INCOSE New England

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Product Family and Product Platform Benchmarking and Redesign

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Commonality-Variety Tradeoff

What the market wants

What company needs for production

A good platform architecture lies somewhere in the middle

What company wants for production

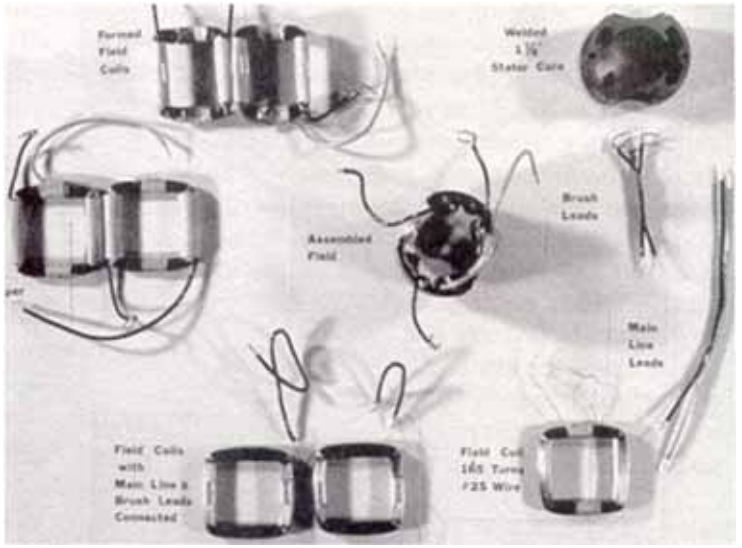
What the company wants to offer

Definitions of Key Terms

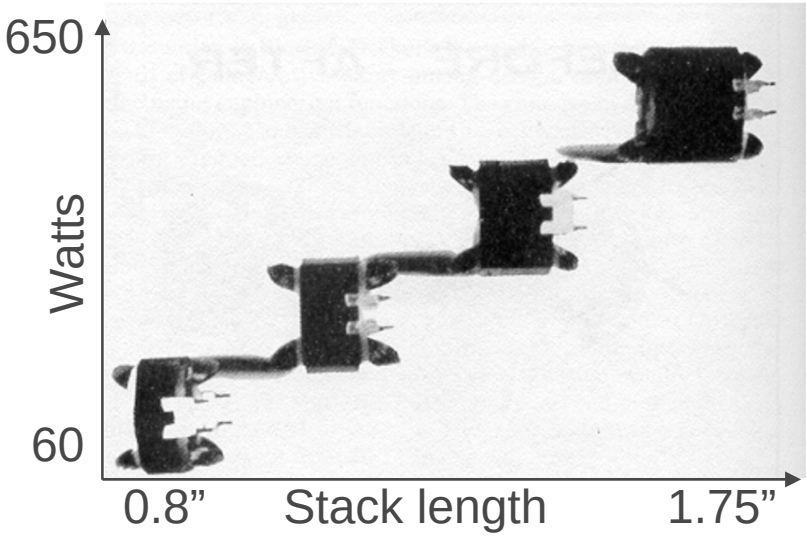
- Product platform
  - "Collection of the common elements, especially the underlying core technology, implemented across a range of products" (McGrath, 1995)
- Product family
  - A group of related products that share common features, parts, and subsystems; yet satisfy a variety of markets
- Variants, derivatives, enhancements, or extensions:
  - Individual products derived from the platform by
    - By addition, removal, and/or substitution of one or more modules = *module-based product family*
    - By scaling or "stretching" the platform in one or more dimensions = *scale-based product family*

BLACK & DECKER Universal Motor

- Universal motor is most common component in power tools
- *Challenge:* redesign the universal motor to fit into 122 basic tools with hundreds of variations
- *Result:* a common platform where
  - geometry and axial profile common
  - stack length varied from 0.8”-1.75” to obtain 60-650 Watts
  - fully automated assembly process
  - material, labor, and overhead costs reduced from $0.51 to $0.31
  - labor reduced from $0.14 to $0.02



Electric motor field components prior to standardization



Universal motor variants

Enabled a Line of Drills

Jigsaws

Source: Al Lenherd, Penn State ME/IE546, Guest Lecture, 2005

Sanders

Source: Al Lenherd, Penn State
ME/IE546, Guest Lecture, 2005

Niche Products: Rotary Cutter

Source: Al Lenherd, Penn State
ME/IE546, Guest Lecture, 2005

Source: DAIMLERCHRYSLER
Development Car Division

Volkswagen A-Platform

Plattform	VW	Audi	Skoda	Seat	Rolls-Royce/ Bentley	Lamborghini	Bugatti?
Sportwagen*	W12 Coupé/ Roadster					Diablo SV/ Diablo VT Roadster	EB 110
D	Luxuslimousine	A8 (Nachfolger)			Silver Seraph/ Arnage*		EB 112*
B/C	Passat Plus Passat	A4/A6					
A	Golf, Bora, Beetle	A3 TT Coupé/ Roadster	Octavia	Toledo (Nachfolger)			
A 00/ A 0	Polo, Lupo	A2	Felicia (Nachfolger)	Ibiza/ Cordoba, Arosa			

Audi A3

(3+ 5-door)

Audi TT coupe

Audi TT roadster

VW Golf IV

(3+5 door, station wagon, convertible, and Minivan)

VW Bora

(Bora sedan, coupe, convertible, and station wagon)

VW Beetle

(New Beetle, New Beetle convertible)

Skoda Octavia

(Octavia sedan, and station wagon)

Seat Toledo Successor

(Toledo, coupe, station wagon, and convertible)

- VW planned 19 vehicles based on A-platform
- VW estimates development and investment cost savings of $1.5 billion/yr using platforms

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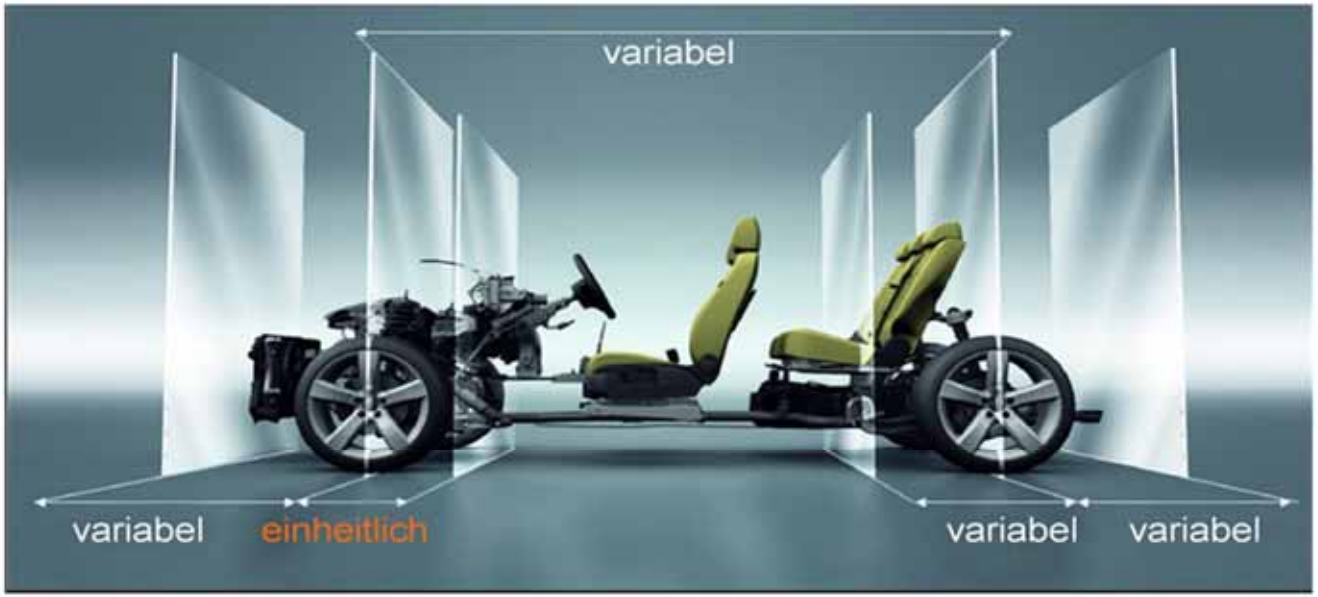
MQB Platform

2012 MQB Platform



Platform Strategy
Scalable vehicle base
Fixed design reference
Modular engine design

Common Elements:
Engine layout
Drive architecture
Information systems
Suspension setup

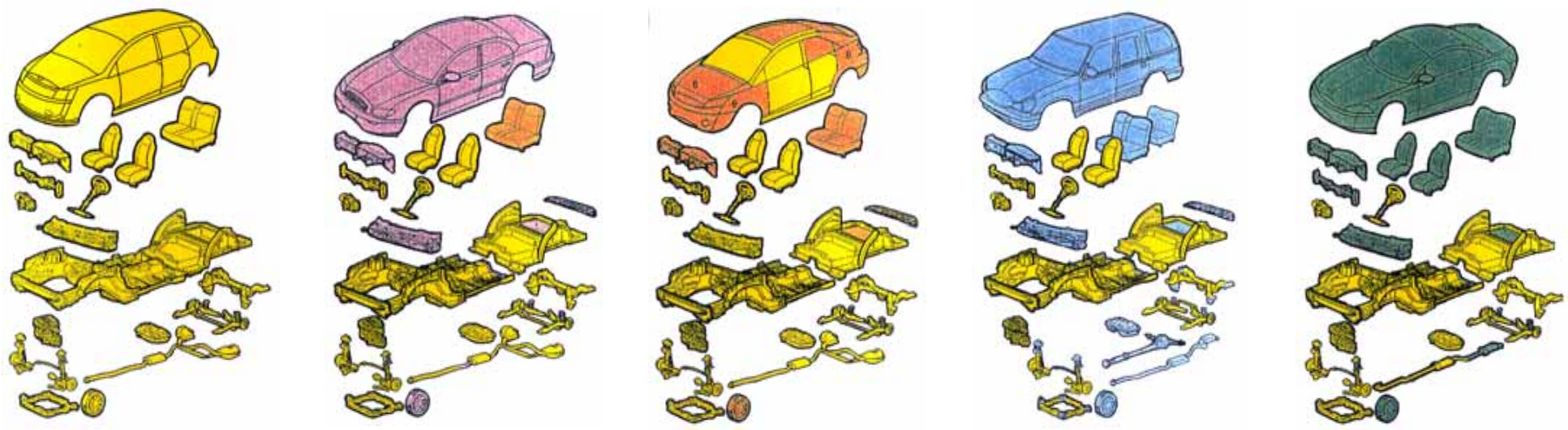
Differentiation
Brands
Markets
Styling
Option codes
Etc.

