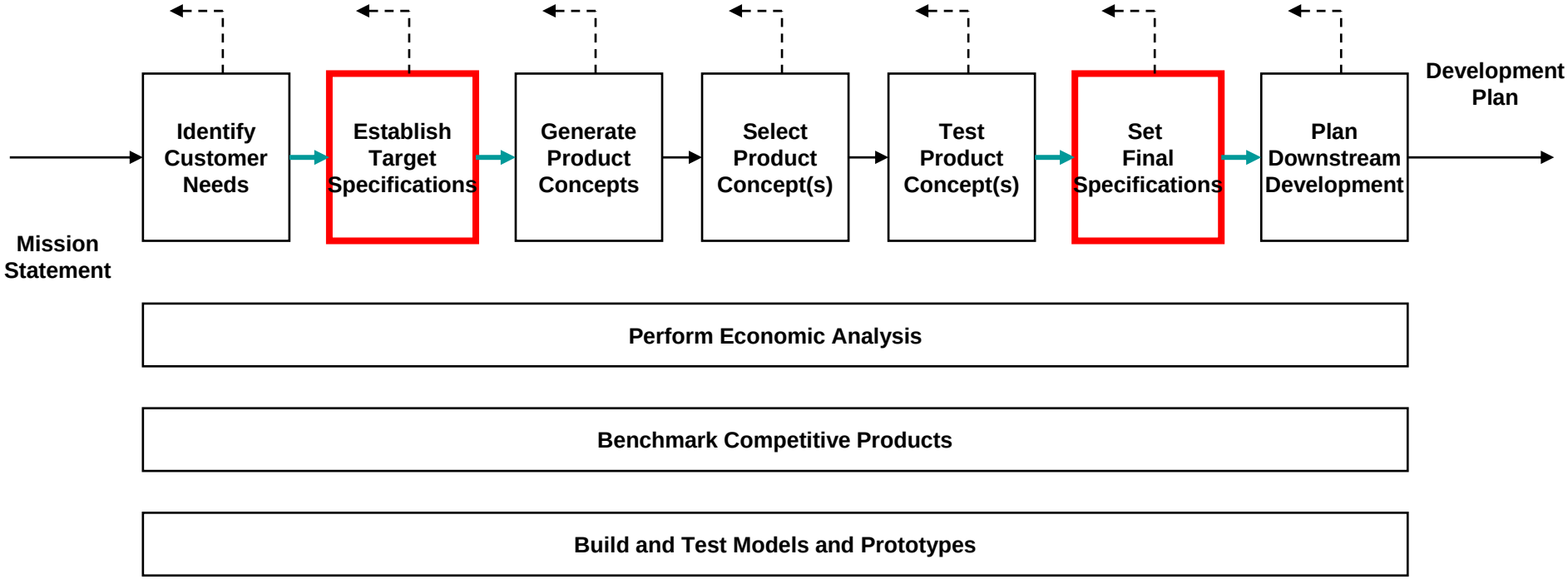
# Product Design & Development

## Product Specifications

# What are specifications?

- Specifications spell out in precise, measurable detail what the product has to do.
- Specifications represent an unambiguous agreement on what the team will attempt to achieve in order to satisfy the identified customer needs.
- **Must** include regulatory and agency approval requirements

# Concept Development Process




**Target Specs**

Based on customer needs and benchmarking

**Final Specs**

Based on selected concept, feasibility, models, testing, and trade-offs

# Product specifications

- Other names for ‘product specifications’
  - Product requirements
  - Technical specifications

# Product Specifications Example: Mountain Bike Suspension Fork

# A specification

- A ‘specification’ (*sing.*) consists of a metric and a value

  Example:

  metric → “Average time to assemble”

  value → “less than 75 seconds”

# When are specs established?

- For simple products (e.g., soap): early in the development process, right after identifying customer needs

- For technology-intensive products: at least twice …

# For technology-intensive products

- Target specifications
  - (representing hopes and aspirations) are set immediately after the team has identified the customer needs it aims to meet.

