at guiding the redesign process.

The Priority Matrix proposed (P*Matrix*) signals which feature in a component has the highest priority for being redesigned, saving some time of the whole redesign process. The case studies demonstrate the usefulness and potential of the proposed approach.

A computational implementation for P*Matrix* has already been developed in order to provide agility for whole iteration process.

A systematic approach applied during the redesign process has the potential to obtain better results and maintain the company competitive in an aggressive market.

A new application is currently being conducted with a die-casting housing (more complex component) for electrical energy meters, which has to be redesigned to reduce silumin (i.e. an aluminium-silicon alloy) consumption. The results will be published in further papers.

Acknowledgements

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