50% reduction in time to market
30% cost savings over previous platforms
Deploy engine technology and information platforms

Automobile Platforms at Ford

Source:
(C. Moccio, K. Ewing, G. Pumpuni, MIT, 2000)

- At Ford, an automobile platform includes:
  - A common architecture (e.g., assembly sequence, joint configuration, system interfaces, etc.)
  - Definition of subsystem and module interfaces
  - A set of common hardpoints used by the range of products that share the platform and the manufacturing processes

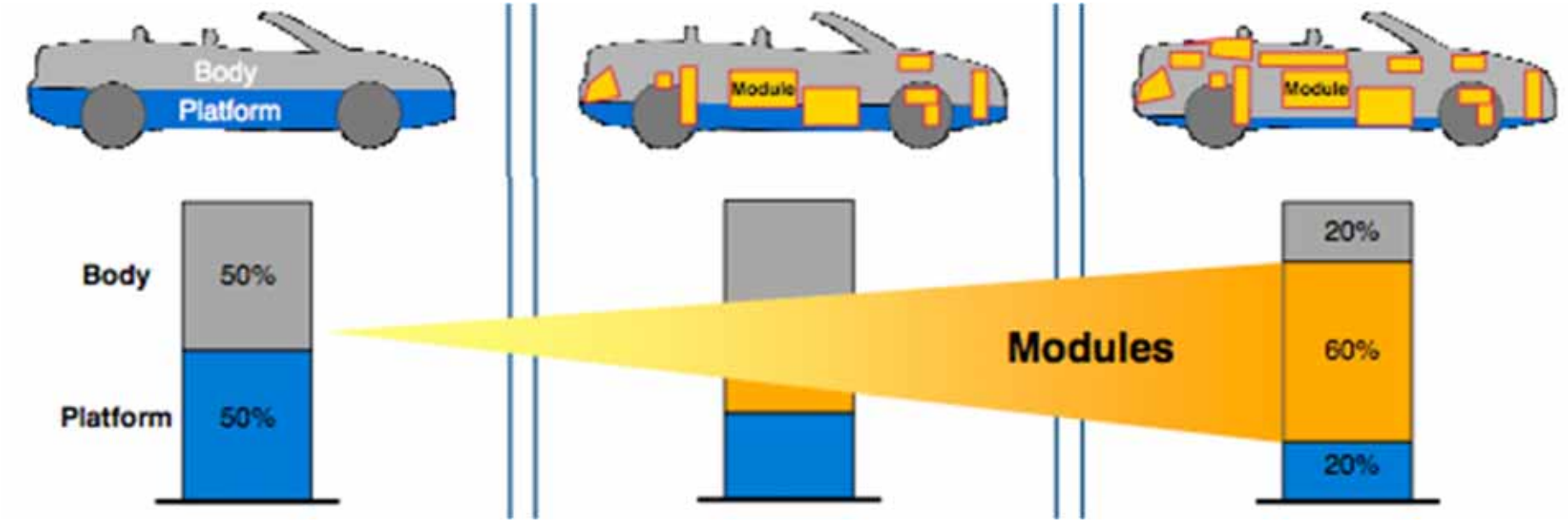


- Ford defines a platform as a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently produced

Platforms to Modules

Source:
CAMERON INDUSTRIES
Platform Strategy Advisory

- BMW and VW have moved from decentralized products to centralized platforms and now centralized modules over the last 20 years



- Ford oscillates between decentralized and centralized
  - Heavyweight programs (e.g., Mustang)
  - World cars (e.g., Fiesta, Focus, CMAX)

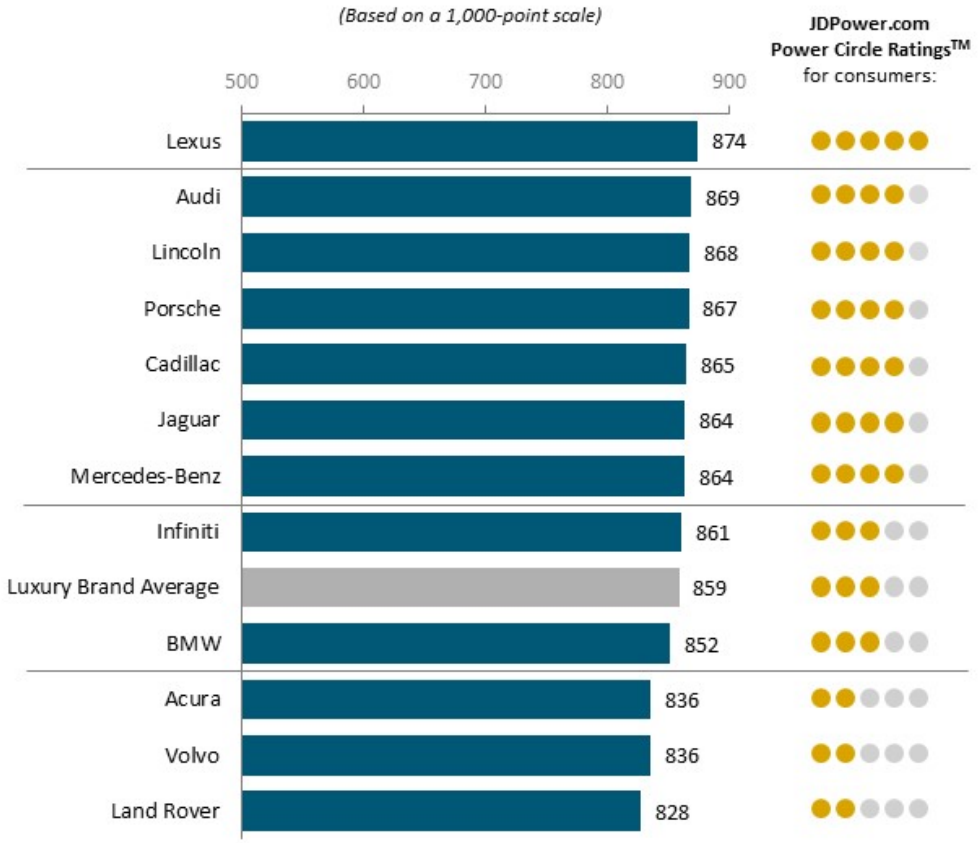
Competitive Teardown

Source: http://www.wired.com/2006/02/teardown/

J.D. Power & Associates

Customer Service Index Ranking
Luxury Brands

(Based on a 1,000-point scale)



Note: The CSI rankings are based on dealer service performance during the first three years of new-vehicle ownership, which typically represents the majority of the vehicle warranty period. Tesla is not included in the ranking due to non-representative sample.

Source: J.D. Power 2017 U.S. Customer Service Index (CSI) Study℠

Power Circle Ratings Legend
- ●●●●● *Among the best*
- ●●●●○ *Better than most*
- ●●●○○ *About average*
- ●●○○○ *The rest*

Consumer Reports

Ratings: Washers

Scores in context: Of the 100 washers tested, the highest scored 83, the lowest, 24. Listed below are the top-scoring models in each category, in order of overall performance. Recommended models offer top performance and specific strengths. CR Best Buys blend value and performance, and are recommended. Similar models are noted and are comparable to the tested model.

☑ CR Best Buy ☑ Recommended

● Excellent ◓ Very Good ○ Good ◒ Fair ● Poor

A. FRONT-LOADERS

Recommended	Rank	BRAND & MODEL	PRICE	SCORE	TEST RESULTS: Washing Performance	Energy Efficiency	Water Efficiency	Capacity	Gentleness	Noise	Vibration	Cycle Time (min.)
☑	1	**LG** WM8500HVA	$1,450	83	●	●	●	●	◓	◓	◓	90
☑	2	**Kenmore** Elite 41073	$1,450	82	●	●	◓	●	◓	◓	◓	95
☑	3	**Maytag** Maxima MHW8100DC	$1,300	80	●	●	●	◓	◓	◓	◓	75
☑	4	**LG** WM8000HVA	$1,450	80	●	●	◓	●	◓	◓	◓	100
☑	5	**Samsung** WF56H9100AG	$1,520	80	◓	●	●	●	◓	◓	◓	85
☑	6	**Maytag** Maxima MHW5100DW	$950	80	●	●	●	◓	◓	○	◓	75

B. HIGH-EFFICIENCY TOP-LOADERS

Recommended	Rank	BRAND & MODEL	PRICE	SCORE	TEST RESULTS: Washing Performance	Energy Efficiency	Water Efficiency	Capacity	Gentleness	Noise	Vibration	Cycle Time (min.)
☑	1	**LG** WT5680HVA	$1,200	73	●	◓	◓	●	○	◓	●	75
☑	2	**Samsung** WA56H9000AP	$1,500	72	◓	◓	◓	●	○	◓	●	75
☑	3	**LG** WT1701CV	$950	72	◓	◓	◓	◓	○	◓	●	75
☑	4	**LG** WT1001CW	$650	72	●	◓	●	○	○	◓	●	70

C. AGITATOR TOP-LOADERS

Recommended	Rank	BRAND & MODEL	PRICE	SCORE	TEST RESULTS: Washing Performance	Energy Efficiency	Water Efficiency	Capacity	Gentleness	Noise	Vibration	Cycle Time (min.)
☑	1	**Whirlpool** WTW4850BW	$580	56	◓	○	●	○	○	○	●	50
☑	2	**GE** GTWN5650FWS	$700	55	◓	○	○	○	◓	○	●	55

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Consumer Reports

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Appliances / Laundry & Cleaning / Washing Machines / Washing Machine Overview

Washing Machines

Overview | Ratings & Reliability | Recommended | Buying Guide

Washing machines have big performance differences in water efficiency, noise, and capacity.

View our ratings and reviews and browse our Buying Guide to find the best top-load, front-load, or HE (high-efficiency) washing machine for your family.

Washing Machine Ratings

403 SHARES

Front-Load Washing Machines (52)

The best front-loaders clean better and are gentler than the best HE top-loading washing machines while using less water. Front-loaders take longer than HE top-loaders but spin faster, extracting more water and reducing dryer time.

Front-Load Washing Machines Ratings

Top-Load Agitator Washing Machines (25)

Agitator models cost less and are faster than top-loading washing machines without an agitator, known as HE washing machines.

Top-Load Agitator Washing Machines Ratings

Top-Load HE Washing Machines (55)

Capacities keep increasing in HE washers, so you can do more laundry at once. HE top-loaders use less water and extract more of it from laundry than agitator top-loaders. This cuts dryer time, saving energy and money.

