Defining engineering characteristics of an electric kit for motorcycle hybridization in the Colombian context using QFD

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CONTENT

- Introduction.
- Related work.
- QFD implementation.
- Conclusions.

http://sostenibilidad.semana.com/medio-ambiente/articulo/contaminacion-del-aire-en-medellin-es-un-problema-cronico/38650

http://agenciadenoticias.unal.edu.co/detalle/article/vehiculos-producen-el-50-de-la-contaminacion-en-bogota.html

https://airenuevobogota.wordpress.com/2015/05/31/echando-humo-blanco-las-motos-de-dos-tiempos/

http://www.bogota.gov.co/article/contaminaci%C3%B3n-de-motos-bogotanas-contin%C3%BAa-disminuyendo

COLOMBIA

57% (7 ´740.838)
Internal Combustion Engine (ICE)

[RUNT, 2018]

COLOMBIA

36.64%
111 c.c and 135 c.c
Street/sport segment

[FENALCO & ANDI, 2017]

MEDELLÍN

59% PM 2.5 of
Land Transportation

15%

[ÁREA METROPOLITANA, 2015]

Emissions from combustion engines is one of the most important causes of air pollution in Colombia.

COLOMBIA

- Autonomy
- Charge points
- Price/benefits

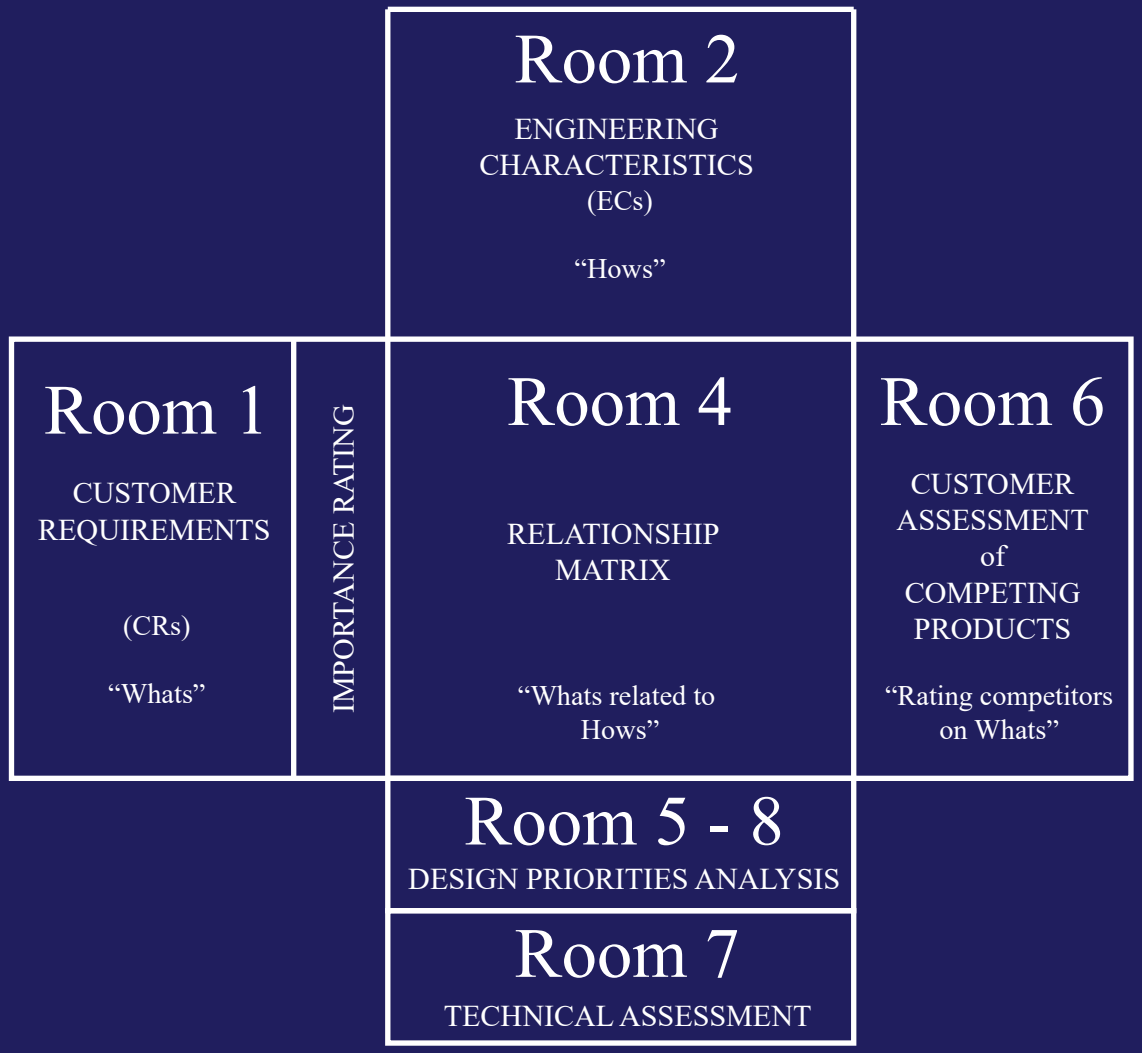
100% ELECTRIC SOLUTIONS

A solution between ICE and pure electric motors, allowing the conversion of the motorcycles currently circulating in the country with an electric kit, is an attractive short term solution.

METHODOLOGIES

- Quality Function Deployment (QFD)
  - Succesfully developed in the industry.
  - Easy understanding.
  - Clear and graphic results.
- Benchmarking
- Product Design Specification (PDS)

House Of Quality (HOQ)



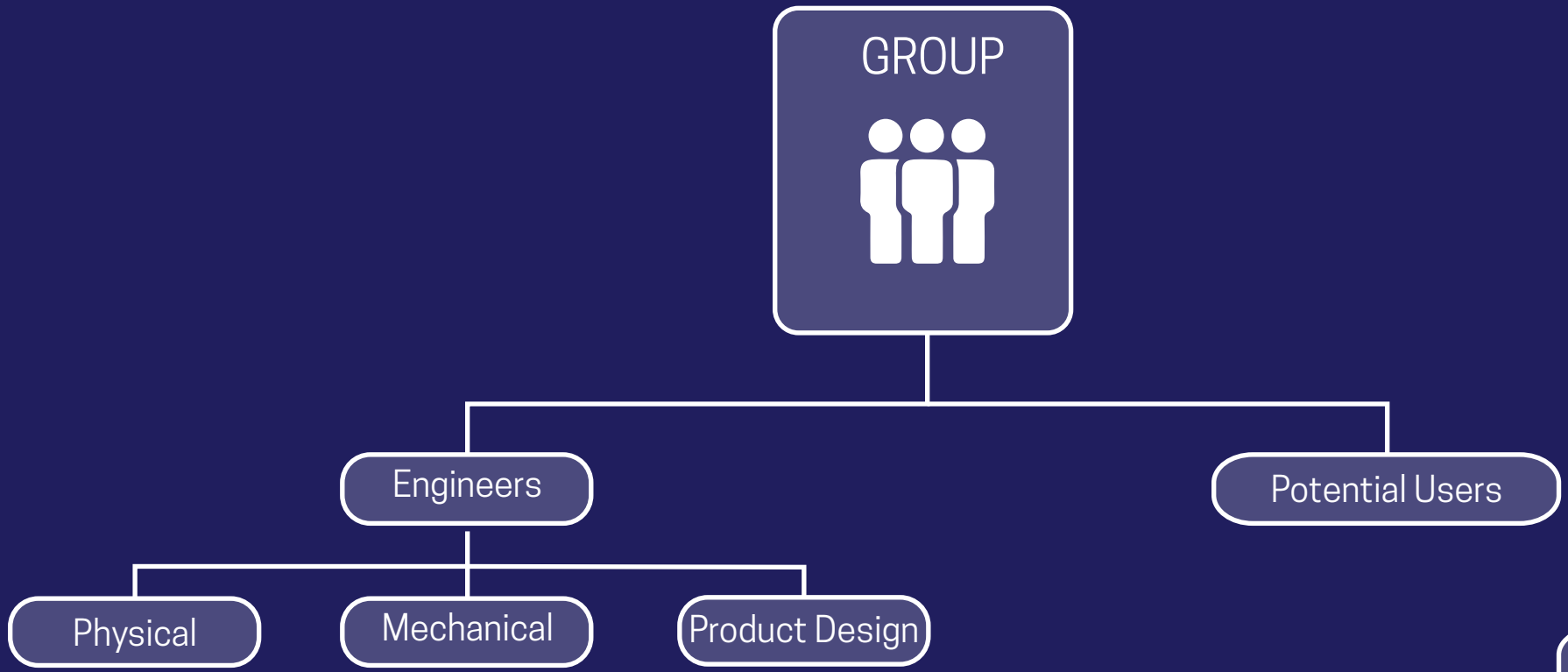
CR to EC Relationship Strength Codes for Room 4

