Quantitative Specifications

MAE 2250

Phases

- Phase 0: Planning
- Phase 1: Conceptual design
- Phase 2: System design
- Phase 3: Detail design
- Phase 4: Testing and refinement
- Phase 5: Production ramp-up

Iterate

Needs drive concept generation

- Identify needs
- Establish target specifications
- Generate concepts
- Select concept(s)
- Test concepts
- Refine specs
- Plan project (downstream activities)

Needs	→	Specifications	→	Design Parameters
CAs		FRs		DPs
(What)	Quantification	(Still What!)	Concept	(How)

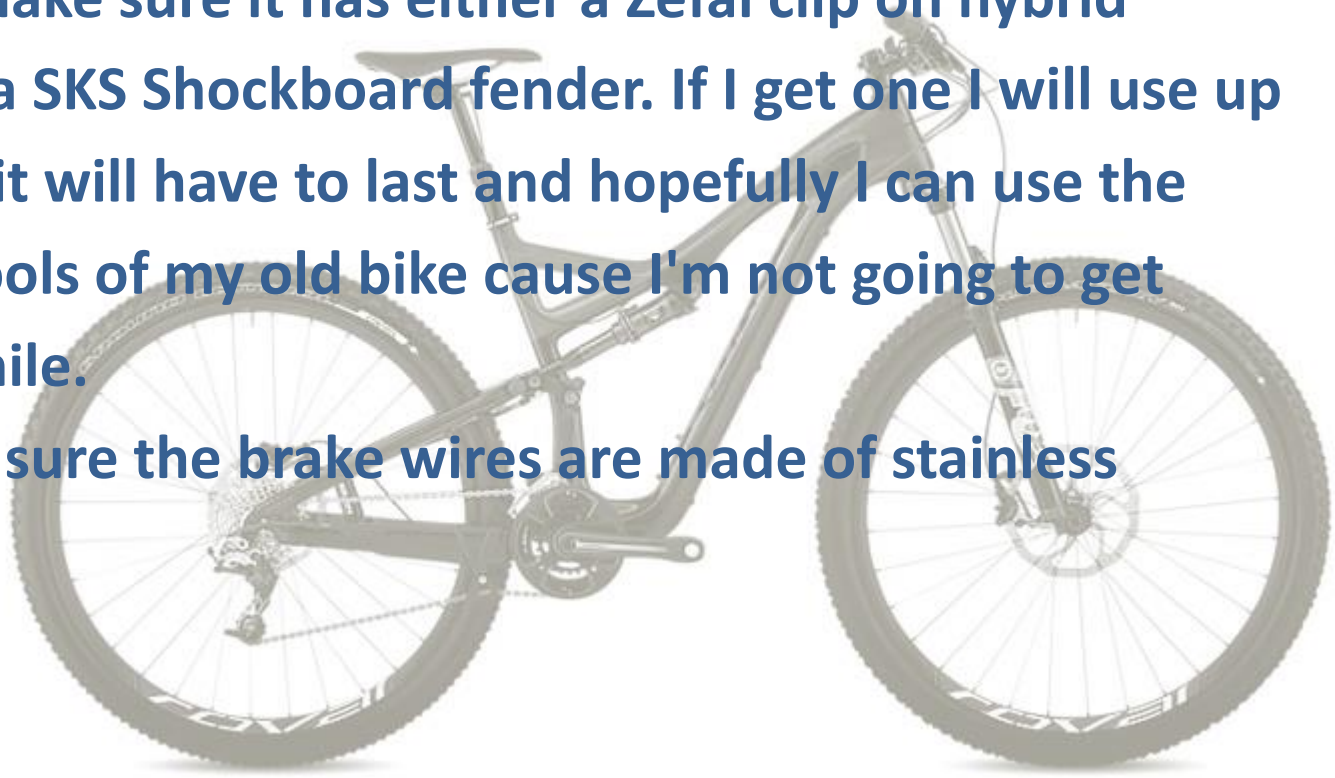
Specification

- Quantitative metric
- Target value + unit
- Max, min, exact, acceptable range, plot

“I'd like my bike to be comfortable to ride, and look good too. I don't like those heavy bikes that you can hardly carry up the stairs or barely lift when you want to put them into a trunk or up on a roof rack. The seat should be mounted on a soft spring. I like to turn it upside down when I need to fix stuff, so it needs to be stable at that position.