Top-Load HE Washing Machines Ratings

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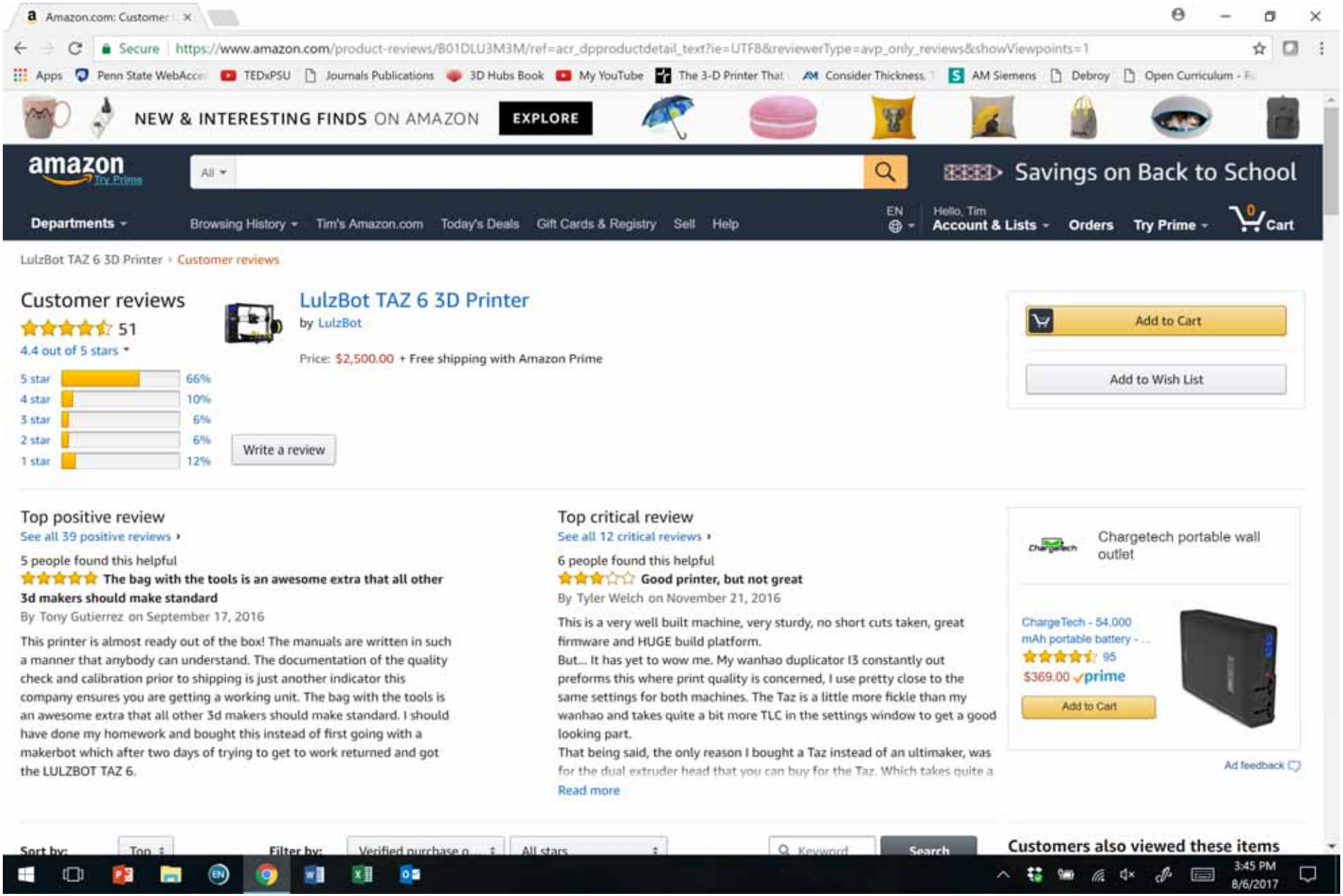
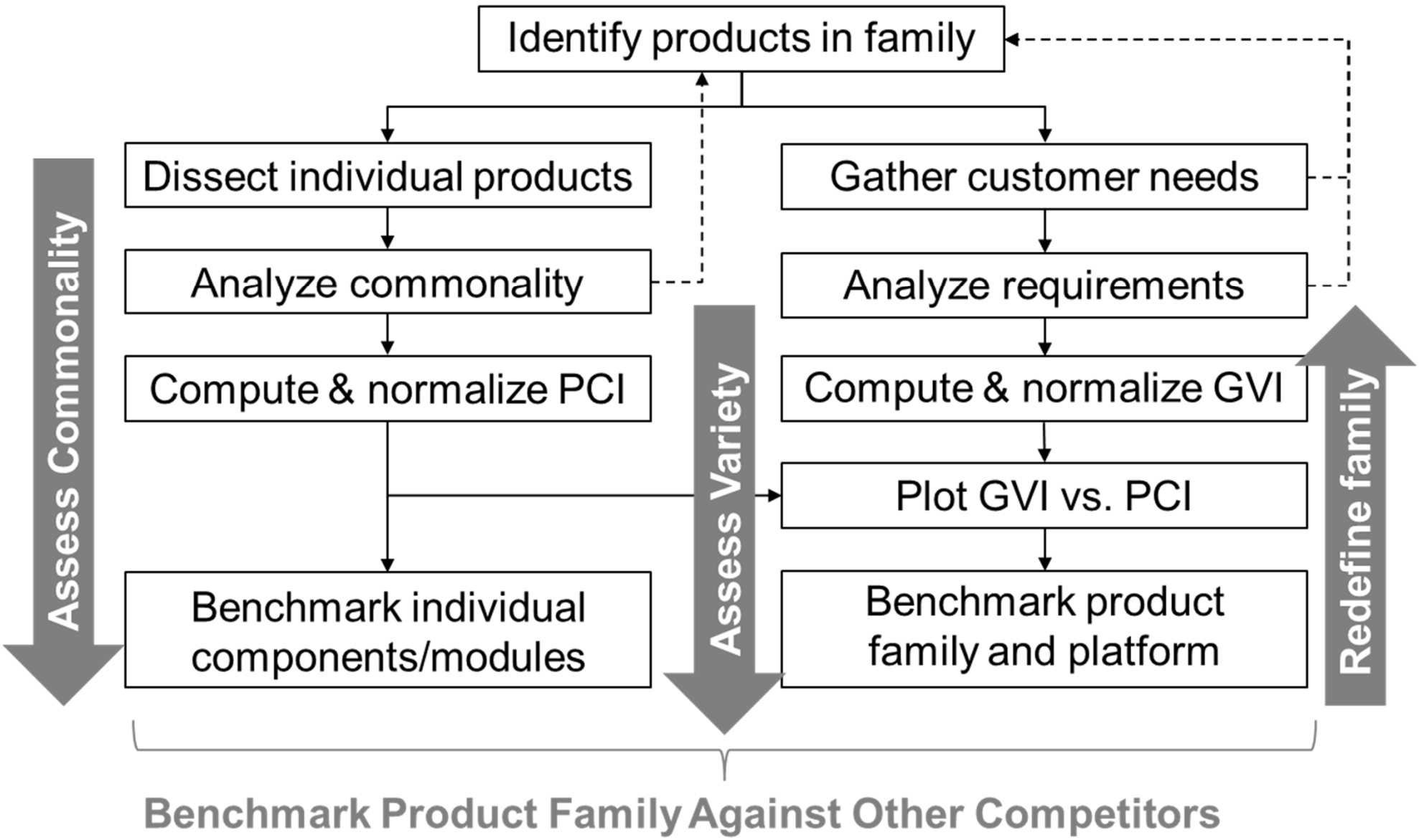
Online Customer Reviews



“War room” used by Jim Dempsey for his platforming efforts at Moen

Product Family Benchmarking Approach



Commonality Indices

- Commonality indices provide a surrogate measure for estimating the benefits of a product family when production cost information is not readily available
- There are a variety of metrics available in the literature for measuring commonality of a set of products:
  - Degree of Commonality Index, DCI
  - Total Constant Commonality Index, TCCI
  - Commonality Index, CI
  - Component Part Commonality Index, $CI^{(C)}$
  - Product Line Commonality Index, PCI
  - Percent Commonality Index, %C
- For more details and a comparison of each, see Chapter 7:

  Thevenot, H. J. and Simpson, T. W. (2005) "Commonality Indices for Assessing Product Families," *Product Platform and Product Family Design: Methods and Applications (Simpson, T. W., Siddique, Z, and Jiao, J., Eds.),* Springer, New York, pp.107-129

Selecting a Commonality Index

- When selecting a commonality index, consider your company's perspective when benchmarking/assessing the product family

	TCCI	CI	PCI	%C	$CI^{(C)}$
Focus on the number of common components	X	X			
Focus on the non-differentiating (non-unique) components			X		
Focus on the number of common connections, and assembly				X	
Focus on the cost of the components					X

- We do not recommend using indices that do not have fixed boundaries since comparisons are difficult
- More comprehensive metrics are being developed

Product Line Commonality Index (PCI)

- Measures differences that should ideally be common
- Ranges from $0 \leq PCI \leq 100$

$$PCI = \frac{\sum_{i=1}^{P} n_i \times f_{1i} \times f_{2i} \times f_{3i} - \sum_{i=1}^{P} \frac{1}{n_i^2}}{\sum_{i=1}^{P} n_i - \sum_{i=1}^{P} \frac{1}{n_i^2}} \times 100$$

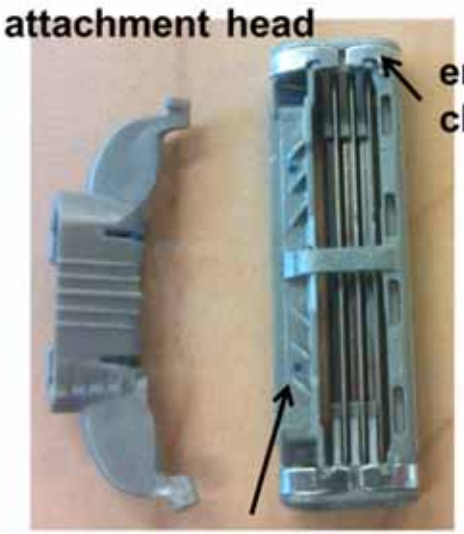
- f_{1i} = part size & shape factor
- f_{2i} = materials & manufacturing factor
- f_{3i} = part assembly & fastening scheme factor

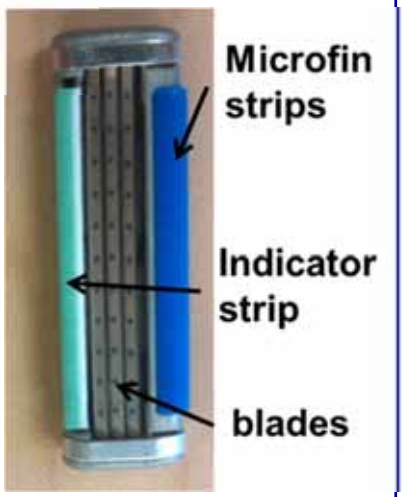
- P = total # of non-differentiating components (i.e., provide unique feature/function)
- n_i = # of products in the product family that have component
- f_{ji} = k/n where k is the # of products that share component i

Source: Kota, S., Sethuraman, K. and Miller, R., 2000, "A Metric for Evaluating Design Commonality in Product Families," *ASME Journal of Mechanical Design*, 122(4), pp. 403-410

Gillette Fusion Razor Example

	Components	# in Family (n)	Dissection assessment: Same Design (j)	Same Material (k)	Same Assembly (l)
Cartidge	Blade housing	4	2	1	4
	Blade frame	4	4	2	4
	Razor blades	4	2	2	4
	Clips	4	4	4	4
	Hood	4	4	3	4
	Lubrication Strip	4	1	1	2
	Trimmer	4	2	2	4
Handle	Main handle	8	2	1	2
	Handle - top grip	7	2	1	2
	Handle - bottom grip	7	2	1	3
	Handle - logo panel	7	3	1	3
	Tank	7	4	1	4
	Button	7	4	1	4
	Spring	8	8	8	8
	Follower	8	8	8	8
	Thumb grip	2	2	1	2
	# of Components	89			





components analyzed

that have same design

that use same material

that assemble the same

Gillette Razor Example: PCI Calculation

	Components	# in Family (n)	Dissection assessment: Same Design (j)	Same Material (k)	Same Assembly (l)	Calculations for PCI calulation: f1 (j/n)	f2 (k/n)	f3 (l/n)	f1*f2*f3	1/(n^2)	Commonality Score
Cartidge	Blade housing	4	2	1	4	0.5	0.25	1	0.125	0.063	0.5
	Blade frame	4	4	2	4	1	0.5	1	0.500	0.063	2
	Razor blades	4	2	2	4	0.5	0.5	1	0.250	0.063	1
	Clips	4	4	4	4	1	1	1	1.000	0.063	4
	Hood	4	4	3	4	1	0.75	1	0.750	0.063	3
	Lubrication Strip	4	1	1	2	0.25	0.25	0.5	0.031	0.063	0.125
	Trimmer	4	2	2	4	0.5	0.5	1	0.250	0.063	1
Handle	Main handle	8	2	1	2	0.250	0.125	0.250	0.008	0.016	0.063
	Handle - top grip	7	2	1	2	0.286	0.143	0.286	0.012	0.020	0.082
	Handle - bottom grip	7	2	1	3	0.286	0.143	0.429	0.017	0.020	0.122
	Handle - logo panel	7	3	1	3	0.429	0.143	0.429	0.026	0.020	0.184
	Tank	7	4	1	4	0.571	0.143	0.571	0.047	0.020	0.327
	Button	7	4	1	4	0.571	0.143	0.571	0.047	0.020	0.327
	Spring	8	8	8	8	1	1	1	1.000	0.016	8
	Follower	8	8	8	8	1	1	1	1.000	0.016	8
	Thumb grip	2	2	1	2	1	0.5	1	0.500	0.250	1
	# of Components	89								0.836	29.728
										PCI =	32.77%

components analyzed

that have same design

that use same material

that assemble the same

Razor Example: Schick

- Similar analysis can be performed on a comparable set of razors from a competitor like Schick