- ◉ Strong
- ○ Medium
- ▲ Weak

Blank - None

[DIETER & SCHMIDT, 2009]

The definition of the Customer Requirements (CR) is the first step in the design process.



Total
15 CRs

Room 1 CUSTOMER REQUIREMENTS (CRs) "Whats"	IMPORTANCE RATING

Customer Requirements (CR)

- Hybrid Motorcycle
- Electric Kit

Row #	Weight	CR #	Customer Requirements	
1	3,0	CR1	The kit should make the motorcycle more ecological	
2	4,0	CR2	The kit should make the motorcycle more efficient	
3	4,0	CR3	The kit must reduce motorcycle opperation cost	
4	4,0	CR4	The kit must be minimally invasive	
5	3,0	CR5	The kit must be affordable	
6	2,0	CR6	The kit must be lightweight	
7	3,0	CR7	The kit must be easy to assembly and disassembly	
8	3,0	CR8	The kit must be small	
9	5,0	CR9	The kit must support water and dust	*
10	5,0	CR10	The kit must have a guarantee	*
11	5,0	CR11	The kit must be safe	*
12	4,0	CR12	The kit must keep motorcycle driving ease	
13	5,0	CR13	The kit must have a long lifespan	*
14	4,0	CR14	The kit must keep the motorcycle loading capacity	
15	5,0	CR15	the kit must keep the motorcycle autonomy	*

* CR 9 -11 * CR 13 * CR 15

Room 2

ENGINEERING CHARACTERISTICS (ECs)

"Hows"

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Direction of Improvement: Minimize (▽), Maximize (△), or Target (X)	▽	▽	▽	△	▽	X	▽	▽	▽	X	X	X	X	X	X	△	X
EC #	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	EC10	EC11	EC12	EC13	EC14	EC15	EC16	EC17
Quality Characteristics "Engineering Characterisics"	CO emissions per Km gr/km) *	HC emissions per Km(gr/km) *	gas consumption(km/gal) *	autonomy (Km) *	Operation cost ($/km) *	Product cost ($)	Product weight (Kg)	Assembly Time (man/hour) *	Volume(m3)	normativity (IP)	Warranty time (Mont)	Design security factor (#)	Opperational extra functions (#) *	Life span(Years)	Loading capacity (Kg) *	Ecological materials (%)	gravity center height (cm) *

Engineering Characteristics (EC)