You guys should make sure it has either a Zefal clip on hybrid cycling fender, or a SKS Shockboard fender. If I get one I will use up all my savings, so it will have to last and hopefully I can use the accessories and tools of my old bike cause I'm not going to get new ones for a while.

Oh yes, and make sure the brake wires are made of stainless steel.”



Quantification

- Not expensive.
  - Price < 400 [$]
- “Powerful Screwdriver” :
  - Torque>800 [Oz-Inch.]
- “Easy to install wheel on fork”:
  - Average time 75+/-10 [Sec]
  - Note this is not perfect. Maybe its fast but painful?
  - Translation should be done by someone that understands the needs.
- “Looks nice”?
  - [unit subj] or use comparative user testing. Might still be critical!
- “Handlebars reduce vibration”:
  - Difficult; attenuation reduction (amplitude reducion) at 10Hz [dB]
- Safe:
  - Passes safety regulation XXYY. [Pass/fail]
- Simple maintenance:
  - Tools required [List]
- High quality.
  - Multiple criteria: Cycles surviving in mud test, rain test, vibration test, temperature test

Organize in a table, showing: Metric No., Need Nos., Metric description, value, range, unit, importance

Metric No.	Need Nos.	Metric	Imp.	Units
1	1, 3	Attenuation from dropout to handlebar at 10 Hz	3	dB
2	2, 6	Spring preload	3	N
3	1, 3	Maximum value from the Monster	5	g
4	1, 3	Minimum descent time on test track	5	s
5	4	Damping coefficient adjustment range	3	N-s/m
6	5	Maximum travel (26-in. wheel)	3	mm
7	5	Rake offset	3	mm
8	6	Lateral stiffness at the tip	3	kN/m
9	7	Total mass	4	kg
10	8	Lateral stiffness at brake pivots	2	kN/m
11	9	Headset sizes	5	in.
12	9	Steertube length	5	mm
13	9	Wheel sizes	5	List
14	9	Maximum tire width	5	in.
15	10	Time to assemble to frame	1	s
16	11	Fender compatibility	1	List
17	12	Instills pride	5	Subj.
18	13	Unit manufacturing cost	5	US$
19	14	Time in spray chamber without water entry	5	s
20	15	Cycles in mud chamber without contamination	5	k-cycles
21	16, 17	Time to disassemble/assemble for maintenance	3	s
22	17, 18	Special tools required for maintenance	3	List
23	19	UV test duration to degrade rubber parts	5	Hours
24	19	Monster cycles to failure	5	Cycles
25	20	Japan Industrial Standards test	5	Binary
26	20	Bending strength (frontal loading)	5	kN

Add target value and range after benchmarking competition

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	Need \ Metric	1 Attenuation from dropout to handlebar at 10 Hz	2 Spring preload	3 Maximum value from the Monster	4 Minimum descent time on test track	5 Damping coefficient adjustment range	6 Maximum travel (26-in. wheel)	7 Rake offset	8 Lateral stiffness at the tip	9 Total mass	10 Lateral stiffness at brake pivots	11 Headset sizes	12 Steertube length	13 Wheel sizes	14 Maximum tire width	15 Time to assemble to frame	16 Fender compatibility	17 Instills pride	18 Unit manufacturing cost	19 Time in spray chamber without water entry	20 Cycles in mud chamber without contamination	21 Time to disassemble/assemble for maintenance	22 Special tools required for maintenance	23 UV test duration to degrade rubber parts	24 Monster cycles to failure	25 Japan Industrial Standards test	26 Bending strength (frontal loading)
1	Reduces vibration to the hands	●		●	●																						
2	Allows easy traversal of slow, difficult terrain		●																								
3	Enables high-speed descents on bumpy trails	●		●	●																						
4	Allows sensitivity adjustment					●																					
5	Preserves the steering characteristics of the bike						●	●																			
6	Remains rigid during hard cornering		●						●																		
7	Is lightweight									●																	
8	Provides stiff mounting points for the brakes										●																
9	Fits a wide variety of bikes, wheels, and tires											●	●	●	●												
10	Is easy to install															●											
11	Works with fenders																●										
12	Instills pride																	●									
13	Is affordable for an amateur enthusiast																		●								
14	Is not contaminated by water																			●							
15	Is not contaminated by grunge																				●						
16	Can be easily accessed for maintenance																					●					
17	Allows easy replacement of worn parts																					●	●				
18	Can be maintained with readily available tools																						●				
19	Lasts a long time																							●	●		
20	Is safe in a crash																									●	●