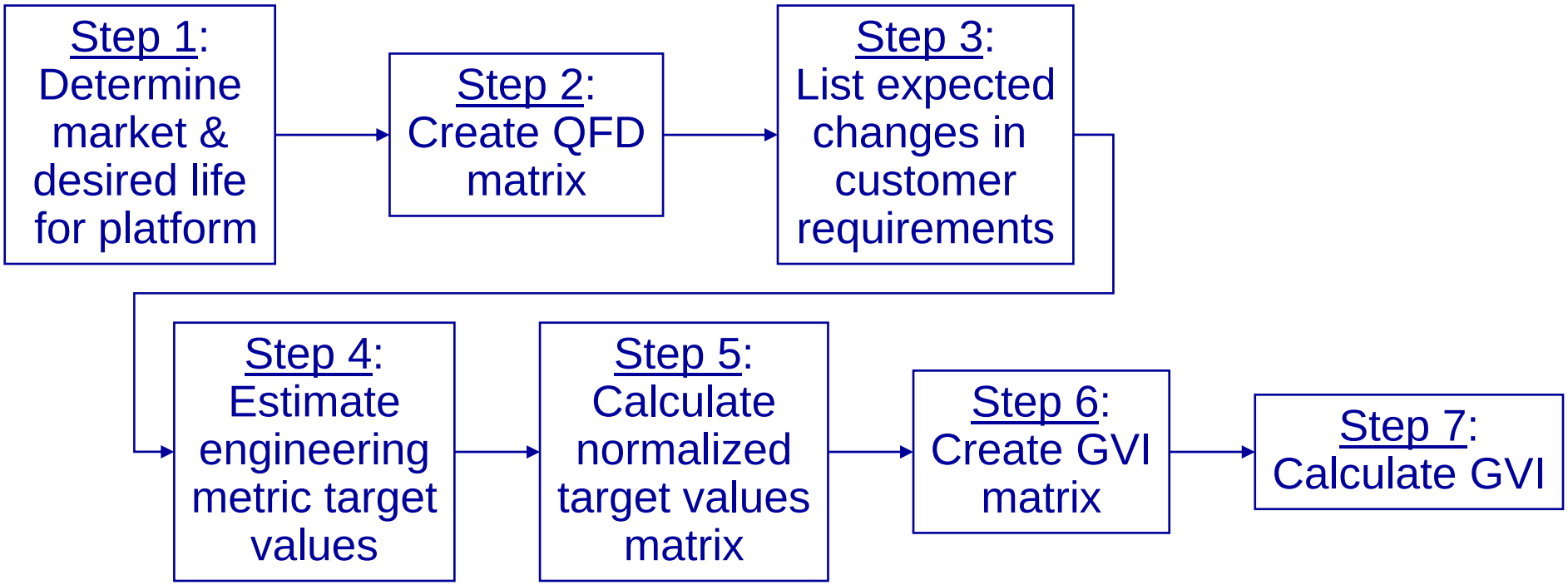
			Dissection assessment			Calculations for PCI calulation					
	Components	# in Family (n)	Same Design (j)	Same Material (k)	Same Assembly (l)	f1 (j/n)	f2 (k/n)	f3 (l/n)	f1*f2*f3	1/(n^2)	Commonality Score
Cartridge	Blade housing	3	2	2	2	0.667	0.667	0.667	0.296	0.111	0.889
	Blade frame	3	2	1	3	0.667	0.333	1	0.222	0.111	0.667
	Razor blades	3	3	3	3	1	1	1	1.000	0.111	3.000
	Clips	3	2	2	2	0.667	0.667	0.667	0.296	0.111	0.889
	Trimmer	3	3	3	3	1	1	1	1.000	0.111	3.000
	Main handle	6	2	1	2	0.333	0.167	0.333	0.019	0.028	0.111
Handle	Handle - top grip	5	2	1	2	0.400	0.200	0.400	0.032	0.040	0.160
	Handle - bottom grip	5	2	1	2	0.400	0.200	0.400	0.032	0.040	0.160
	Handle - logo panel	5	2	1	2	0.400	0.200	0.400	0.032	0.040	0.160
	Tank	6	5	4	5	0.833	0.667	0.833	0.463	0.028	2.778
	Button	5	3	2	5	0.600	0.400	1.000	0.240	0.040	1.200
	Spring	5	5	5	5	1	1	1	1.000	0.040	5.000
	Follower	5	5	5	5	1	1	1	1.000	0.040	5.000
	Thumb grip	5	5	2.5	5	1	0.5	1	0.500	0.040	2.500
	Sum of Column	62								0.891	25.513
										PCI =	**40.29%**

PCI for Gillette: 32.77%

Generational Variety Index (GVI)

- Differentiation is driven by extent of variety needed to satisfy customers in given market segment(s)
- Generational Variety Index (GVI) indicates extent of redesign required to satisfy different market needs

  → GVI identifies what you can platform and what not to platform



Source: Martin, M. V. and Ishii, K., 2002, "Design for Variety: Developing Standardized and Modularized Product Platform Architectures," *Research in Engineering Design,* 13(4), pp. 213-235.

User Needs → Engineering Requirements

- GVI starts by mapping customer needs to requirements

What are customer needs for shaving?

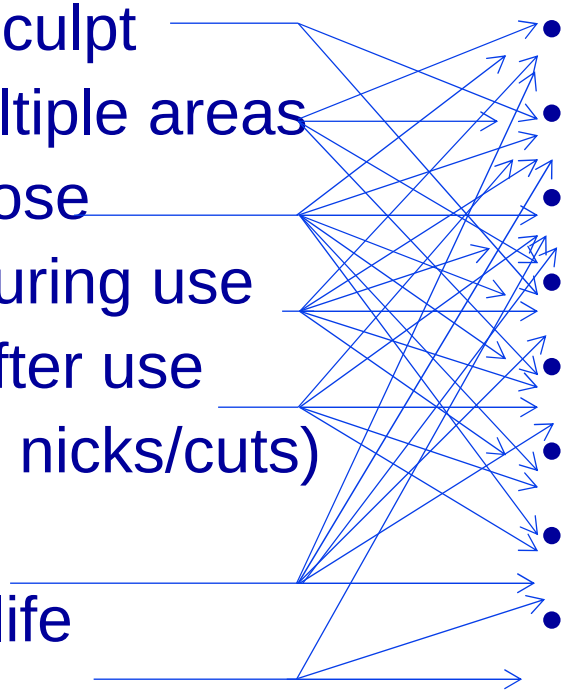
What are some engineering requirements for a razor?

User Needs → Engineering Requirements

- GVI starts by mapping customer needs to requirements

Consumer Needs

- Ability to sculpt
- Shave multiple areas
- Shaves close
- Comfort during use
- Comfort after use
- Safety (no nicks/cuts)
- Efficiency
- Cartridge life
- …



Engineering Requirements

- Pull skin taught
- Manage skin bulge
- Manage blade/skin load
- Align hairs
- Conform to skin
- Protect skin
- Lubricate skin
- Blade life
- …

User Needs → Engineering Specifications

- GVI starts by mapping customer needs to requirements

Consumer Needs

- Ability to sculpt
- Shave multiple areas
- Shaves close
- Comfort during use
- Comfort after use
- Safety (no nicks/cuts)
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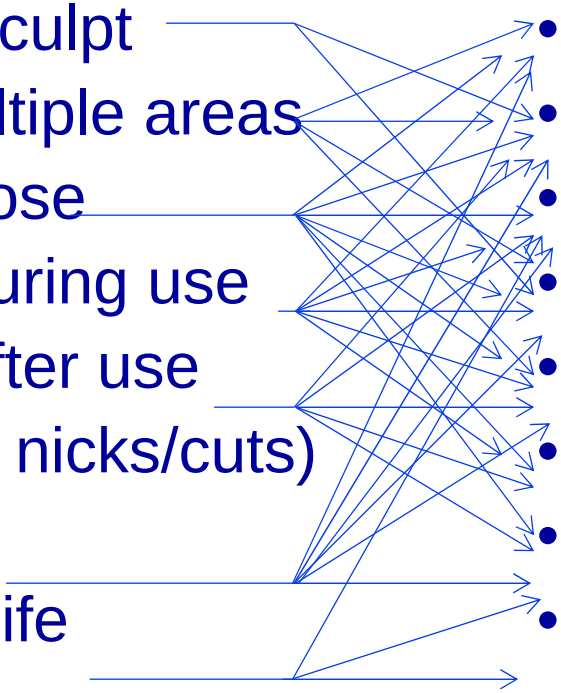
- …



Engineering Requirements

- Pull skin taught
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- …

User Needs → Engineering Specifications

- GVI starts by mapping customer needs to requirements

Consumer Needs **Engineering Requirements**

- Ability
- Shav
- Shav
- Comf
- Comf
- Safet
- Efficie
- Cartri
- …

Engineering Specifications	Consumer Needs									
	Ability to Sculpt	Shaves Close	Comfort During Use (pull/tug/scrape)	Comfort after (post irritation)	Safety (no nicks/cuts)	Speed of Use	Cartridge Life (how many shaves)	Cleanliness (clogging/buildup)	Efficiency (restroking)	Shave Multiple Body Areas
Pull skin taught		x	x		x	x			x	x
Manage skin bulge	x	x	x	x	x				x	x
Manage blade/skin load		x	x	x	x		x		x	
Conform to skin		x	x	x	x	x			x	x
Protect skin		x	x	x	x					x
Lubricate skin			x	x			x	x		
Reduce friction			x		x	x				
Apply shave aid			x	x	x		x	x		
Exfoliate skin		x	x	x	x		x	x		
Present Blade (Span)	x	x	x	x	x	x	x		x	x
Present Blade (Angle)	x	x	x	x	x	x	x		x	x
Present Blade (Exposure)	x	x	x	x	x	x	x		x	x
Blade last long		x	x	x	x		x		x	

User Needs → Engineering Requirements

- GVI starts by mapping customer needs to requirements

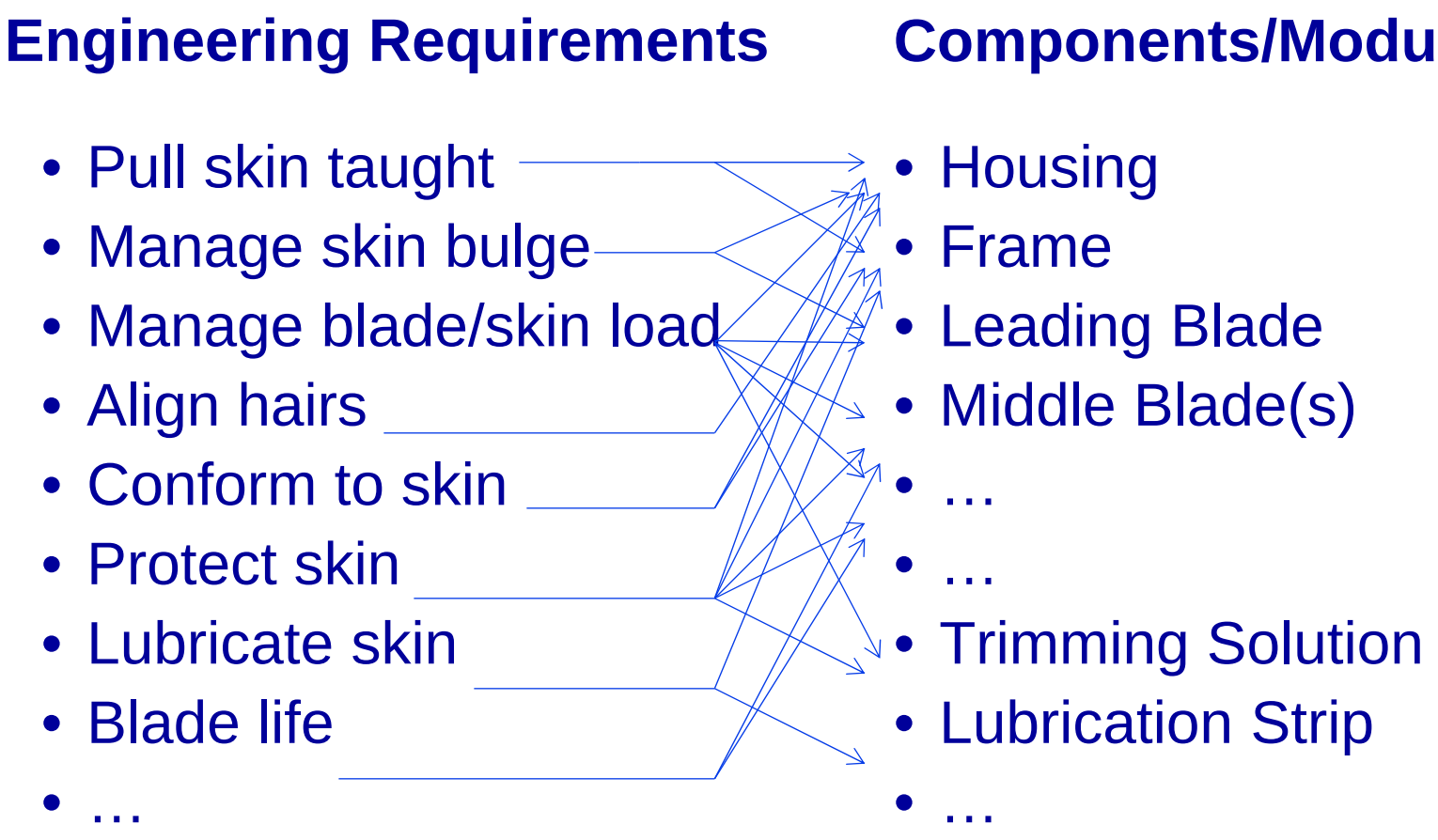
What components constitute a razor?