- Hybrid Motorcycle
- Electric Kit

Total 17

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	CR #	Quality Characteristics "Engineering Characterisics" / Demanded Quality "Customer Requirements"	CO emissions per Km gr/km) *	HC emissions per Km(gr/km) *	gas consumption(km/gal) *	autonomy (Km) *	Operation cost ($/km) *	Product cost ($)	Product weight (Kg)	Assembly Time (man/hour) *	Volume(m3)	normativity (IP)	Warranty time (Mont)	Design security factor (#)	Opperational extra functions (#) *	Life span(Years)	Loading capacity (Kg) *	Ecological materials (%)	gravity center height (cm) *
Column #						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Direction of Improvement: Minimize (▽), Maximize (△), or Target (X)						▽	▽	▽	△	▽	X	▽	▽	▽	X	X	X	X	X	X	△	X
EC #						EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	EC10	EC11	EC12	EC13	EC14	EC15	EC16	EC17
1	9	7,7	5,0	CR1	The kit should make the motorcycle more ecological	Θ	Θ	Θ	▲	▲	▲	▲		▲					▲		Θ	
2	9	6,2	4,0	CR2	The kit should make the motorcycle more efficient	Θ	Θ	Θ	Θ	Θ		O								O		
3	9	6,2	4,0	CR3	The kit must reduce motorcycle opperation cost	O	O	Θ	▲	Θ		▲	▲							▲		
4	9	6,2	4,0	CR4	The kit must be minimally invasive							▲	Θ	O				▲				
5	9	6,2	4,0	CR5	The kit must be affordable					▲	Θ		▲			▲			▲			
6	9	7,7	5,0	CR6	The kit must be lightweight	▲	▲	▲	O	▲		Θ		▲			O			O		O
7	9	4,6	3,0	CR7	The kit must be easy to assembly and disassembly					▲	▲	O	Θ	▲	O			▲				
8	9	4,6	3,0	CR8	The kit must be small						▲	▲	▲	Θ	▲		▲			▲		
9	9	7,7	5,0	CR9	The kit must support water and dust					O	O	▲	▲		Θ	▲	▲		O			
10	9	7,7	5,0	CR10	The kit must have a guarantee					▲	O		▲		O	Θ	▲		O			
11	9	7,7	5,0	CR11	The kit must be safe						▲		▲		O	▲	Θ	▲	▲			
12	9	6,2	4,0	CR12	The kit must keep motorcycle driving ease				▲			O		▲				Θ		▲		Θ
13	9	7,7	5,0	CR13	The kit must have a long lifespan						▲				O	Θ	▲		Θ			
14	9	6,2	4,0	CR14	The kit must keep the motorcycle loading capacity							O		▲			▲			Θ		▲
15	9	7,7	5,0	CR15	the kit must keep the motorcycle autonomy			O	Θ	▲	▲	▲		▲						▲		▲
Max Relationship Value in Column						9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Weight / Importance						150.8	150.8	210.8	167.7	175.4	141.5	178.5	136.9	100.0	156.9	160.0	126.2	80.0	136.9	121.5	69.2	92.3
Relative Weight						6.4	6.4	8.9	7.1	7.4	6.0	7.6	5.8	4.2	6.7	6.8	5.4	3.4	5.8	5.2	2.9	2.9

Θ Strong Relationship
O Moderate Relationship
▲ Weak Relationship

Room 4 - RESULTS

- EC3 - gas consumption (Km/gal) - 8.9%
- EC7 - Product weight (Kg) - 7.6%
- EC5 - Operation cost ($/Km) - 7.4%

TOP 3 ECs

It's necessary to take into account the others variables according to the relative weight for a future product development.

Room 6

CUSTOMER ASSESSMENT of COMPETING PRODUCTS

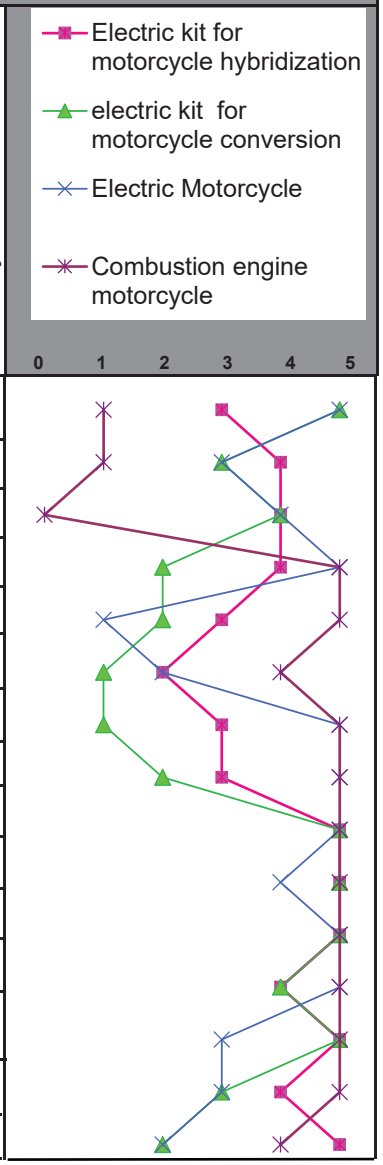
"Rating competitors on Whats"

Competitors

- Electric Kit for motorcycle hybridization
- Electric Kit for motorcycle conversion
- Electric motorcycle
- Combustion engine motorcycle.