- Refined specifications
  - (i.e., the specs the team aims to achieve) are documented in the project´s “contract book”.

# Target specifications

To establish target specs:

- Prepare list of metrics, using the needs/metrics matrix.
- Collect benchmarking information.
- Set ideal and marginally acceptable target values for each metric.
- Reflect on results and process.

# Metrics

- Prepare a list of metrics

  The underlying assumption is that consumer needs can be translated into precise, measurable specs and that meeting specs will result in satisfaction of the associated customer needs.

# The Product Specs Process

- Set Target Specifications
  - Based on customer needs and benchmarks
  - Develop metrics for each need
  - Set ideal and acceptable values
- Refine Specifications
  - Based on selected concept and feasibility testing
  - Technical modeling
  - Trade-offs are critical
- Reflect on the Results and the Process
  - Critical for ongoing improvement

# Start with the Customer Needs

| # | NEED | | Imp |
|---|---|---|---|
| 1 | The suspension | reduces vibration to the hands. | 3 |
| 2 | The suspension | allows easy traversal of slow, difficult terrain. | 2 |
| 3 | The suspension | enables high speed descents on bumpy trails. | 5 |
| 4 | The suspension | allows sensitivity adjustment. | 3 |
| 5 | The suspension | preserves the steering characteristics of the bike. | 4 |
| 6 | The suspension | remains rigid during hard cornering. | 4 |
| 7 | The suspension | is lightweight. | 4 |
| 8 | The suspension | provides stiff mounting points for the brakes. | 2 |
| 9 | The suspension | fits a wide variety of bikes, wheels, and tires. | 5 |
| 10 | The suspension | is easy to install. | 1 |
| 11 | The suspension | [illegible] | 1 |

# … but remember

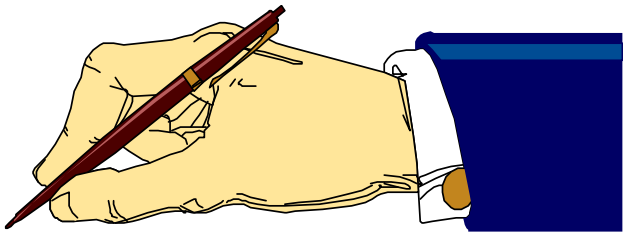
- Metrics should be dependent, NOT independent, variables.
- Metrics should be practical.
- Some needs cannot be easily translated into quantifiable metrics (subjective needs).
- Metrics should include popular criteria used for ‘marketplace’ comparisons.

# Establish Metrics and Units

| Metric # | Need #s | Metric | Imp | Units |
|---|---|---|---|---|
| 1 | 1,3 | Attenuation from dropout to handlebar at 10hz | 3 | dB |
| 2 | 2,6 | Spring pre-load | 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 (26in 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 |

# Metrics Exercise: Ball Point Pen

- Customer Need:
  - The pen writes smoothly.
- Metric(s):
  1. Variation in line thickness (mm)
  2. Variation in ink coverage ($cc/mm^2$)
  3. Functional range of writing force (N)
  4. Functional range of writing velocity (mm/sec)
  5. Functional range of pen angle from vertical (deg)
  6. Variation in resistance to translational motion (N)



Assuming that smooth writing can be characterized by:
- Good quality line
- Preservation of line quality
- Ease of use...

# Needs vs. Metrics

| | Need | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Metric | Attenuation from dropout to handlebar at 10 Hz | Spring preload | Maximum value from the Monster | Minimum descent time on test track | Damping coefficient adjustment range | Maximum travel (26 in. wheel) | Rake offset | Lateral stiffness at the tip | Total mass | Lateral stiffness at brake pivots | Headset sizes | Steertube length | Wheel sizes | Maximum tire width | Time to assemble to frame | Fender compatibility |
| 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 | | | | | | | | | | | | | | | ● | |

# Benchmarking

- No product development team can expect to succeed without ‘benchmarking’ the project against competing products
  - Warning: Data in competitors’ catalogues and supporting literature may *not* be accurate. Values for key metrics should be verified by independent testing and observation.