What are customer needs for shaving?

What are some engineering requirements for a razor?

Engineering Requirements → Components

- Requirements are then mapped to components/modules



Engineering Requirements → Components

- Requirements are then mapped to components/modules

Engineering Requirements **Components/Modules**

- Pull skin tau
- Manage skin
- Manage blad
- Align hairs
- Conform to s
- Protect skin
- Lubricate sk
- Blade life
- …

	Components/Modules								
Engineering Requirements	Housing	Frame (or Frame Assembly)	First Blade	Middle Blade(s)	Last Blade	Clips	Hood	Lubrication Strip	Trimming solution
Pull skin taught	x	x							
Manage skin bulge	x		x	x	x				
Manage blade/skin load	x		x	x	x			x	x
Conform to skin	x	x							
Protect skin	x	x	x	x	x			x	x
Lubricate skin		x						x	
Reduce friction	x	x	x	x	x			x	
Apply shave aid		x						x	
Exfoliate skin	x		x	x	x				
Present Blade (Span)	x								x
Present Blade (Angle)									x
Present Blade (Exposure)						x		x	
Blade last long			x	x	x				x

Compile Matrices

QFD I

Engineering Specifications	Consumer Needs: Ability to Sculpt	Shaves Close	Comfort During Use (pull/tug/scrape)	Comfort after (post irritation)	Safety (no nicks/cuts)	Speed of Use	Cartridge Life (how many shaves)	Cleanliness (clogging/buildup)	Efficiency (restroking)	Shave Multiple Body Areas
Pull skin taught		x	x		x	x			x	x
Manage skin bulge	x	x	x	x	x				x	x
Manage blade/skin load		x	x	x	x		x		x	
Conform to skin		x	x	x	x	x			x	x
Protect skin		x	x	x	x					x
Lubricate skin			x	x			x	x		
Reduce friction			x		x	x				
Apply shave aid			x	x	x		x	x		
Exfoliate skin		x	x	x	x		x	x		
Present Blade (Span)	x	x	x	x	x	x	x		x	x
Present Blade (Angle)	x	x	x	x	x	x	x		x	x
Present Blade (Exposure)	x	x	x	x	x	x	x		x	x
Blade last long		x	x	x	x		x		x	

QFD II

Engineering Requirements	Components/Modules: Housing	Frame (or Frame Assembly)	First Blade	Middle Blade(s)	Last Blade	Clips	Hood	Lubrication Strip	Trimming solution
Pull skin taught	x	x							
Manage skin bulge	x		x	x	x				
Manage blade/skin load	x		x	x	x			x	x
Conform to skin	x	x							
Protect skin	x	x	x	x	x			x	x
Lubricate skin		x						x	
Reduce friction	x	x	x	x	x			x	
Apply shave aid		x						x	
Exfoliate skin	x		x	x	x				
Present Blade (Span)	x								x
Present Blade (Angle)									x
Present Blade (Exposure)						x		x	
Blade last long			x	x	x				x

GVI Scoring

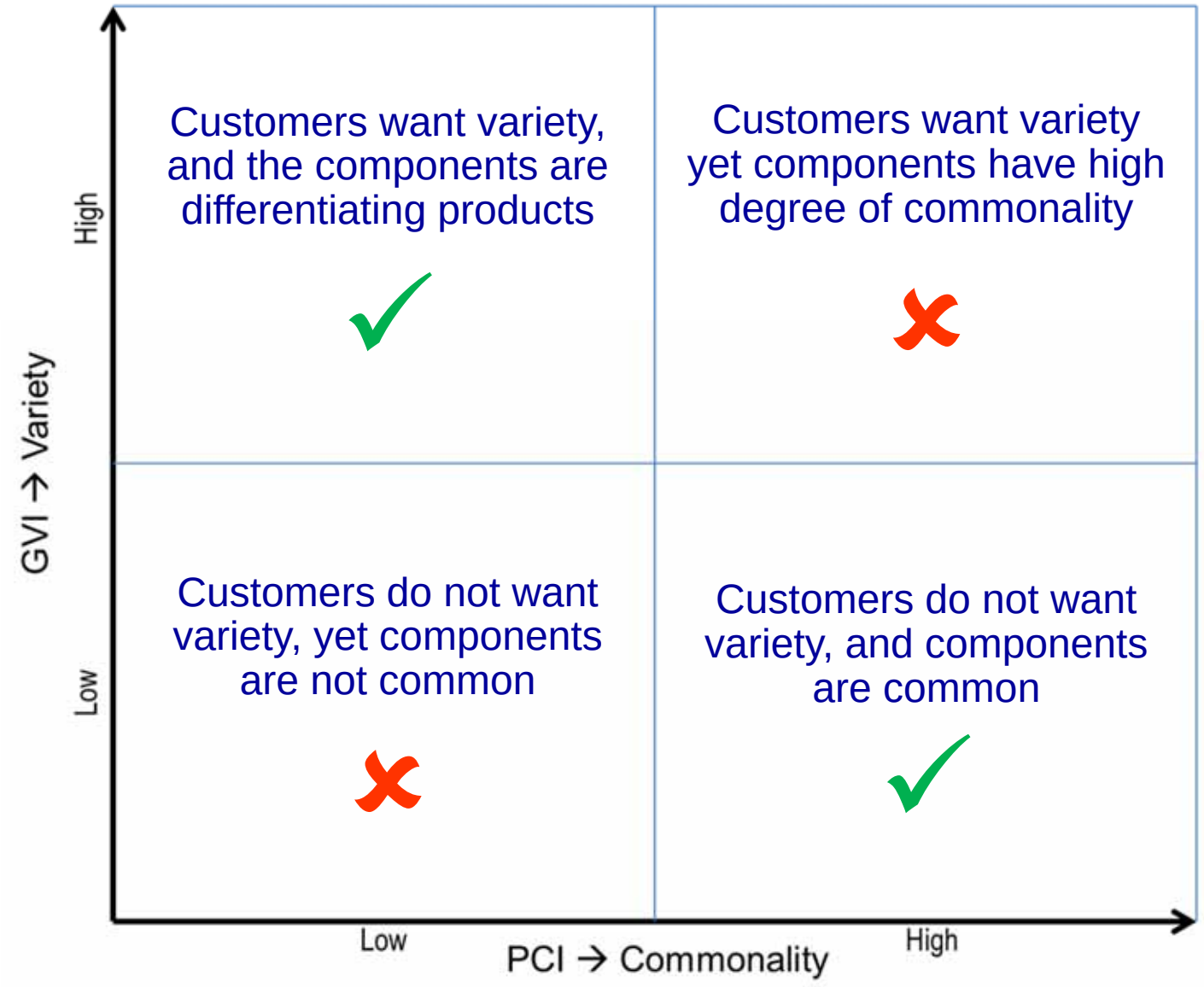
- Score extent to which component/module will have to be redesigned to meet variation in the customer needs

Variation in “Pull skin taught”
→ moderate “Housing” changes
→ major changes to “Frame”

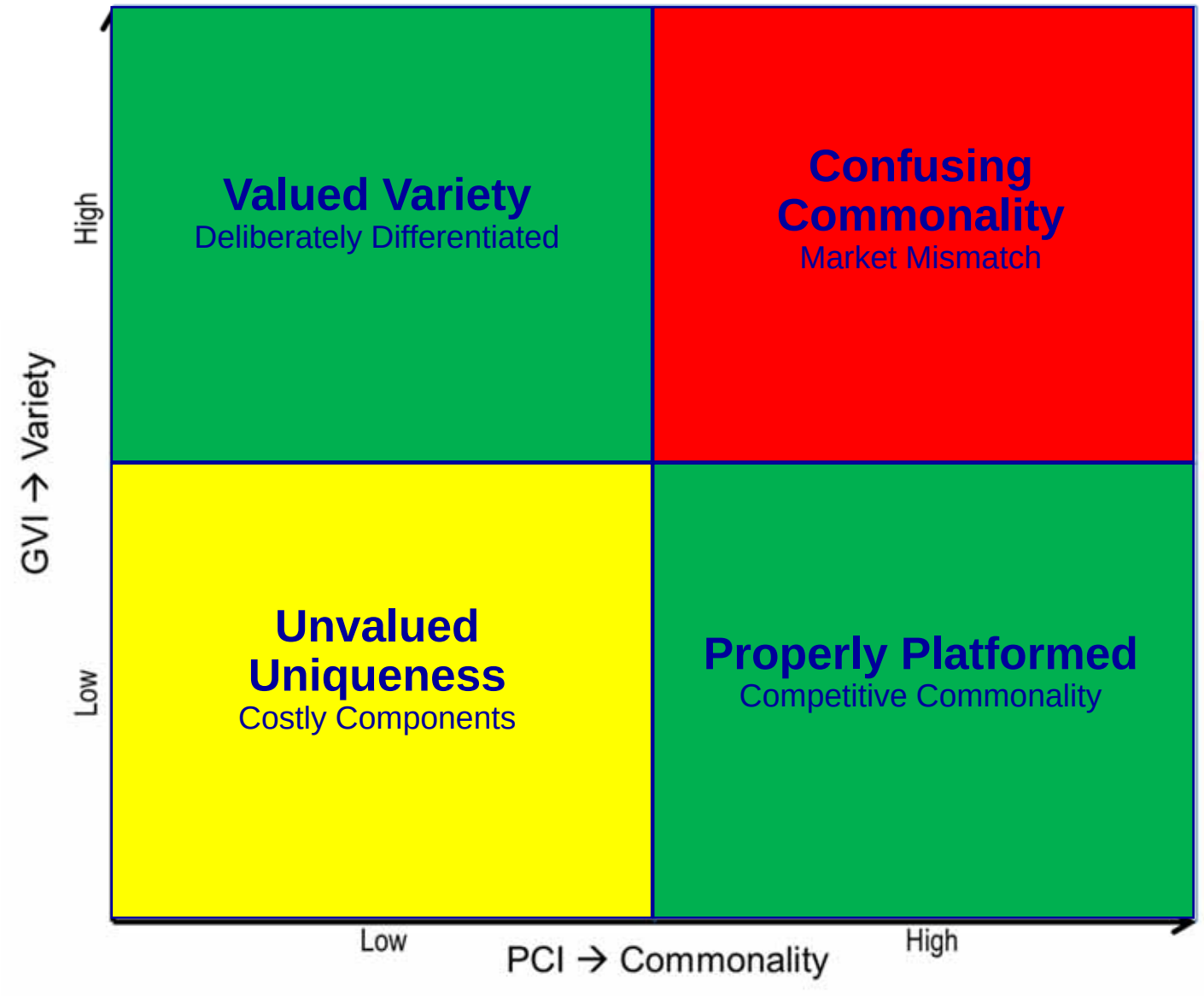
Variation in “Manage skin load”
→ few “Housing” changes
→ major changes to “First Blade” and “Last Blade”
→ moderate change to “Middle Blade(s)”

	Components/Modules								
Engineering Requirements	Housing	Frame (or Frame Assembly)	First Blade	Middle Blade(s)	Last Blade	Clips	Hood	Lubrication Strip	Trimming solution
Pull skin taught	6	9							
Manage skin bulge	6		6	3	6				
Manage blade/skin load	1		9	6	9			6	1
Conform to skin	9	9							
Protect skin	3	9	9	6	9			6	1
Lubricate skin		9						9	
Reduce friction	6	9	3	3	3			6	
Apply shave aid		9						9	
Exfoliate skin	6		9	6	9				
Present Blade (Span)	1								1
Present Blade (Angle)									1
Present Blade (Exposure)						9		9	
Blade last long			9	6	9				6

Commonality-Variety Tradeoff Chart



Commonality-Variety Tradeoff Chart



Men's Razor Example

- Men's razors is $3B market
- Gillette is the market leader (60%) but 5th in online sales
- Dollar Shave Club only sells $153M (5%) but is disrupting shaving market and forcing Gillette and others to adapt