Competitive Analysis (0=Worst, 5=Best)

	Electric kit for motorcycle hybridization	Electric kit for motorcycle conversion	Electric motorcycle	Combustion engine Motorcycle
CR1	3,0	5,0	5,0	1,0
CR2	4,0	3,0	3,0	1,0
CR3	4,0	4,0	4,0	0,0
CR4	4,0	2,0	5,0	5,0
CR5	3,0	2,0	1,0	5,0
CR6	2,0	1,0	2,0	4,0
CR7	3,0	1,0	5,0	5,0
CR8	3,0	2,0	5,0	5,0
CR9	5,0	5,0	5,0	5,0
CR10	5,0	5,0	4,0	5,0
CR11	5,0	5,0	5,0	5,0
CR12	4,0	4,0	5,0	5,0
CR13	5,0	5,0	3,0	5,0
CR14	4,0	3,0	3,0	5,0
CR15	5,0	2,0	2,0	4,0

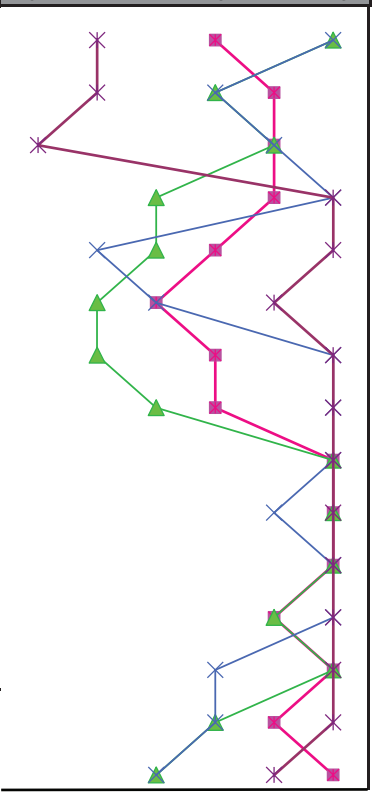


Room 6 - RESULTS

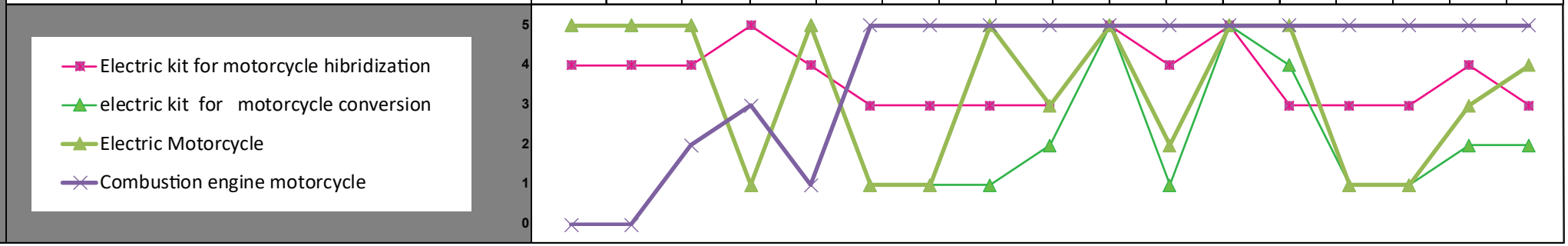
- Combustion engine motorcycle.
  - ✕ Enviromental, efficience and opperation cost.
  - ✓ Technical and security.
- Electric motorcycle
  - ✕ Product weight and economic.
  - ✓ Technical and security.
- Electric Kit for motorcycle conversion
  - ✕ Loading capacity and assembly time.
  - ✓ Enviromental, security and efficience .
- Electric Kit for motorcycle hybridization
  - ✕ Product Weight.
  - ✓ Variable results with a high weight.

Competitive Analysis (0=Worst, 5=Best)

