Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 32
ISSUE 1
January
2009

Risk evaluation supported by annotated paraconsistent logic: a study of a vehicle manufacturer

A.R. Albuquerque, J.B. Kliewer, I.P. de Arruda Campos*, C. Studzinski, M. Kliewer
PPGEP, ICET, UNIP, Sao Paulo, SP, Brazil
* Corresponding author: E-mail address: ipdacamp@uol.com.br

Received 01.11.2008; published in revised form 01.01.2009

Industrial management and organisation

ABSTRACT

Purpose: In the present communcation we present a FMEA derived survey questionnaire, designed to be nalysed by means of annotated paraconsistent logic techniques, which allows for both the detection of contradictions and inconsistencies on the part of the respondents, as well as for the continuous improvement of the adequacy of the instrument in itself, and its application to truck manufacture.

Design/methodology/approach: The methodology used in this study is based in the partial adoption of elements and pre-requisites needed to apply the FMEA tool and the concepts of the Paraconsistent Logic, aiming to develop a method for risk of failure criticality evaluation to new products development.

Findings: The main advantage of the novel method presented herein consists in the ability to integrate coherently the insights of many expert opinions, instead of relying on a single specialist to perform the FMEA, thus improving the accuracy and reliability of this kind of analysis. method proposed does not lead to future decision process but the future consequence of a today's decision. The method here applied describes the results in an intelligible way and points that if the company decides to minimize the project risks doing all preventive actions, it will necessary to increase costs. That is, as more conservative is the strategic company approach bigger the resultant criticality indices from specialist's evaluations more investment is need to mitigate the risks.

Practical implications: As the method takes in account all specialists evaluations and strategic parameters directly related to the Company's Strategic plan, it is considered a good project management tool concerning to the risk management process and decision making. the integration of different opinions and expertise areas, as well as multiple critical factors and failures modes analysis lead to more reliable statistics analysis and reduce the company dependency of only one specialist, during critical decision process moments.

Originality/value: The risk evaluation method described in this work allows project managers to make decisions related to project risks in order to mitigate threatens, maximize competitiveness factors and better explore market opportunities.

Keywords: Paraconsistent logic; Risk evaluation; Risk management; New product failure; FMEA

1. Introduction

According to a Booz, Allen & Hamilton's [2] market research results "In the next three years, about 75% of growth in sales volume in Brazil will be due the new products, including new brandings". In another words, new products launching from small innovations up to completely new brands, and will be the most important trigger to increase the sales ratio. Launching regularly new products is a market survival and lasting strategy for companies in a competitive world.

Launching a product inevitable requires an evaluation of risk associated to the product. There are always a finite number of probable failure modes, that even they could be handled by the technical assistance coverage or by the warranty package service, could cause inconveniences or/and expose the customers to harm and the company to a distressful situation.

Customer expects the products to work properly as advertised by the manufacturer. Recalls and failure result on slowing down sales, damages to the corporate public image, elevated costs to review and modify product project, reviewing engineering process and rising cost of warranty (Hussain, [5] 2003; Priest [9] and Sanchez, 2001; Leech, [7] 1995).

In this study, it is described a risk evaluation method in order to determine and quantifying critic levels of potential component mode of failures associated to a truck model development project. This study was performed at an automotive manufacturer company and used the Paraconsistent Logic integrated with Failure Mode and Effect Analysis (FMEA hereafter) methodologies.

2. Theoretical concepts

2.1. Paraconsistent logic annotated

The binary principles of the Classic Paraconsistent Logic do not acknowledge some situation that frequently occur in real life, such as distorted and conflict situations, the uncertainties, the ambiguities and even the vague and subjective ones (Abe [1] and Silva Filho, 2000).

The Paraconsistent Logic belongs to a non-classic logic category. Its development was motivated by the need to deal with contradictory situations, demonstrating that Paraconsistent logic is more useful when facing real world problems (DA COSTA [3, 4], 1999). According to Abe [1] and Silva Filho (2000), in the real world, the inconsistencies only occur when two or more specialists give opinions about the same subject.