Men's Razor Families

	Gillette	Schick
Best		
Better	Mach 3 Sensor 3	 Quattro
Good	Sensor Atra/Trac II Good News	 Xtreem3 SlimTwin

GVI for Men's Razors

- Score extent to which component/module will have to be redesigned to meet variation in the customer needs

Variation in "Pull skin taught"
→ moderate "Housing" changes
→ major changes to "Frame"

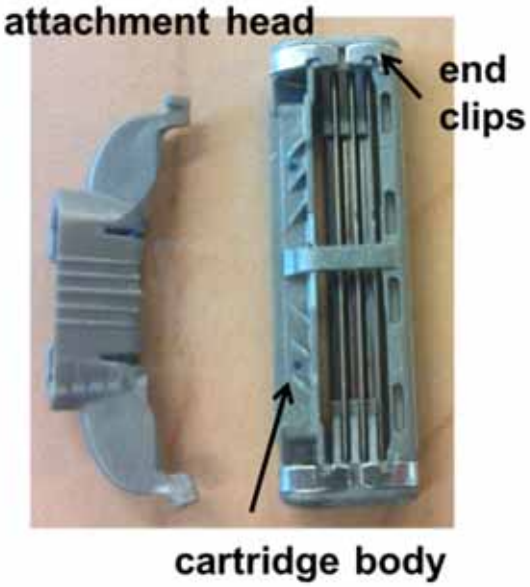
Variation in "Manage skin load"
→ few "Housing" changes
→ major changes to "First Blade" and "Last Blade"
→ moderate change to "Middle Blade(s)"

	Components/Modules								
Engineering Requirements	Housing	Frame (or Frame Assembly)	First Blade	Middle Blade(s)	Last Blade	Clips	Hood	Lubrication Strip	Trimming solution
Pull skin taught	6	9							
Manage skin bulge	6		6	3	6				
Manage blade/skin load	1		9	6	9			6	1
Conform to skin	9	9							
Protect skin	3	9	9	6	9			6	1
Lubricate skin		9						9	
Reduce friction	6	9	3	3	3			6	
Apply shave aid		9						9	
Exfoliate skin	6		9	6	9				
Present Blade (Span)	1								1
Present Blade (Angle)									1
Present Blade (Exposure)						9		9	
Blade last long			9	6	9				6

PennState

Commonality Assessment

- Dissect and analyze the family of razors to compute commonality in the market



Gillette Fusion

	# in Family (n)	Same Design (j)	Same Material (k)	Same Assembly (l)	Commonality Score
Housing	4	2	1	4	0.5
Clips	4	4	4	4	4
Hood	4	4	3	4	3
Lubrication Strip	4	1	1	2	0.125
Trimming Solution	4	2	2	4	1
First Blade	4	2	2	4	1
Middle Blade(s)	4	2	2	4	1
Last Blade	4	2	2	4	1

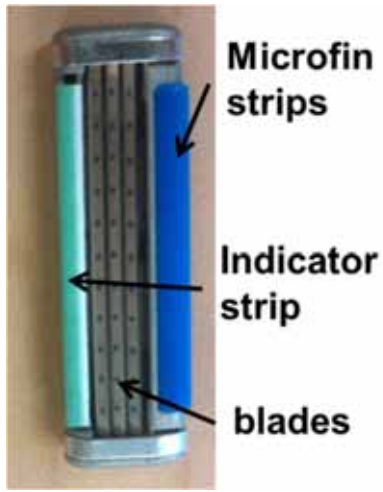
Commonality score

that assemble the same

that use same material

that have same design

cartridges analyzed



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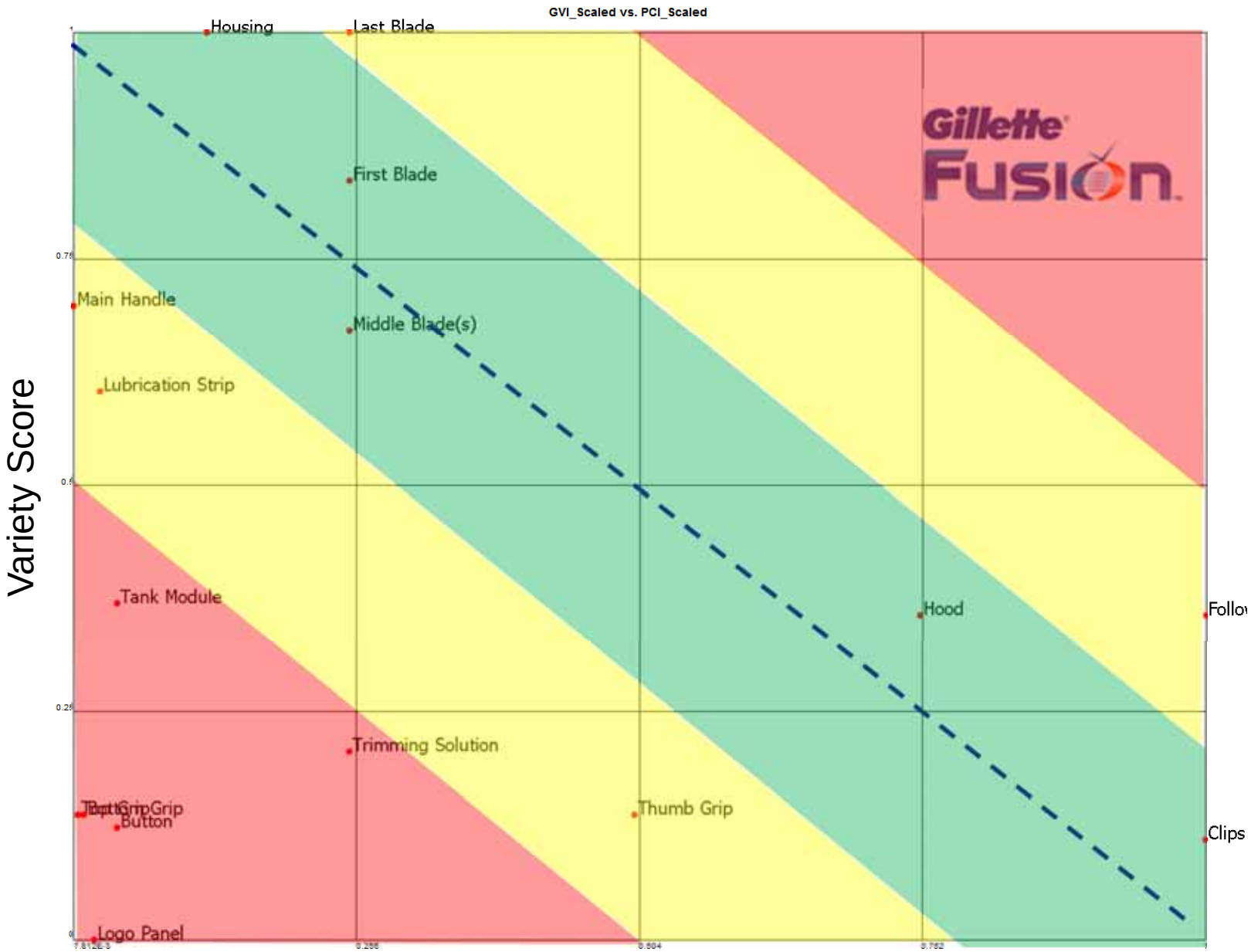
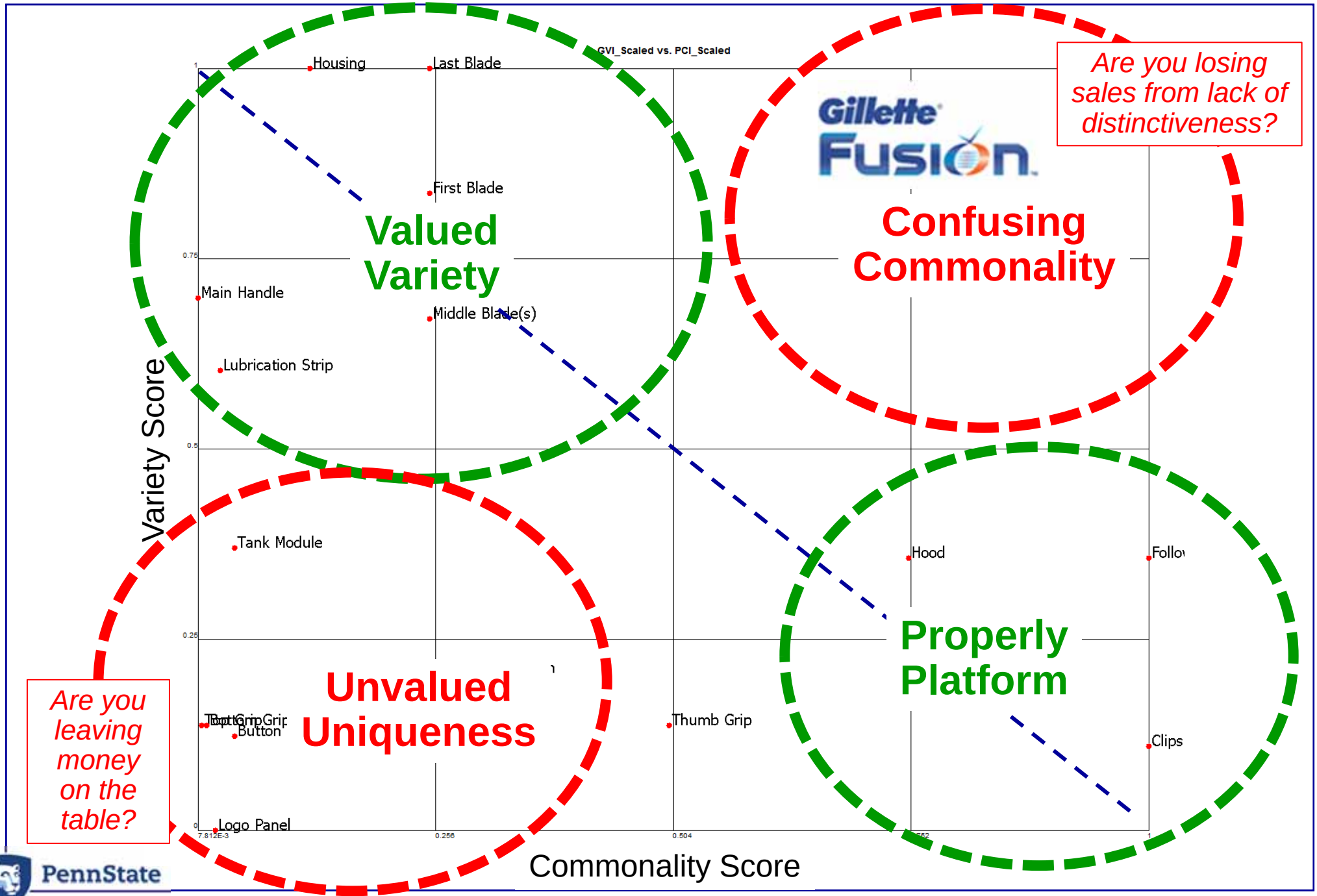
Gillette Men's Razor Family