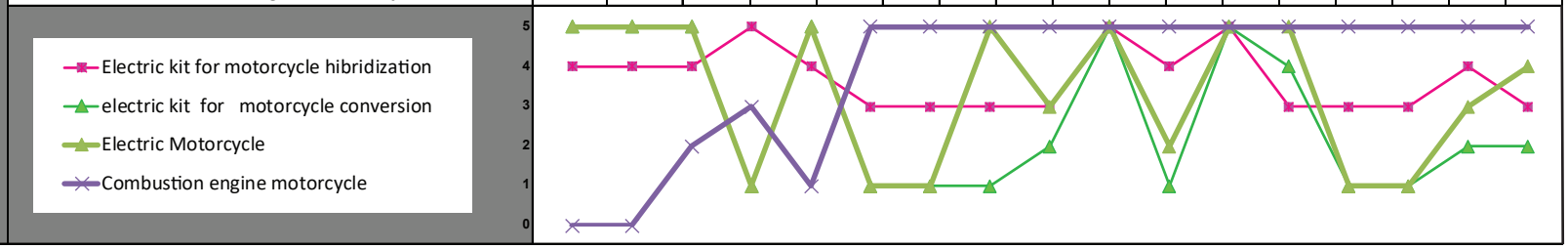
	Electric kit for motorcycle hybridization	Electric kit for motorcycle conversion	Electric motorcycle	Combustion engine Motorcycle
CR1	3,0	5,0	5,0	1,0
CR2	4,0	3,0	3,0	1,0
CR3	4,0	4,0	4,0	0,0
CR4	4,0	2,0	5,0	5,0
CR5	3,0	2,0	1,0	5,0
CR6	2,0	1,0	2,0	4,0
CR7	3,0	1,0	5,0	5,0
CR8	3,0	2,0	5,0	5,0
CR9	5,0	5,0	5,0	5,0
CR10	5,0	5,0	4,0	5,0
CR11	5,0	5,0	5,0	5,0
CR12	4,0	4,0	5,0	5,0
CR13	5,0	5,0	3,0	5,0
CR14	4,0	3,0	3,0	5,0
CR15	5,0	2,0	2,0	4,0



	EC #	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	EC10	EC11	EC12	EC13	EC14	EC15	EC16	EC17
	Target or Limit Value	x<12,0gr/Km	x<0,8gr/Km	x>140Km/gal	x>365km	x<131 $/Km	x<=2,500,000	x<30Kg	x<4 man/hours	x<0,3m3	x>=54	x= 15 months	x<=2	x<=2	x<8 años	x>100Kg	x<=20%	x<= x motorcycle
Technical Analysis (0=Worst, 5=Best)	Electric kit for motorcycle hybridization	4	4	4	5	4	3	3	3	3	5	4	5	3	3	3	4	3
	electric kit for motorcycle conversion	5	5	5	1	5	1	1	1	2	5	1	5	4	1	1	2	2
	Electric Motorcycle	5	5	5	1	5	1	1	5	3	5	2	5	5	1	1	3	4
	Combustion engine motorcycle	0	0	2	3	1	5	5	5	5	5	5	5	5	5	5	5	5



	EC #	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	EC10	EC11	EC12	EC13	EC14	EC15	EC16	EC17
	Target or Limit Value	x<12,0gr/Km	x<0,8gr/Km	x>140Km/gal	x>365km	x<131 $/Km	x<=2,500,000	x<30Kg	x<4 man/hours	x<0,3m3	x>=54	x= 15 months	x<=2	x<=2	x<8 años	x>100Kg	x<=20%	x<= x motorcycle
Technical Analysis (0=Worst, 5=Best)	Electric kit for motorcycle hybridization	4	4	4	5	4	3	3	3	3	5	4	5	3	3	3	4	3
	electric kit for motorcycle conversion	5	5	5	1	5	1	1	1	2	5	1	5	4	1	1	2	2
	Electric Motorcycle	5	5	5	1	5	1	1	5	3	5	2	5	5	1	1	3	4
	Combustion engine motorcycle	0	0	2	3	1	5	5	5	5	5	5	5	5	5	5	5	5



- Combustion engine motorcycle.

✕ Enviromental efficiency and operation cost.
✓ Cost, technical and guarantee.

- Electric Kit for motorcycle conversion

✕ Product Weight, autonomy, loading capacity.
✓ Emissions, operation cost, guarantee.

- Electric motorcycle

✕ Autonomy, product cost, life span, loading capacity.
✓ Emissions, operation cost, guarantee.

- Electric Kit for motorcycle hybridization

✓ Variable results with a high weight.