2.2. Failure Mode and Effect Analysis

In the assessment of risk criticality of potential component failure is necessary, first of all, to identify the failures followed by the risk management plan related to those failures. In this article, it was adopted the FMEA technique usually applied to evaluate possible project's product failures before is it sent to manufacturing. The FMEA focus on project failure related to the degree of accomplishment defined for each one of the objectives pre-established for a project. FMEA defines the need for changes in a product project; establishes priorities for improvements and helps on test definitions, product validation, identification of critical characteristics and also in requirements' evaluation and project alternatives (STAMATIS, [11] 2003).

2.3. Risks related to potential components failures

Risk is a common factor in all projects, due to its distinct characteristics and the environment in which each project is developed. It is necessary to perform risk evaluation of the project; although the risk can't be completely eliminated most of them can be anticipated and preventively controlled.

Under such reality, some objectives were the motivator of this study, such as:

- Evaluation of criticality of each failure mode, using not only one specialist opinion but many of them, followed by a weight process of the resultant opinions. Such method leads to a more objective approach in determining impacts to the customer, in the hypothesis of occurrence of a failure.

- Individual criticality determination and detailed analysis of each potential failure mode. This step is a fundamental one because allows the determination of the most suitable action, in order to minimize the risks associated to each component and consequently to the new product.

3. Methodology

The methodology used in this study is based on the partial adoption of elements and pre-requisites needed to apply the FMEA tool and the concepts of the Paraconsistent Logic, aiming to develop a method for risk of failure criticality evaluation in new products development. The flow chart in Figure 1 illustrates step by step of the adopted method here.

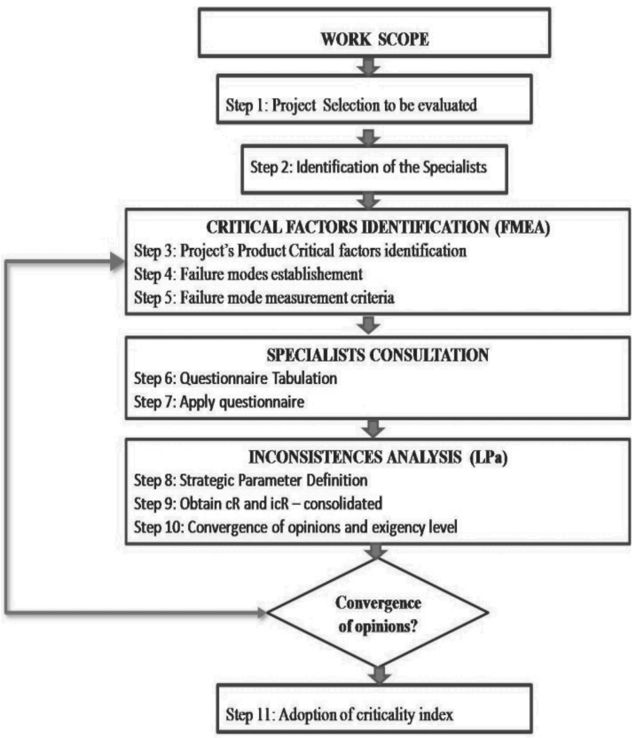

Fig. 1. Risk evaluation method flow chart

4. Method application

The methodology illustrated above was applied in a case study of a truck development in an automotive manufacture company, as described as follows:

Step 1 – Selection of product's project to be evaluated.

It was chosen a truck development project for testing the method.

Step 2 – Classification of the Specialists

The Specialists were gathered in five distinct classes, as:

Class A – Parts Design / Test Specialists

Class B – Entire Vehicle Specialists

Class C – Vehicle Test Specialists

Class D – Quality Management Specialists

Class E – After Sales Specialists

The classification of the specialists in the project followed this classification rank, since they all were involved in the truck development, as in the product development (Classes A, B and C) or as in the translation of customer expectations related to the product adequacy as in the monitoring of accomplishment of such expectation, during the whole process of product development (Classes D and E).