Things to consider

- Metrics should be complete (cover all needs)
- Dependent on DPs (what not how, e.g. weight)
- Practical (easy to observe and measure; not requiring complex procedures/equipment)
- Use popular criteria when available. use established tests,
  - like Mountain Bike Consumer reports standard Monster test: shock transmitted when riding over a 50mm block at certain speed.

Benchmarking

Metric No.	Need Nos.	Metric	Imp.	Units	ST Tritrack	Maniray 2	Rox Tahx Quadra	Rox Tahx Ti 21	Tonka Pro	Gunhill Head Shox
1	1, 3	Attenuation from dropout to handlebar at 10Hz	3	dB	8	15	10	15	9	13
2	2, 6	Spring preload	3	N	550	760	500	710	480	680
3	1, 3	Maximum value from the Monster	5	g	3.6	3.2	3.7	3.3	3.7	3.4
4	1, 3	Minimum descent time on test track	5	s	13	11.3	12.6	11.2	13.2	11
5	4	Damping coefficient adjustment range	3	N-s/m	0	0	0	200	0	0
6	5	Maximum travel (26 in. wheel)	3	mm	28	48	43	46	33	38
7	5	Rake offset	3	mm	41.5	39	38	38	43.2	39
8	6	Lateral stiffness at the tip	3	kN/m	59	110	85	85	65	130
9	7	Total mass	4	kg	1.409	1.385	1.409	1.364	1.222	1.100
10	8	Lateral stiffness at brake pivots	2	kN/m	295	550	425	425	325	650
11	9	Headset sizes	5	in.	1.000 1.125	1.000 1.125 1.250	1.000 1.125	1.000 1.125 1.250	1.000 1.125	NA
12	9	Steertube length	5	mm	150 180 210 230 255	140 165 190 215	150 170 190 210	150 170 190 210 230	150 190 210 220	NA
13	9	Wheel sizes	5	List	26 in	26 in	26 in	26 in 700C	26 in	26 in

Continued

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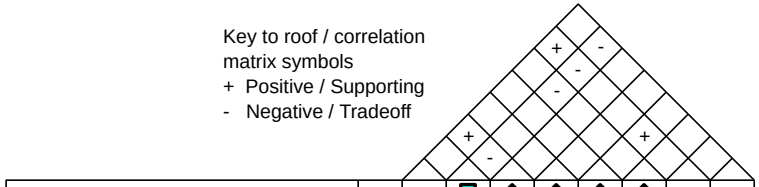
2	2, 6	Spring preload	3	N	550	760	500	710	480	680
3	1, 3	Maximum value from the Monster	5	g	3.6	3.2	3.7	3.3	3.7	3.4
4	1, 3	Minimum descent time on test track	5	s	13	11.3	12.6	11.2	13.2	11
5	4	Damping coefficient adjustment range	3	N-s/m	0	0	0	200	0	0
6	5	Maximum travel (26 in. wheel)	3	mm	28	48	43	46	33	38
7	5	Rake offset	3	mm	41.5	39	38	38	43.2	39
8	6	Lateral stiffness at the tip	3	kN/m	59	110	85	85	65	130
9	7	Total mass	4	kg	1.409	1.385	1.409	1.364	1.222	1.100
10	8	Lateral stiffness at brake pivots	2	kN/m	295	550	425	425	325	650
11	9	Headset sizes	5	in.	1.000 1.125	1.000 1.125 1.250	1.000 1.125	1.000 1.125 1.250	1.000 1.125	NA
12	9	Steertube length	5	mm	150 180 210 230 255	140 165 190 215	150 170 190 210	150 170 190 210 230	150 190 210 220	NA
13	9	Wheel sizes	5	List	26 in	26 in	26 in	26 in 700C	26 in	26 in