# Benchmark on Metrics

| Metric # | Need #s | 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 pre-load | 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 (26in 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 | 1.1 |
| 10 | 8 | Lateral stiffness at brake pivots | 2 | kN/m | 295 | 550 | 425 | 425 | 325 | 650 |
| 11 | 9 | Headset sizes | 5 | in | 1.000<br>1.125 | 1.000<br>1.125<br>1.250 | 1.000<br>1.125 | 1.000<br>1.125<br>1.250 | 1.000<br>1.125 | NA |
| 12 | 9 | Steertube length | 5 | mm | 150<br>180<br>210<br>230<br>255 | 140<br>165<br>190<br>215 | 150<br>170<br>190<br>210 | 150<br>170<br>190<br>210<br>230 | 150<br>190<br>210<br>220 | NA |
| 13 | 9 | Wheel sizes | 5 | list | 26in | 26in | 26in | 26in<br>700C | 26in | 26in |
| 14 | 9 | Maximum tire width | 5 | in | 1.5 | 1.75 | 1.5 | 1.75 | 1.5 | 1.5 |
| 15 | 10 | Time to assemble to frame | 1 | s | 35 | 35 | 45 | 45 | 35 | 85 |
| 16 | 11 | Fender compatibility | 1 | list | Zefal | none | none | none | none | all |
| 17 | 12 | Instills pride | 5 | subj | 1 | 4 | 3 | 5 | 3 | 5 |

# Benchmark on Customer Needs

| # | NEED | | Imp | ST Tritrack | Maniray 2 | Rox Tahx Quadra | Rox Tahx Ti 21 | Tonka Pro | Gunhill Head Shox |
|---|---|---|---|---|---|---|---|---|---|
| 1 | The suspension | reduces vibration to the hands. | 3 | • | •••• | •• | ••••• | •• | ••• |
| 2 | The suspension | allows easy traversal of slow, difficult terrain. | 2 | •• | •••• | ••• | ••••• | ••• | ••••• |
| 3 | The suspension | enables high speed descents on bumpy trails. | 5 | • | ••••• | •• | ••••• | •• | ••• |
| 4 | The suspension | allows sensitivity adjustment. | 3 | • | •••• | •• | ••••• | •• | ••• |
| 5 | The suspension | preserves the steering characteristics of the bike. | 4 | •••• | •• | • | •• | ••• | ••••• |
| 6 | The suspension | remains rigid during hard cornering. | 4 | • | ••• | • | ••••• | • | ••••• |
| 7 | The suspension | is lightweight. | 4 | • | ••• | • | ••• | •••• | ••••• |
| 8 | The suspension | provides stiff mounting points for the brakes. | 2 | • | •••• | ••• | ••• | •• | ••••• |
| 9 | The suspension | fits a wide variety of bikes, wheels, and tires. | 5 | •••• | ••••• | ••• | ••••• | ••• | • |
| 10 | The suspension | is easy to install. | 1 | •••• | ••••• | •••• | •••• | ••••• | • |
| 11 | The suspension | works with fenders. | 1 | | | | | | |

# Setting target values

- Set ideal and marginally acceptable target values for each metric.
  - At least X
  - At most X
  - Between X and Y
  - Exactly X
  - A set of discrete values