Step 3 – Product's critical factors identification

Table 1.
Components Potentially Critics for the selected Project

POTENTIALLY CRITICAL PARTS	
1	Access handle
2	Cable bridge
3	Harness
4	Rearview mirror
5	Headlamp
6	Leaf spring front
7	Rear axle parabolic spring
S	Tail lamp
9	Spring saddle, rear axle
10	Axle Bearing (disk brake)
11	Axle Bearing (drum brake)
12	Fifth wheel table
13	Auxiliar spring
14	Mudguard front
15	Muffler
16	Retarder
17	Frame
18	Fifth wheel
19	Temperature sensor
20	Electromagnetic key bracket
21	Gear box bracket
22	Engine bracket
23	Cab suspension
24	Door lock
25	Flexible pipe
26	Tunnel of short cabin + comfortable
27	Turbo brake
23	Electrical glasses
29	Compressor
30	Driving mechanism of fan
31	Driven plate / single plate clutch
32	Mounting throw out shaft / Throw out
33	Pressure plate
34	Shifting system (Pneumatic system)
35	Shifting system (Hydraulic system)
36	Gear box cooling pipe
37	Fifth wheel bracket
38	Axle
39	Driveline
40	Driveline
41	Brake disc
42	Brake
43	Brake pad
44	Solenoid valve bracket
45	Air tank bracket (circuit 2)
46	Air tank bracket (circuit 1)
47	Air tank bracket (circuit 2)
48	Air tank bracket (circuit 3)
49	Air tank bracket (circuit 4)
50	Air tank bracket (circuit 5)
51	Fuel tank bent
52	Fuel tank fixing bracket
53	Fuel tank
54	Cooling of retarder
55	Dog house
56	Hose clear air
57	Battery box

It was identified 57 factors for that product project, considered here as the potential critic components for the truck (Table 1).

Step 4 Establishment of failure modes

There were identified the failure modes of each factor, that in this present study represent different potential failure modes of the selected critic components. "Failure Modes" is a manner description of a component or system which could potentially fail, or not be suitable in attending customer needs and expectations, during its functions. Here were not considered whether the failure is going to happen or not but indeed were considered possible ways of a certain potential failure mode happen, due the project deficiencies. After a data compiling, there were identified 107 potential failure modes, as shown in Table 2 as follows.

Table 2
Components and Potential Failure Modes

	PARTS	POTENTIAL FAILURE MODES
1	Access handle	Pipe crack
2	Cable bridge	Fixing torque incorrect
3		Interference with driveline on bracket
4		Harness belt fixing release
5	Harness	Melting heat
6	Rearview mirror	Undesirable closing
7		Vibration
8	Headlamp	Water penetration in headlamp and function damage
9	Leaf spring front	Leaf spring breake
10	Rear axle parabolic spring	Break
11	Tail lamp	Water and dust penetration
12		Fixing break of tail lamp
13		Connection break of tail lamp
14		Head lamp damage
15		Release of reflector
16		Lens crack
17	Spring saddle, rear axle	Break
18	Axle Bearing (disk brake)	Break of barr V bracket
19	Axle Bearing (drum brake)	Break of barr V bracket
20	Fifth wheel table	Crack / break
21	Auxiliar spring	Spring breake
22	Mudguard front	Clamp breake
23		Clamp crack
24	Muffler	New
25	Retarder	Impossible assembly
26	Frame	Side member brake
27		Cross member brake (above gear box has high risk)
28		Screw release
29	Fifth wheel	Excessive wear
30		Rupture of internal screw
31		Crack of cast surface
32	Temperature sensor	Temperature sensor failure
33	Electroma-gnetic key bracket	Friction between bracket battery and cable
34	Gear box bracket	Bracket break
35	Engine bracket	Bracket break
36	Cab suspension	Uncomfortable
37		Interference between rear suspension tie rod and dog h
38		Interference between running board and front bumper
39	Door lock	Mechanism mal function
40	Flexible pipe	Loss fixing torque
41		Ring rupture
42	Tunnel of short cabin + comfortable suspension	Tunnel crack
43	Turbo brake	Function damage
44		Turbo brake break
45	Electrical glasses	Electrical glasses failure
46		System locking
47	Compressor	System used in access
48	Driving mechanism of fan	Leakage on viscous Horton
49	Driven plate / single plate clutch	Friction material centrifuging
50		Hub wear
51		Damping wear
52		Covering wear excessive
53		Brake of cushion spring
54		Brake of torsion spring
55		Rivet covering release
56	Mounting throw out shaft / Throw out bearing	Particles contamination
57		Loss of lubrification
58		Bearing break