Analysis of Gillette Men's Razor Family



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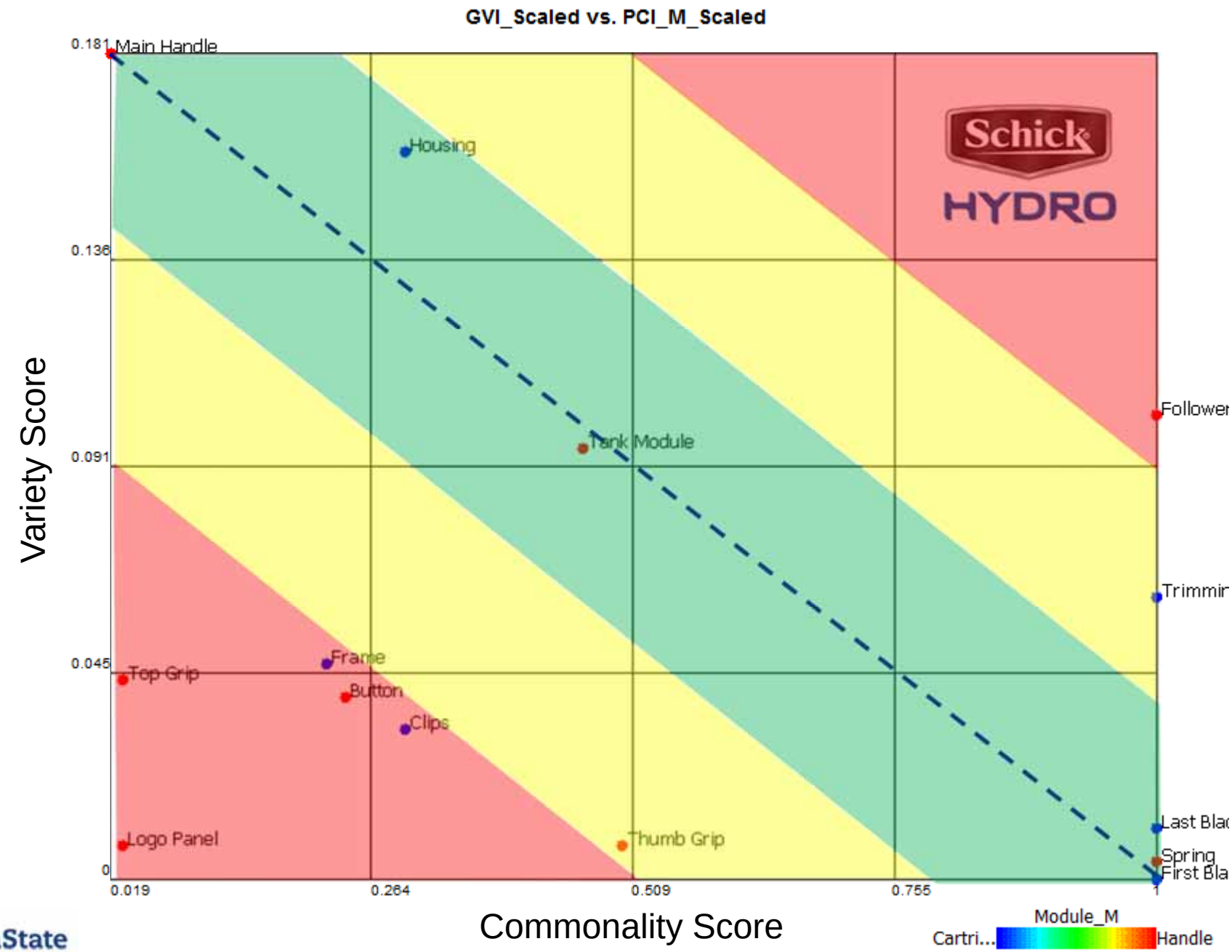
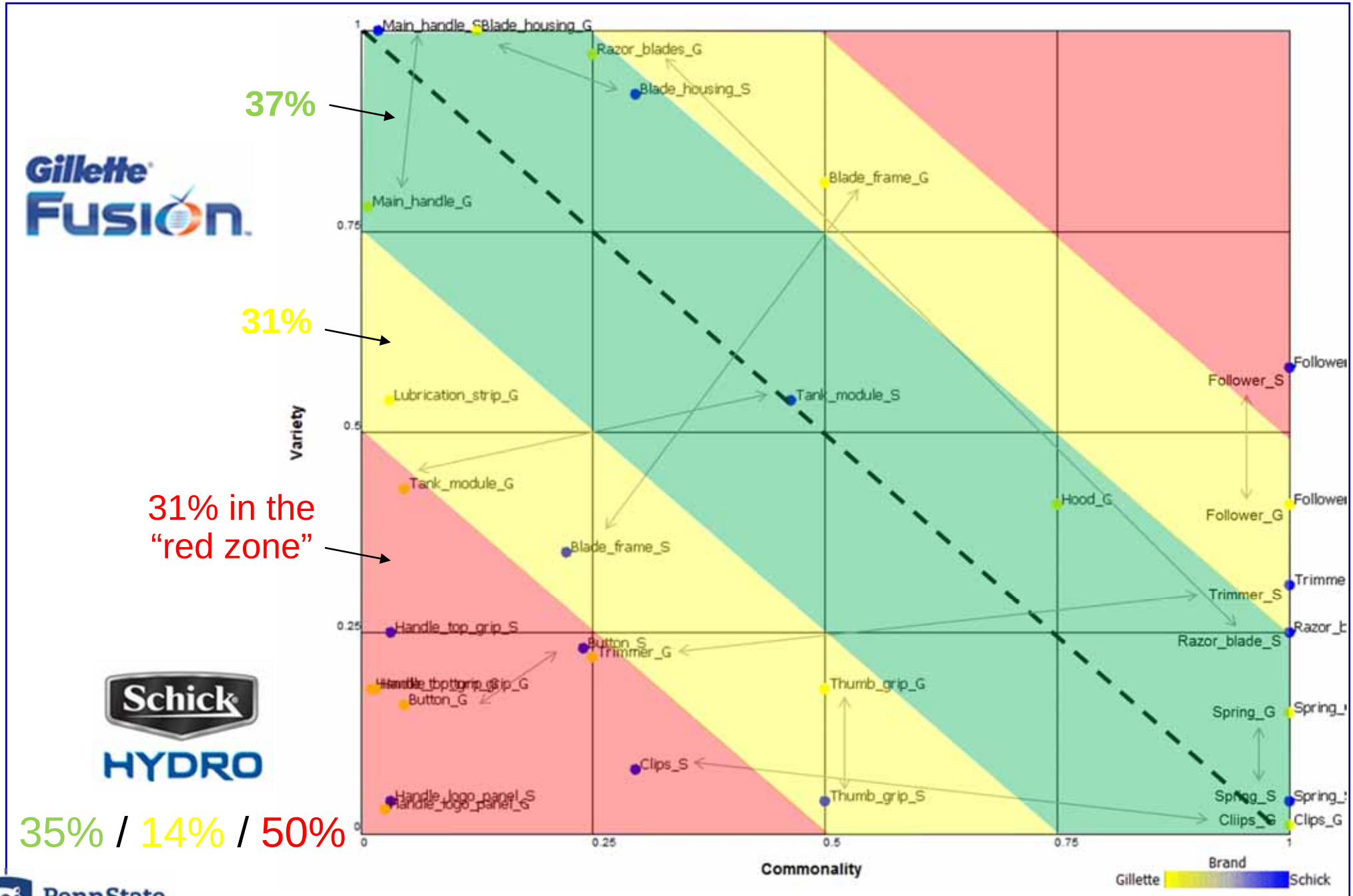
Schick Men's Razor Family



Gillette vs. Schick Men's Razor Families



Gillette vs. Schick

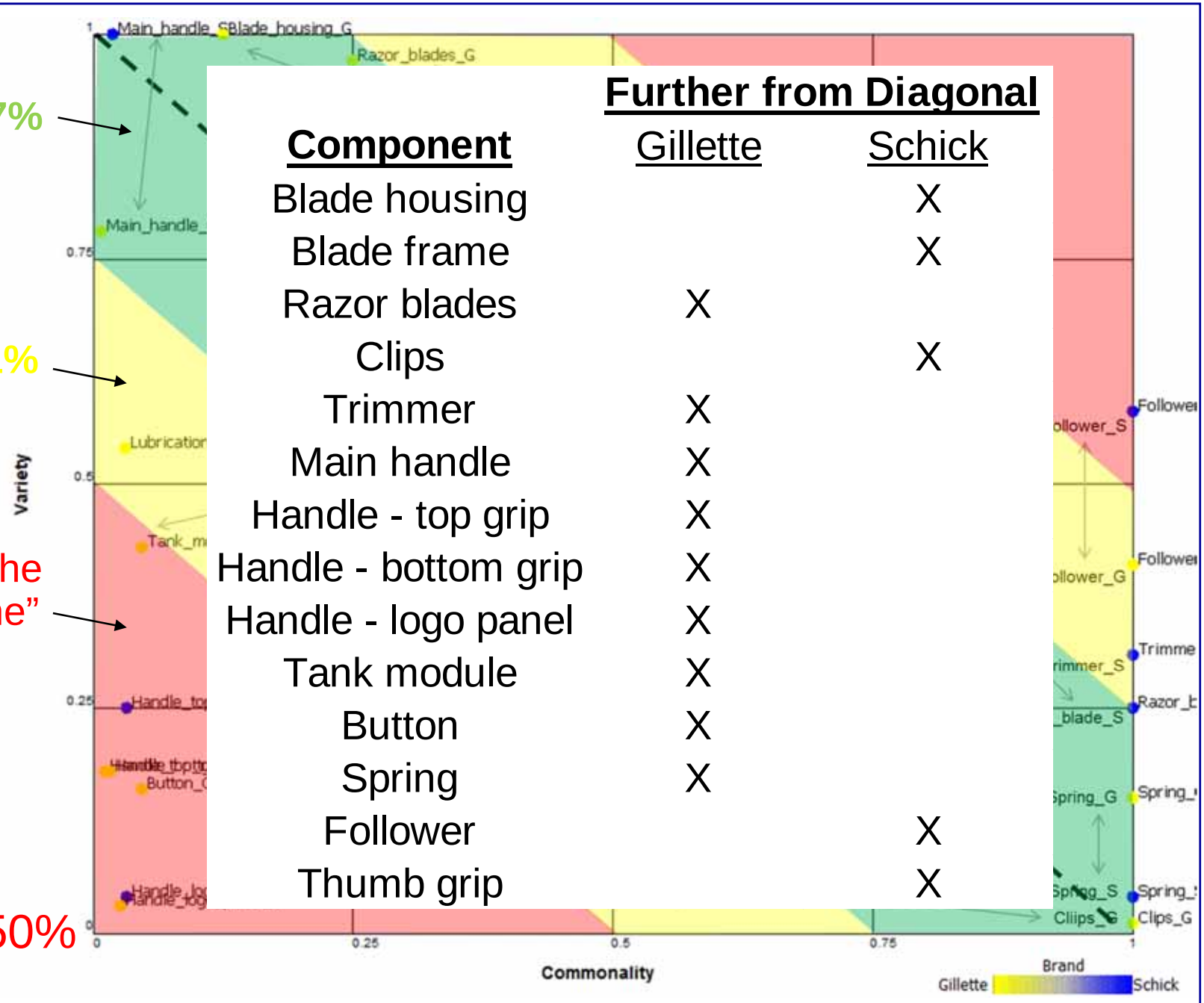
37%

31%

31% in the "red zone"

35% / 14% / 50%

Component	Further from Diagonal: Gillette	Further from Diagonal: Schick
Blade housing		X
Blade frame		X
Razor blades	X	
Clips		X
Trimmer	X	
Main handle	X	
Handle - top grip	X	
Handle - bottom grip	X	
Handle - logo panel	X	
Tank module	X	
Button	X	
Spring	X	
Follower		X
Thumb grip		X