# Assign Marginal and Ideal Values

| | Metric | Units | Marginal Value | Ideal Value |
|---|---|---|---|---|
| 1 | Attenuation from dropout to handlebar at 10hz | dB | >10 | >15 |
| 2 | Spring pre-load | N | 480 - 800 | 650 - 700 |
| 3 | Maximum value from the Monster | g | <3.5 | <3.2 |
| 4 | Minimum descent time on test track | s | <13.0 | <11.0 |
| 5 | Damping coefficient adjustment range | N-s/m | 0 | >200 |
| 6 | Maximum travel (26in wheel) | mm | 33 - 50 | 45 |
| 7 | Rake offset | mm | 37 - 45 | 38 |
| 8 | Lateral stiffness at the tip | kN/m | >65 | >130 |
| 9 | Total mass | kg | <1.4 | <1.1 |
| 10 | Lateral stiffness at brake pivots | kN/m | >325 | >650 |
| 11 | Headset sizes | in | 1.000<br>1.125 | 1.000<br>1.125<br>1.250 |
| 12 | Steertube length | mm | 150<br>170<br>190<br>210 | 150<br>170<br>190<br>210<br>230 |
| 13 | Wheel sizes | list | 26in | 26in<br>700c |
| 14 | Maximum tire width | in | >1.5 | >1.75 |
| 15 | Time to assemble to frame | s | <60 | <35 |

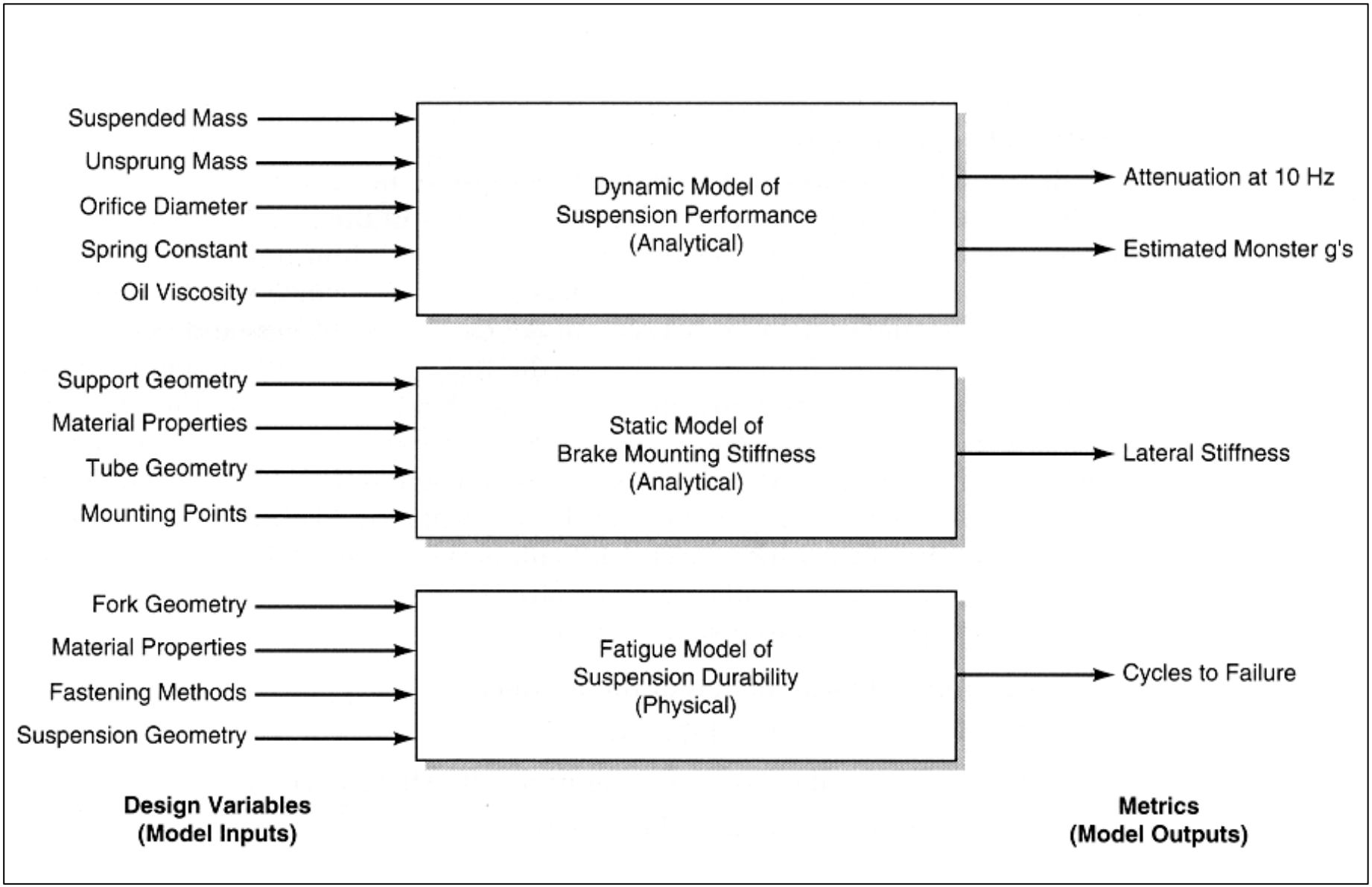
# Refining the specs
## (at the end of the Concept Development phase)