	PARTS	POTENTIAL FAILURE MODES
59	Pressure plate	Load loss of press ion plate
60		Moving loss of pression plate
61		Brake of membran spring
62	Shifting system (Pneumatic system)	Scratchement
63		Module failure
64		Solenoid failure
65	Shifting system (Hydraulic system)	Pipe wear
66		Air on hydraulic system
67	Gear box cooling pipe	Pipe rupture
68	Fifth wheel bracket	Crack / break
69	Axle	Oil wear
70		Ring release in Rear Axle
71		Leakage of oil from hub
72		Leakage of oil from seal ring
73	Driveline	Axial wear
74		Crosspiece wear
75	Driveline	Axial wear
76		Crosspiece wear
77	Brake disc	Surface disk contamination
78		Blocking nets
79		Break
80		Crack
81	Brake	
82	Brake pad	Friction material surface contamination
83		Crack
84		Vitrification
85	Solenoid valve bracket	Break
86	Air tank bracket (circuit 2)	Break
87	Air tank bracket (circuit 1)	Break
88	Air tank bracket (circuit 2)	Break
89	Air tank bracket (circuit 3)	Break
90	Air tank bracket (circuit 4)	Break
91	Air tank bracket (circuit 5)	Break
92	Fuel tank bent	Loss torque of belt
93		Welding rupture of belt (two side)
94		Welding rupture of belt (one side)
95	Fuel tank fixing bracket	Loss torque of fixing screw
96		Crack / bracket rupture
97	Fuel tank	Tank hole
98		Release and rupture internal components of tank
99		Crack on drain plug region
100		Welding crack of filler cap
101		Welding crack of closing tank
102	Cooling of retarder	Incorrect functioning of retarder sensor
103		Water leakage from pipe
104	Dog house	Dog house impossible assembly
105	Hose clear air	Hole
106	Battery box	Box breake
107		Cover breake

Step 5 Determination of a measurement criteria for failure modes.

It was created a criticality scale to evaluate the severity of failure modes by the specialists, as shown in the Figure 2, as follows:

0,0 – 0,10	0,11 – 0,30	0,31 – 0,50	0,51 – 0,80	0,81 – 1
Very Low	Low	Medium	High	Very High

Fig. 2. Criticality Classification Index

The criteria associated to each one of criticality index are presented in the Table 3.

Step 6 Questionnaire Tabulation

An Excel spreadsheet were built with selected critical factors and associated its potential failure modes in rows and the Specialists Classes (evaluators) in the columns

Step 7 Questionnaire's Application

The questionnaire was answered by 23 specialists. In doing that, it was possible to collect the criticality degree (c) and the criticality inexistence degree (ic) associated to each one of the 107 failure mode identified previously as shown in Table 4.

Table 3
Criteria associated to each criticality classification indices

Criteria	Criticality
Customer barely perceive the failure	Very Low
Lightness impair in performance with minor customer dissatisfaction	Low
Significant impair in performance and apparent customer dissatisfaction	Medium
System malfunction causing marked customer dissatisfaction	High
System malfunction affecting customer safety	Very High

Step 8 Definition of strategic parameters
It was adopted three parameters: conservative, intermediate and optimist for an evaluation of criticality indices, as a result of the specialist's opinion.

Step 9 Consolidation of the criticality degree (cR) and criticality inexistence (icR)
The criticality degree (cR) and criticality inexistence (icR), resultant of each component failure mode, were compiled through Paraconsistent logic, verified considering the three evaluation criteria (conservative, moderate and optimistic).

Step 10 Analysis of convergence of opinions
The resultant contradiction degrees (Gcontr) were calculated. In order to accept the contradiction degree, the minimum exigency level (LexiJg min) and maximum exigency level (Lexig max) were calculated comparing them with the criticality scale shown in Fig. 1, in the following way:
Conservative strategic parameter Lexig min = 0.10 e Lexig máx = 0.3;
Intermediate strategic parameter: Lexig min = 0.30 e Lexig máx = 0.5;
Optimistic strategic parameter: Lexig mín = 0.50 e Lexig máx = 0.8.
Subsequently, the contradiction degree of each one of the 107 potential failure modes were analyzed and categorized as "coherent", "inconsistent" and "incomplete".

Step 11 Criticality Index adoption for coherent Evaluation.
There were obtained 2 (two) criticality resultants (cR and cR1) for the failure modes which criticality evaluation were classified as "coherent". Afterwards, it was used the highest criticality index, among the obtained ones in step 10 (cR or cR1), considering only the "coherent" evaluation, for each one of the strategic parameters.