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Requirement Category	CR	EC	Units	Value	Priority
PERFORMANCE	CR1	EC1	Gr/Km	x<12,0	7
		EC2	Gr/Km	x<0,8	7
		EC3	Km/gal	x>140	1
		EC16	%	x=20	14
	CR2	EC5	$/Km	x<131	3
		EC4	Km	x>365	4
		EC3	Km/gal	x>140	1
		EC2	Gr/Km	x<0,8	7
		EC1	Gr/Km	x<12,0	7
	CR3	EC3	Km/gal	x>140	1
		EC5	$/Km	x<131	3
	CR12	EC13	#	x<=2	13
		EC17	cm	x<=x	14
	CR14	EC15	Kg	x>100	11
	CR15	EC4	Km	x>365	4
MANUFACTURING FACILITY	CR7	EC8	Man/hour	x<4	9
PRODUCT VOLUME	CR4	EC8	Man/hour	x<4	9
PRODUCT LIFE SPAN	CR13	EC11	Months	x=15	5
		EC14	Years	x<8	9
WEIGHT	CR6	EC7	Kg	x<30	2
TARGET COSTS	CR5	EC6	$	x=2,500,000	8
ENVIRONMENT	CR9	EC10	IP normativity	x>=54	6
SIZE	CR8	EC9	m^3	x<0,3	12
DISPOSAL	CR10	EC11	Months	x=15	5
SAFETY	CR11	EC12	#	x<=2	10

Conclusions

- Engineering Characteristics as EC3-EC5 (gas consumption,operation cost) are variables that need to be take into account to the hybridization kit to be attractive in the market, since it is necessary to increase the benefits provided by the current ICE motorcycles.

- EC1 - EC2 (CO and HC emissions) are the environmental variables to work in order to reduce the pollution of the country. CO emissions must be less than 12gr / km and HC emissions less than 0.8gr / km

- The price of the hybridization kit must be affordable, that's why the variable EC5 (product cost) is important; The final price of the product must have an estimated price less than COP $ 2,500,000 to be competitive in the market.

- Engineering characteristics as EC8 to EC17 are technical variables that the other competitors satisfy and that the hybridization kit must satisfy to.

THANK YOU

References

[1] J. Acevedo Bohórquez et al. Caracterización de la contaminación atmosférica en colombia.

[2] RUNT. Balance de trámites del sector de tránsito en el 2017 según runt, 1 2018.

[3] ÁREA METROPOLITANA Valle de Aburrá. Presentación del plan operacional de episodios críticos de contaminación atmosférica –poeca. http://www.metropol.gov.co/CalidadAire/isdocConvenio243/Protocolo- Plan-Operacional-dic2015.pdf.

[4] FENALCO & ANDI. La motocicleta herramienta significativa para la inclusión social. http://www.andi.com.co/Uploads/9.INFORME%20DE%20MOTOCICLETAS

[5] Stuart Pugh. Total design: integrated methods for successful product engineering. Wokingham, England, 1993.

[6] Hong-Sen Yan. Creative design of mechanical devices, 1998.

[7] Elmar Sauerwein, Franz Bailom, Kurt Matzler, and Hans H Hinterhuber. The kano model: How to delight your customers. In International Working Seminar on Production Economics, volume 1, pages 313–327,1996.

[8] George E Dieter, Linda C Schmidt, and SHAPOUR AZARM. Engineering design, 2009.

[9] Bo-Young Bae, Sangho Kim, Jae-Woo Lee, Nhu Van Nguyen, and Bong-Cheul Chung. Process of establishing design requirements and selecting alternative configurations for conceptual design of a vla. Chinese Journal of Aeronautics, 30(2):738–751, 2017.

[10] CIV Kerr, Rajkumar Roy, and Peter J Sackett. Requirements management: an enabler for concurrent engineering in the automotive industry. International Journal of Production Research, 44(09):1703–1717, 2006.

[11] Hilma Raimona Zadry, Dina Rahmayanti, Lusi Susanti, and Dicky Fatrias. Identification of design requirements for ergonomic long spinal board using quality function deployment (qfd). Procedia Manufacturing, 3:4673 – 4680, 2015. 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015.

References

[12] Hilmi Y¨uksel. Design of automobile engines for remanufacture with quality function deployment. International Journal of Sustainable Engineering, 3(3):170–180, 2010.

[13] John M Kamara and Chimay J Anumba. Requirements capture in building design. The Design Journal, 5(1):50–61, 2002.

[14] P. Beckerle, A. De Beir, T. Sch¨urmann, and E. A. Caspar. Human body schema exploration: Analyzing design requirements of robotic hand and leg illusions. In 2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), pages 763–768, Aug 2016.