- Develop technical models of product.
- Develop cost model.
- Refine specs, making trade-offs where necessary.
- Base trade-offs on tests using technical models and preliminarily cost model.
- Reflect on results and process.

# Technical models

Develop technical models of the product:

- A technical model is a tool for predicting the values of different metrics for a particular set of design decisions.
  - As used here, a ‘model’ may be an analytical or physical approximation of the product.


Suspended Mass
Unsprung Mass
Orifice Diameter
Spring Constant
Oil Viscosity
Dynamic Model of
Suspension Performance
(Analytical)
Attenuation at 10 Hz
Estimated Monster g's
Support Geometry
Material Properties
Tube Geometry
Mounting Points
Static Model of
Brake Mounting Stiffness
(Analytical)
Lateral Stiffness
Fork Geometry
Material Properties
Fastening Methods
Suspension Geometry
Fatigue Model of
Suspension Durability
(Physical)
Cycles to Failure
Design Variables
(Model Inputs)
Metrics
(Model Outputs)

# Cost model

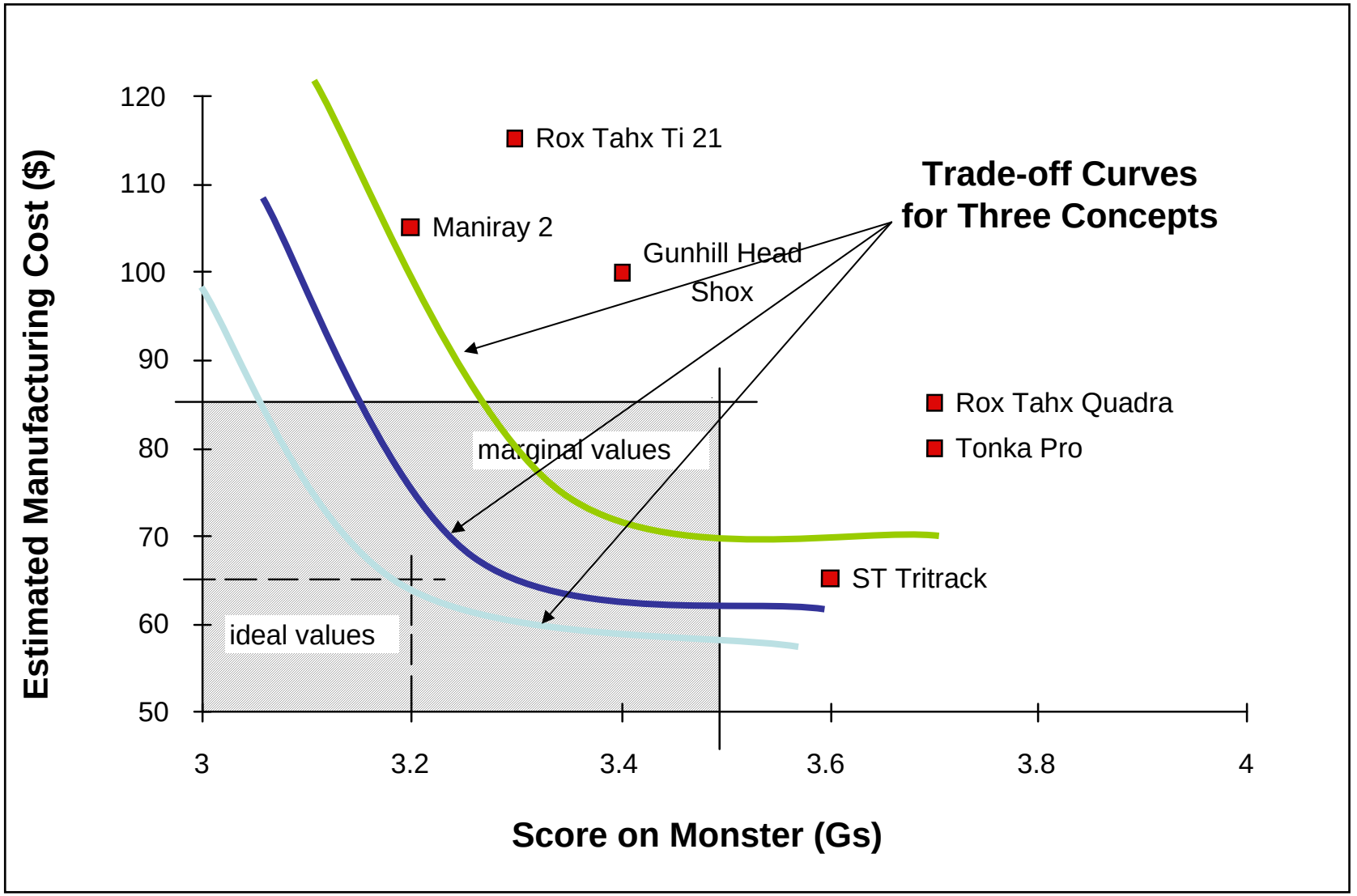
Develop a cost model of the product:

- Goal is to make sure product can be produced at a reasonable cost.

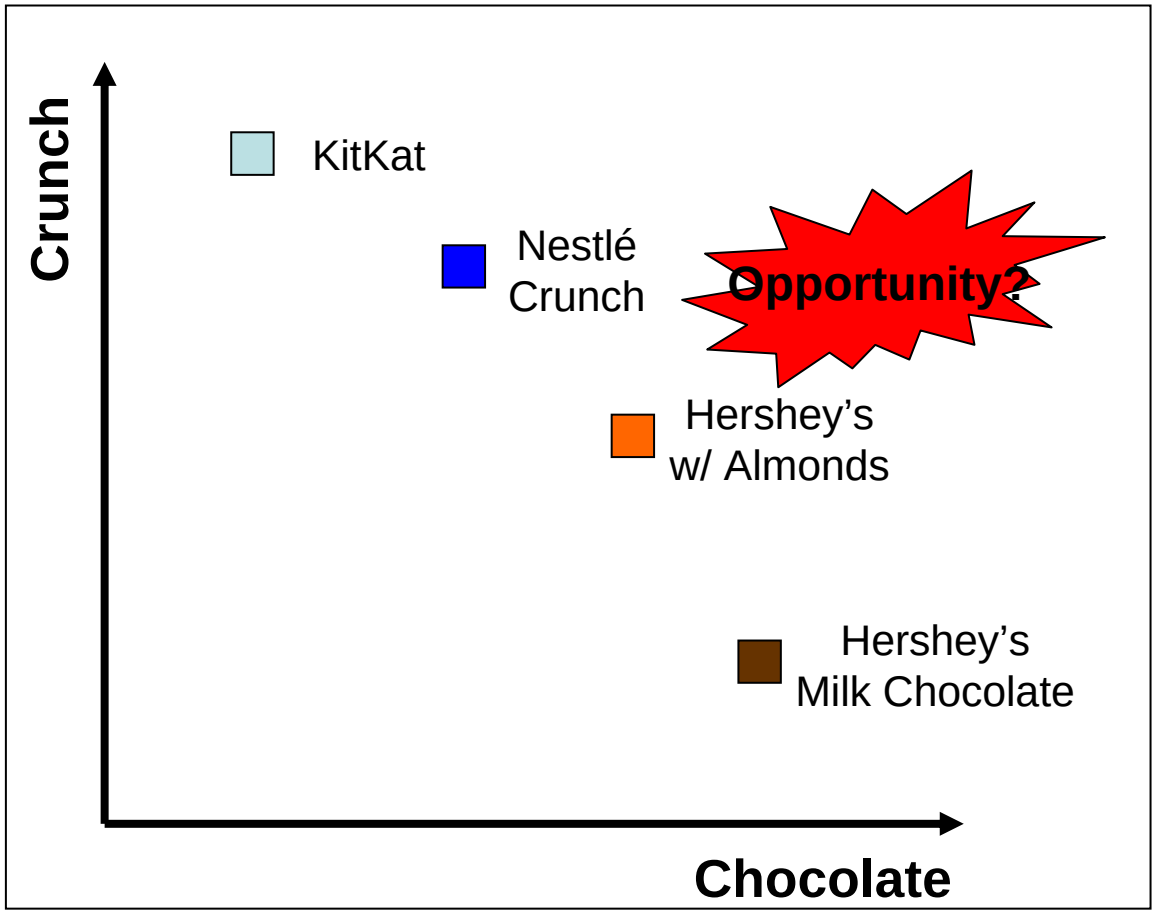
- How much uncertainty is there in the technical and cost models?
- Is concept chosen by team best for target market, or might it be more suitable for another market or segment (low-end or high-end instead of middle?)