Table 4
Questionnaire for criticality evaluation

Factor	Parts	Failure mode	Group A Parts Design / Test Specialist		Group B Entire Vehicle Specialist		Group C Vehicle Test Specialist		Group D Quality Management Specialist		Group E After Sales Specialist	
F1	Access handle	Pipe crack	0.4	0.65	0.15	0.9	0.11	0.9	0.3	0.5	0.1	0.65
F2	Cablebridge	Fixing torque incorrect	0.2	0.7	0.05	0.9	0.2	0.9	0.4	0.75	0.3	0.2
F3		Interference with driveline on bracket	0.1	0.55	0.25	0.7	0.9	0.9	0.3	0.75	0.3	0.2
F4		Harness beltfixinq release	0.1	0.55	0.2	0.7	0.81	0.9	0.3	0.75	0.2	0.75
F5	Harness	Melting heat	0.8	0.3	0.9	0	0.81	0.2	0.5	0.1	1	0.01
F6	Rearview mirror	Undesirable closing	0.5	0	0.45	0.2	0.5	0	0.7	0.5	0.9	0.4
F7		Vibration	0.3	0.3	0.35	0.5	0.4	0.2	0.5	0.7	0.6	0.5
F8	Headlamp	Water penetration in headlamp and function damage	0.8	0.5	0.65	0.5	0.2	0	0.4	0.2	0.1	0.2
F9	Leaf spring front	Leaf spring breake	0.51	0.45	0.75	0	0.8	0	0.8	0.2	0.6	0.2
F10	Rear axle parabolic spring	Break	0.51	0.45	0.75	0	0.8	0	0.8	0.2	0.6	0
F11	Tail lamp	Water and dust penetration	0.2	0.65	0.15	0.8	0.2	0.9	0.7	0.8	0.2	0.65
F12		Fixing break of tail lamp	0.5	0.65	0.25	0.2	0.7	0.7	0.7	0.4	0.81	0.65
F13		Connection break of tail lamp	0.5	0.65	0.15	0.2	0.6	0.7	0.6	0.4	0.6	0.6
F14		Head lamp damage	0.4	0.7	0.35	0.5	0.5	0.2	0.6	0.7	0.1	0.6
F15		Release of reflector	0.3	0.9	0.08	0.7	0.6	0.9	0.5	0.7	0.1	0.6
F16		Lens crack	0.3	0.8	0.05	0.5	0.3	0.9	0.5	0.5	0.2	0.6

Table 5
Quantitative failure modes versus convergence of specialist's opinions, considering the three strategic parameters

Specialists Evaluation		Failure Modes		Decision
		Amount	%	
Conservative Strategical Parameter	COEHERENT EVALUATION	76	71%	Acceptable Convergence to criticity evaluation
	INCONSISTENT EVALUATION	4	4%	The research must be fullfilled using different specialists
	INCOMPLETED EVALUATION	27	25%	New discussion looping between the specialists
		107	100%	
Intermediate Strategical Parameter	COEHERENT EVALUATION	101	94%	Acceptable Convergence to criticity evaluation
	INCONSISTENT EVALUATION	0	0%	The research must be fullfilled using different specialists
	INCOMPLETED EVALUATION	6	6%	New discussion looping between the specialists
		107	100%	
Optimistic Strategical Parameter	COEHERENT EVALUATION	107	100%	Acceptable Convergence to criticity evaluation
	INCONSISTENT EVALUATION	0	0%	The research must be fullfilled using different specialists
	INCOMPLETED EVALUATION	0	0%	New discussion looping between the specialists
		107	100%	

Table 6
Number of failure modes evaluated (Coherent) versus Criticality Indices

Criticity Index		Total	% View
Conservative Strategical Parameter	VERY LOW	0	0%
	LOW	0	0%
	MEDIUM	3	4%
	HIGH	17	22%
	VERY HIGH	56	74%
		76	100%
Intermediate Strategical Parameter	VERY LOW	0	0%
	LOW	8	8%
	MEDIUM	10	10%
	HIGH	57	56%
	VERY HIGH	26	26%
		101	100%
Optimistic Strategical Parameter	VERY LOW	10	9%
	LOW	23	21%
	MEDIUM	38	36%
	HIGH	35	33%
	VERY HIGH	1	1%
		107	100%