Continued

Metric No.	Need Nos.	Metric	Imp.	Units	Marginal Value	Ideal Value
1	1, 3	Attenuation from dropout to handlebar at 10 Hz	3	dB	>10	>15
2	2, 6	Spring preload	3	N	480–800	650–700
3	1, 3	Maximum value from the Monster	5	g	<3.5	<3.2
4	1, 3	Minimum descent time on test track	5	s	<13.0	<11.0
5	4	Damping coefficient adjustment range	3	N-s/m	0	>200
6	5	Maximum travel (26-in. wheel)	3	mm	33–50	45
7	5	Rake offset	3	mm	37–45	38
8	6	Lateral stiffness at the tip	3	kN/m	>65	>130
9	7	Total mass	4	kg	<1.4	<1.1
10	8	Lateral stiffness at brake pivots	2	kN/m	>325	>650
11	9	Headset sizes	5	in.	1.000 1.125	1.000 1.125 1.250
12	9	Steertube length	5	mm	150 170 190 210	150 170 190 210 230
13	9	Wheel sizes	5	List	26 in.	26 in. 700C
14	9	Maximum tire width	5	in.	>1.5	>1.75
15	10	Time to assemble to frame	1	s	<60	<35
16	11	Fender compatibility	1	List	None	All
17	12	Instills pride	5	Subj.	>3	>5
18	13	Unit manufacturing cost	5	US$	<85	<65
19	14	Time in spray chamber without water entry	5	s	>2300	>3600
20	15	Cycles in mud chamber without contamination	5	k-cycles	>15	>35
21	16, 17	Time to disassemble/assemble for maintenance	3	s	<300	<160
22	17, 18	Special tools required for maintenance	3	List	Hex	Hex
23	19	UV test duration to degrade rubber parts	5	Hours	>250	>450
24	19	Monster cycles to failure	5	Cycles	>300k	>500k
25	20	Japan Industrial Standards test	5	Binary	Pass	Pass
26	20	Bending strength (frontal loading)	5	kN	>7.0	>10.0



		TECHNICAL REQUIREMENTS / CUSTOMER REQUIREMENTS	CUSTOMER IMPORTANCE	Performance measures: Meets European standards	Performance measures: Harness weight ↓	Performance measures: Webbing strength ↑	Size of range: No. of colors ↑	Size of range: No. of sizes ↑	Technical details: Padding thickness ↑	Technical details: No. of buckles	Technical details: No. of gear loops	PLANNING MATRIX: Our product	Competitor A's product	Competitor B's product	Planned rating	Improvement factor	Sales point	**Overall weighting**	Percentage of total
Facilitates climbing	Usability	Easy to put on	2					□		●		3	3	4	4	1.2	1.1	2.6	7
		Comfortable when hanging	5					□	●	□		4	4	2	5	1.2	1.4	8.4	22
		Fits over different clothes	1					□	□	●		1	1	5	2	1.2	1.0	1.2	3
		Accessible gear loops	3								●	3	4	1	3	1.0	1.0	3.0	8
	Performance	Does not restrict movement	5		□			□	●	□		2	2	3	5	1.6	1.4	11.2	29
		Lightweight	3		●	□			□	▲	▲	3	2	5	3	1.0	1.0	3.0	8
		Safe	5	●	□	●						4	3	3	4	1.0	1.2	6.0	16
		Attractive	2		▲		●		▲	▲		2	2	5	3	1.2	1.1	2.6	7
		TECHNICAL PRIORITIES		54	81.2	63	23.4	70.2	191.6	98.6	30	612			Total (100%)			38	
		PERCENTAGE OF TOTAL		9	13	10	4	12	31	16	5	Total (100%)							
	Technical Benchmarking	Our product		Y	174g	250	5	4	4mm	1	4								
		Competitor A's product		Y	193g	321	3	5	8mm	4	5								
		Competitor B's product		Y	157g	198	6	4	3mm	1	3								
		DESIGN TARGETS		Y	160g	250	8	6	4mm	2	4								

Key to interrelationship matrix symbols

● Strong interrelationship

□ Medium interreltionship

▲ Weak interrelationship

”House of Quality” for Climbing Harness