- Should the firm initiate a formal effort to develop better technical models of some aspect of product performance for future use?

# Specification Trade-offs



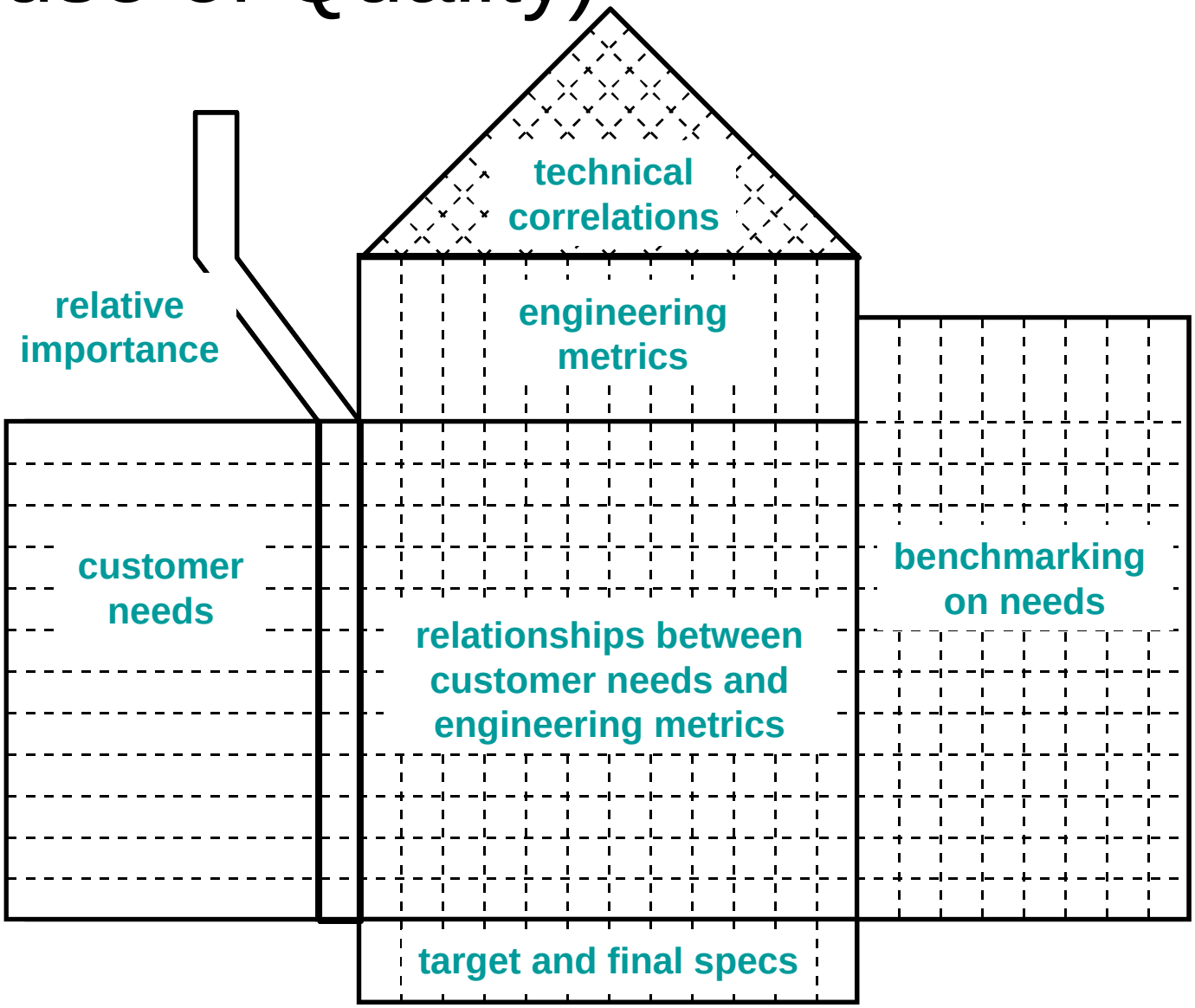
# Perceptual Mapping Exercise



# Set Final Specifications

| | METRIC | Units | Value |
|---|---|---|---|
| 1 | Attenuation from dropout to handlebar at 10hz | dB | >12 |
| 2 | Spring pre-load | N | 650 |
| 3 | Maximum value from the Monster | g | <3.4 |
| 4 | Minimum descent time on test track | s | <11.5 |
| 5 | Damping coefficient adjustment range | N-s/m | >100 |
| 6 | Maximum travel (26in wheel) | mm | 43 |
| 7 | Rake offset | mm | 38 |
| 8 | Lateral stiffness at the tip | kN/m | >75 |
| 9 | Total mass | kg | <1.4 |
| 10 | Lateral stiffness at brake pivots | kN/m | >425 |
| 11 | Headset sizes | in | 1.000<br>1.125 |
| 12 | Steertube length | mm | 150<br>170<br>190<br>210<br>230 |
| 13 | Wheel sizes | list | 26in |
| 14 | Maximum tire width | in | >1.75 |
| 15 | Time to assemble to frame | s | <45 |
| 16 | Fender compatibility | list | Zefal |

# Quality Function Deployment (House of Quality)



# Reflect on results and process

- Are team members ‘gaming’?
- Should team consider offering multiple products?
- Are any specification missing?

# Reflect on results and process

Is the product a winner?

- Product concept should allow team to see specs in a way that the price will meet the customer needs and excel competitively.
- Product concept + specs should offer prospect of competitive pricing + performance meeting or exceeding customer needs
- If not, return to concept generation and selection phase or abandon project.

# Summary

- Customer needs expressed in the “language of the customer”
- First target specifications than final specs
- For target specifications:
  - Prepare the list of metrics
  - Collect benchmarking information
  - Set ideal and marginally acceptable values
  - Reflect on the results and the process

# Summary

- Final specifications are developed by assessing the actual technological constraints and the expected production costs using analytical and physical models

# Summary

- Five step process for refining specifications
  - Develop technical models of the product
  - Develop a cost model of the product
  - Refine the specifications, making trade-offs where necessary
  - Flow down the specifications as appropriate
  - Reflect on the results and the process