5. Results presentation

Some qualitative results obtained by applying the method here described, were distinguished, as follows:
Criticality indices for risk evaluation resultants of the proposed method (only the failure modes classified by specialists as "coherent" – see Table 6)

6. Comparison with other risk evaluation methodology, based on criticality of potential failure modes

The resultant criticality indices, presented here, were compared against the ones used by the manufacture company to determine risk level. It was verified that the indices were very similar to the ones used by the company case, once they apply the theory suggested by the FMEA, although the evaluation at the company case is done by only specialist, in a simplified approach. The company's criticality indices used are shown in Table 7.

It was adopted a coherency index for the sake of comparison between the indices obtained through the proposed methodology and the ones calculated a systematic approach at the company used in the present study case. Such index is nothing more than the maximum difference acceptable between the two results (between the two methods). It was taken 0,3 as a reference value for such index.
Methods comparison: if the bigger cR (resultant criticality index obtained as described in Step 11 minus the company's criticality index) is smaller or equal to 0.30, we conclude that both methods evaluate in the same way the potential failures and the evaluation is classified as "coherent".

Table 7
Criticality Indices adopted by the Company's case study

FACTOR	PARTS	FAILURE MODE	Severity Index evaluated by the company
F1	Access handle	Pipe crack	0.4
F2	Cablebridge	Fixing torque incorrect	0.4
F3		Interference with driveline on bracket	1
F4		Harness belt fixing release	0.7
F5	Harness	Melting heat	0.7
F6	Rearview mirror	Undesirable closing	1
F7		Vibration	1
F8	Headlamp	Water penetration in headlamp and function damage	1
F9	Leaf spring front	Leaf spring breake	0.4
F10	Rear axle parabolic spring	Break	0.4
F11	Tail lamp	Water and dust penetration	1
F12		Fixing break of tail lamp	1
F13		Conection break of tail lamp	1
F14		Head lamp damage	1
F15		Release of reflector	1
F16		Lens crack	1

Table 8
Conservative Strategic parameter – Proposed Method versus Company's adopted method

Factor	Parts	Failure mode	Decision for the evalution	Bigger Value between CR/ CR1	Final Index of Severity - Proposed Method	Severity Index evaluated by the company	Final Evaluation - 2 Methods Comparison
F1	Access handle	Pipe crack	coherent evaluation	0.5	Medium	0.4	coherent
F2	Cablebridge	Fixing torque incorrect	inconsistent evaluation			0.4	
F3		Interference with driveline on bracket	coherent evaluation	0.9	Very high	1	coherent
F4		Harness belt fixing release	inconsistent evaluation			0.7	
F5	Harness	Melting heat	coherent evaluation	1	Very High	0.7	reevaluate
F6	Rearview mirror	Undesirable closing	coherent evaluation	1	Very High	1	coherent
F7		Vibration	incompleted evaluation			1	
F8	Headlamp	Water penetration in head-lamp and function damage	incompleted evaluation			1	
F9	Leaf spring front	Leaf spring breake	incompleted evaluation			0.4	
F10	Rear axle parabolic spring	Break	incompleted evaluation			0.4	
F11	Tail lamp	Water and dust penetration	inconsistent evaluation			1	
F12		Fixing break of tail lamp	coherent evaluation	0.8	High	1	coherent
F13		Conection break of tail lamp	incompleted evaluation			1	
F14		Head lamp damage	incompleted evaluation			1	
F15		Release of reflector	incompleted evaluation			1	
F16		Lens crack	coherent evaluation	0.5	Medium	1	coherent

Table 9
Intermediate strategic parameter - Proposed Method versus Company's adopted method

Factor	Parts	Failure mode	Decision for the evalution	Bigger Value between CHI CR1	Final Index of Severity - Proposed Method	Severity Index evaluated by the company	Final Evaluation - 2 Methods Comparison
F1	Access handle	Pipe crack	coherent evaluation	0.4	Medium	0.4	Coherent
F2	Cablebridge	Fixing torque incorrect	coherent evaluation	0.3	Low	0.4	Coherent
F3		Interference with driveline on bracket	coherent evaluation	0.3	Low	1	Coherent
F4		Harness beltfixinq release	coherent evaluation	0.3	Low	0.7	Coherent
F5	Harness	Melting heat	coherent evaluation	0.9	Very high	0.7	Coherent
F6	Rearview mirror	Undesirable closing	coherent evaluation	0.8	High	1	Coherent
F7		Vibration	coherent evaluation	0.5	Medium	1	Coherent
F8	Headlamp	Water penetration in headlamp and function damage	incompleted evaluation			1	
F9	Leaf spring front	Leaf spring breake	coherent evaluation	0.8	High	0.4	Reevaluate
F10	Rear axle parabolic spring	Break	coherent evaluation	1	Very high	0.4	Reevaluate
F11	Tail lamp	Water and dust penetration	coherent evaluation	0.2	Low	1	Coherent
F12		Fixing break of tail lamp	incompleted evaluation			1	
F13		Conection break of tail lamp	coherent evaluation	0.6	High	1	Coherent
F14		Head lamp damage	coherent evaluation	0.4	Medium	1	Coherent
F15		Release of reflector	coherent evaluation	0.3	Low	1	Coherent
F16		Lens crack	coherent evaluation	0.4	Medium	1	Coherent

Table 10
Optimistic Strategic parameter – Proposed Method versus Company's adopted method

Factor	Parts	Failure mode	Decision for the evalution	Bigger Value between CRI CR1	Final Index of Severity - Proposed Method	Severity Index evaluated by the company	Final Evaluation - 2 Methods Comparison
F1	Access handle	Pipe crack	coherent evaluation	0.1	Very low	0.4	Coherent
F2	Cablebridge	Fixing torque incorrect	coherent evaluation	0.1	Very low	0.4	Coherent
F3		Interference with driveline on bracket	coherent evaluation	0.1	Very low	1	Coherent
F4		Harness beltfixinq release	coherent evaluation	0.1	Very low	0.7	Coherent
F5	Harness	Melting heat	coherent evaluation	0.7	High	0.7	Coherent
F6	Rearview mirror	Undesirable closing	coherent evaluation	0.5	Medium	1	Coherent
F7		Vibration	coherent evaluation	0.3	Low	1	Coherent
F8	Headlamp	Water penetration in headlamp and function damage	coherent evaluation	0.5	Medium	1	Coherent
F9	Leaf spring front	Leaf spring breake	coherent evaluation	0.6	High	0.4	Coherent

Factor	Parts	Failure mode	Decision for the evalution	Bigger Value between CRI CR1	Final Index of Severity - Proposed Method	Severity Index evaluated by the company	Final Evaluation - 2 Methods Comparison
F10	Rear axle parabolic spring	Break	coherent evaluation	0.6	High	0.4	Coherent
F11	Tail lamp	Water and dust penetration	coherent evaluation	0.2	Low	1	Coherent
F12		Fixing break of tail lamp	coherent evaluation	0.3	Low	1	Coherent
F13		Conection break of tail lamp	coherent evaluation	0.3	Low	1	Coherent
F14		Head lamp damage	coherent evaluation	0.3	Low	1	Coherent
F15		Release of reflector	coherent evaluation	0.1	Very low	1	Coherent
F16		Lens crack	coherent evaluation	0.1	Very low	1	Coherent

Otherwise, the two methods evaluations were not convergent suggesting "reevaluation" (table 8-10).

The results for the 107 potential failures comparison between the two methods are presented in Table 11.

The evaluation results in the "non-conclusive" category are related to failure modes classified as "inconsistent" and "incomplete" at step 10.

Table 11
Comparison results between the proposed study method and the company's adopted one.

	Result	Amount of Failure Modes	% View
Conservative Strategical Parameter	Reevaluate	44	41%
	Coherent	32	30%
	Non-conclusive evaluation	31	29%
		107	100%
Intermediate Strategical Parameter	Reevaluate	22	21%
	Coherent	79	74%
	Non-conclusive evaluation	6	6%
		107	100%
Optimistic Strategical Parameter	Reevaluate	0	0%
	Coherent	107	100%
	Non-conclusive evaluation	0	0%
		107	100%

7. Conclusions and recommendations for further studies

This study presents a new product's risk evaluation method associated to potential failures in the critic components applied in a new truck case study. It was evaluated 107 potential failure modes from the specific truck development project, using Paraconsistent Logic associated with Failure Mode and Effect Analysis (FMEA) technique. The methodology has been proved to be extremely flexible and adequate as an analysis criterion for criticality of failure modes in new products project. As the method takes in account all specialists evaluations and strategic parameters directly related to the Company's Strategic plan, it is considered a good project management tool concerning to the risk management process and decision making. The method identifies, analyzes and quantifies the criticality associated to the new product potential failure modes improving the preventive action plan in order to mitigate project risks and consequently save company costs.

When a project's potential failure mode criticality evaluation is performed by only one specialist it can diminish the trustworthiness of the evaluation because some risk factors could be neglected once they are not related to his/her area of expertise. In this way, the integration of different opinions and expertise areas, as well as multiple critical factors and failures modes analysis lead to more reliable statistics analysis and reduce the company dependency of only one specialist, during critical decision process moments.

As an example of the proposed method, let's take that a product development and a manufacturer specialist evaluate the criticality index of potential failure as very 0.1 and a third specialist (Quality specialist) as very high (0.9). Such evaluation would result in an average of 0.55 leading to a "moderate" criticality, as a result of a very commonly applied arithmetic process. However, this result undervalues the third specialist opinions related to the risk level. In applying the proposed method, by the present study, it could be solved in a better way. Analogous consideration could be made to the specialist's opinions such as "intermediate" or "optimistic" which fit better to the strategic company approach and, at the same time contemplates all specialists' evaluation in the analysis.

It is important to point out that the risk evaluation method proposed does not lead to future decision process but the future consequence of a today's decision. The method here applied describes the results in an intelligible way and points that if the company decides to minimize the project risks doing all preventive actions, it will necessary to increase costs. That is, as more conservative is the strategic company approach hihger the resultant criticality indices from specialist's evaluations more investment is need to mitigate the risks.

The risk evaluation method described in this work allows project managers to make decisions related to project risks in order to mitigate threatens, maximize competitiveness factors and better explore market opportunities.

Nomenclature

(cR) = criticality degree
(icR) = non-existent criticality
(Gcontr) = resultant contradiction degree
(Lexig mín) = minimum exigency level
(Lexig máx) = maximum exigency level

References

[1] Abe, JSF, J. I. "Introdução à Lógica Paraconsistente Anotada com Ilustrações". 1ª. ed. Santos, SP: Emmy, 2000.

[2] B.A. Hamilton, The Customer Connection: The Global Innovation 1000, Pesquisa disponível em: http://www.boozallen.com/media/file/Global_Innovation_1000_2007.pdf, 2008.

[3] N.C.A. Da Costa, et al, Lógica Paraconsistente Aplicada, SP: Atlas, São Paulo, 1999.

[4] N.C.A. Da Costa, On the Theory of Inconsistent Formal Systems, Notre Dame Journal of Formal Logic 15/4 (1974) 497-510.

[5] A.Z.M.O. Hussain, D.N.P. Murthy, Warranty and optimal reliability improvement through product development, Mathematical and Computer Modelling 38/1-13 (2003) 1211-1217.

[6] P.C. Kaminski, Desenvolvendo Produtos, Planejamento, Criatividade e Qualidade, RJ: LTC, Rio de Janeiro, 2000.

[7] D.J. Leech, Proof of Designed Reliability, Engineering Management Journal 5/4 (1995) 169-174.

[8] P. Palady, Análise dos Modos de Falha e Efeitos: Prevendo e Prevenindo Problemas Antes que Ocorram, SP: IMAM, São Paulo, 1997.

[9] WJ Priest, JM. Sanchez, Product development and design for manufacturing, Second Edition, Marcel Dekker NY, New York, 2001.

[10] J.R.C. Salles, et al., Gerenciamento de Riscos em Projetos". First Edition, Editora FGV, Rio de Janeiro, 2007.

[11] D.H. Stamatis, Failure Mode and Effect Analysis: FMEA from theory to execution, Second Edition, ASQC, WI: Quality Press, Milwaukee, 2003.

[12] S.F. Simões, Aplicação de FMEA e FMECA na Tecnologia Submarina, Sp: Cenpes/Pdp/Ts Petrobrás, São Paulo, 2004.

[13] S. Woiler, W.F. Mathias, Projetos: planejamento, elaboração, análise, SP: Atlas, São Paulo, 1996.