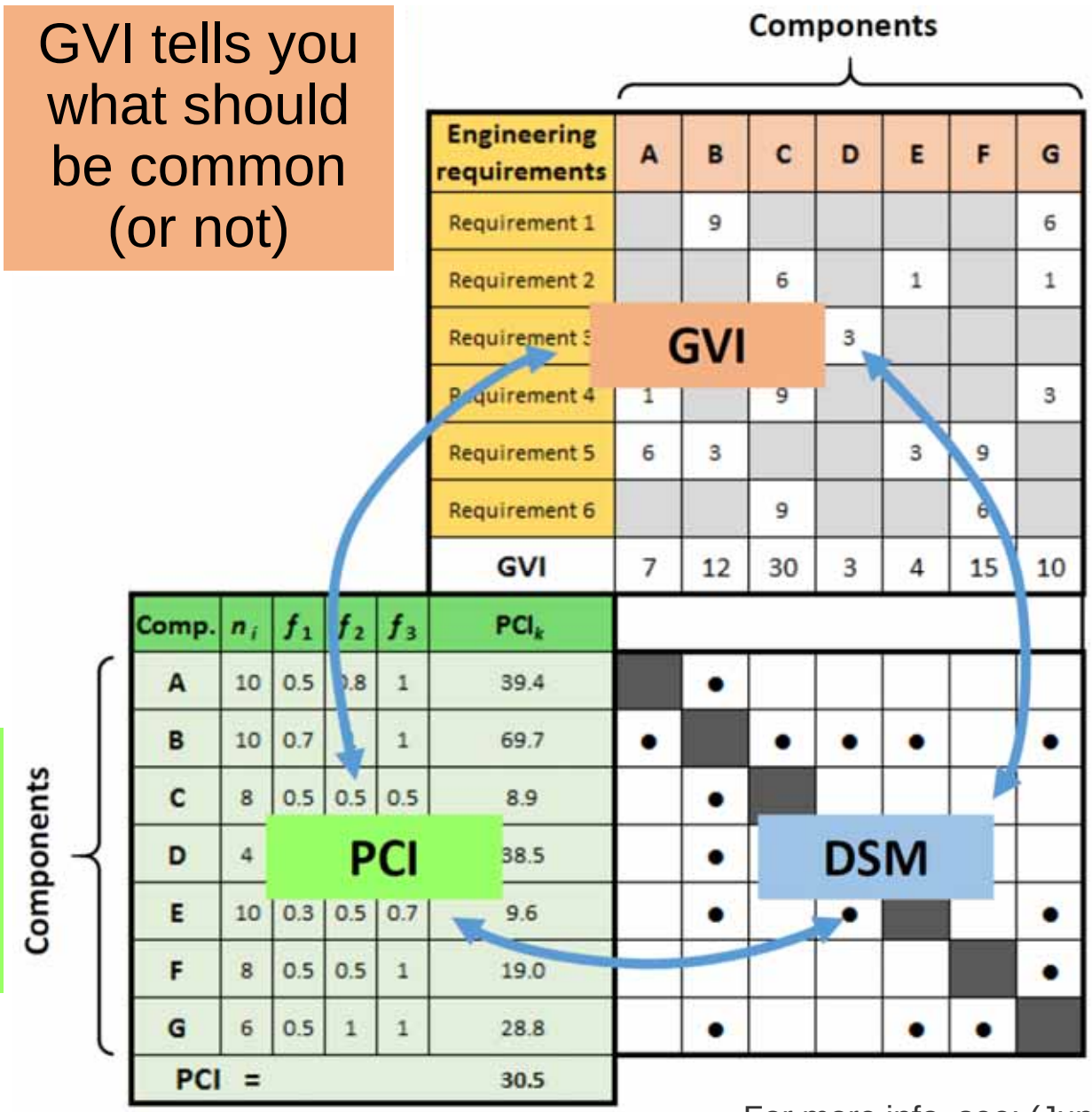


Integrated Approach for Product Family Redesign

GVI tells you what should be common (or not)

PCI tells you what is common (or not)

DSM tells you how parts are connected (or not)



For more info, see: (Jung and Simpson, 2016)

Computer Mice Example

- Selected and dissected three products among Microsoft wireless computer mice (2009-2010)

Product			
	Wireless Mobile Mouse 1000	Wireless Mobile Mouse 3500	Wireless Mobile Mouse 4000
MSRP	$14.95	$29.95	$34.95
Release date	Oct. 2010	Jun. 2010	Nov. 2009

For more info, see: S. Jung and T. W. Simpson, 2016, "An Integrated Approach to Product Family Redesign Using Commonality and Variety Metrics," *Research in Engineering Design*, 27, 391-412.

Variety Assessment

- Use GVI to identify what should be common (and unique) based on targeted customer segments(s)

QFD matrix								GVI matrix											
Accurate translation of mouse movement to pointer movement	Use on variety of surfaces	Easy file navi-gation	Small force needed to press button	Smooth and precise scrolling	Ergono-mically designed	Aesthe-tically pleasing	Longe-vity	Engineering Requirements	Top Cover	Upper Housing	Lower Housing	PCB	Side Cover	On/Off Button	Battery Cover	Non-friction Strip	Lens	Wheel	Tran-sceiver
X								Optical resolution (DPI)				6					3		3
X								Polling rate (Hz)				6							3
	X							Surface reflectivity			1	6					6		
	X							Frictional force on surface	1	1	3	1	1	1	3	6	1	1	
		X						Functions of buttons	3	1	1	6	1					3	
			X					Button force	6	1		6							
				X				Sensitivity of scroll-wheel				6						6	
					X			Curvature of grip surface	9	6	6	3	9					1	
						X		Casing	6	3	3		6	1	1	1		3	
							X	Battery life (hours)				6					1		1
								GVI	25	12	14	46	17	2	4	7	11	14	7

For more info, see: S. Jung and T. W. Simpson, 2016, "An Integrated Approach to Product Family Redesign Using Commonality and Variety Metrics," *Research in Engineering Design*, 27, 391-412.

Commonality Assessment

- Use PCI to identify what was made common (and unique) based on dissected product family

No.	Component	n_i	f_{1i}	f_{2i}	f_{3i}	$n_i \cdot f_{1i} \cdot f_{2i} \cdot f_{3i}$	PCI_k
1	Top Cover	3	0.333	0.333	1.000	0.333	7.692
2	Upper Housing	3	0.333	0.333	0.333	0.111	0.000
3	Lower Housing	3	0.333	0.333	0.333	0.111	0.000
4	PCB	3	0.333	0.333	0.333	0.111	0.000
5	Left Side Cover	2	0.500	0.500	0.500	0.250	0.000
6	Right Side Cover	2	0.500	0.500	0.500	0.250	0.000
7	Battery Cover	3	0.333	0.333	1.000	0.333	7.692
8	Non-friction Strip 1	3	0.667	1.000	1.000	2.000	65.385
9	Non-friction Strip 2	3	0.333	1.000	1.000	1.000	30.769
10	On/Off Button	3	0.667	1.000	1.000	2.000	65.385
11	Lens	3	0.333	0.667	0.667	0.444	11.538
12	Wheel	3	0.667	0.333	0.667	0.444	11.538
13	Transceiver	3	1.000	1.000	1.000	3.000	100.00
14	Product Label	3	0.333	1.000	1.000	1.000	30.769
15	Battery Label	3	0.333	1.000	1.000	1.000	30.769
16	LED Cover	2	0.500	0.500	0.500	0.250	0.000
Sum of $n_i \cdot f_{1i} \cdot f_{2i} \cdot f_{3i}$							12.639
Sum of $1/n_i^2$							2.194
Number of parts, P							16
Number of products, N							3
PCI							22.082

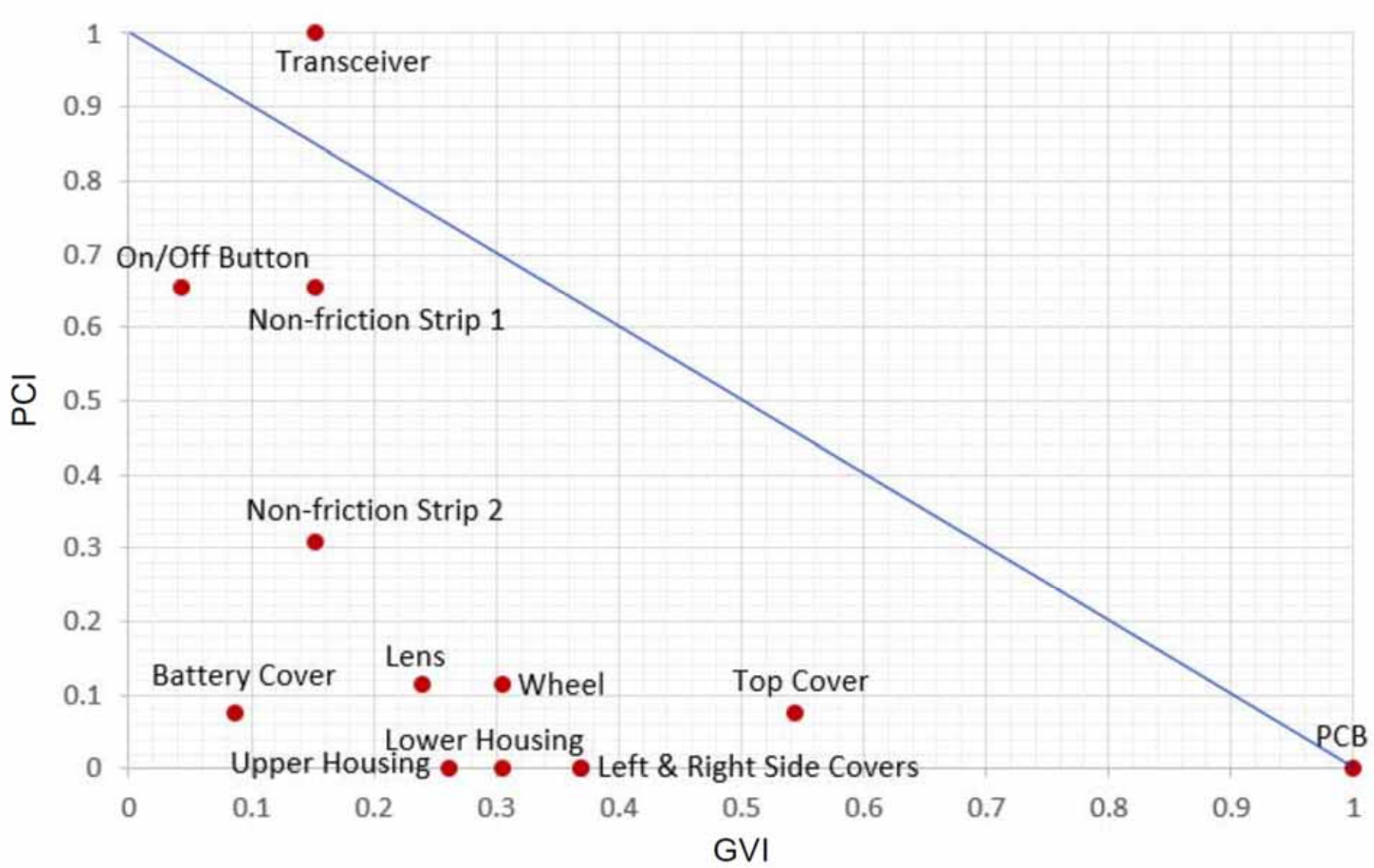
Commonality values for each component,

$$PCI_k = \frac{\sum_{i=1}^{P_k} n_i \times f_{1i} \times f_{2i} \times f_{3i} - \sum_{i=1}^{P_k} \frac{1}{n_i^2}}{P_k \times N - \sum_{i=1}^{P_k} \frac{1}{n_i^2}} \times 100$$

For more info, see: S. Jung and T. W. Simpson, 2016, "An Integrated Approach to Product Family Redesign Using Commonality and Variety Metrics," *Research in Engineering Design*, 27, 391-412.

Commonality-Variety Tradeoff Chart

- Plot GVI vs. PCI to identify components for redesign



For more info, see: (Jung and Simpson, 2016)

Redesign Assessment

- Use DSM to assess impact of proposed redesign
  - Direct connections: components directly linked to component being considered for redesign
  - Indirect connections: components that may be affected as changes propagate through the architecture

reduce the number of interfaces as well as increase the value of PCI

the connectivity between the PCB and the other components should be decreased

2009-2010		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Top Cover	1		•	•	•												
Upper Housing	2	•		•	•	•	•										•
Lower Housing	3	•	•		•	•	•	•	•	•	•	•	•		•	•	•
PCB	4	•	•	•		•	•				•	•	•				
Left Side Cover	5		•	•	•												
Right Side Cover	6		•	•	•												
Battery Cover	7			•													
Non-friction Strip 1	8			•													
Non-friction Strip 2	9			•													
On/Off Button	10			•	•												
Lens	11			•	•												
Wheel	12			•	•												
Transceiver	13																
Product Label	14			•													
Battery Label	15			•													
LED Cover	16		•	•													

For more info, see: (Jung and Simpson, 2016)

Validation Check

- Compare results and recommendations against a more recent set of wireless computer mice (2013-2014)

Released in 2009-2010

	Product		
			
	Wireless Mobile Mouse 1000	Wireless Mobile Mouse 3500	Wireless Mobile Mouse 4000
MSRP	$14.95	$29.95	$34.95
Release date	Oct. 2010	Jun. 2010	Nov. 2009

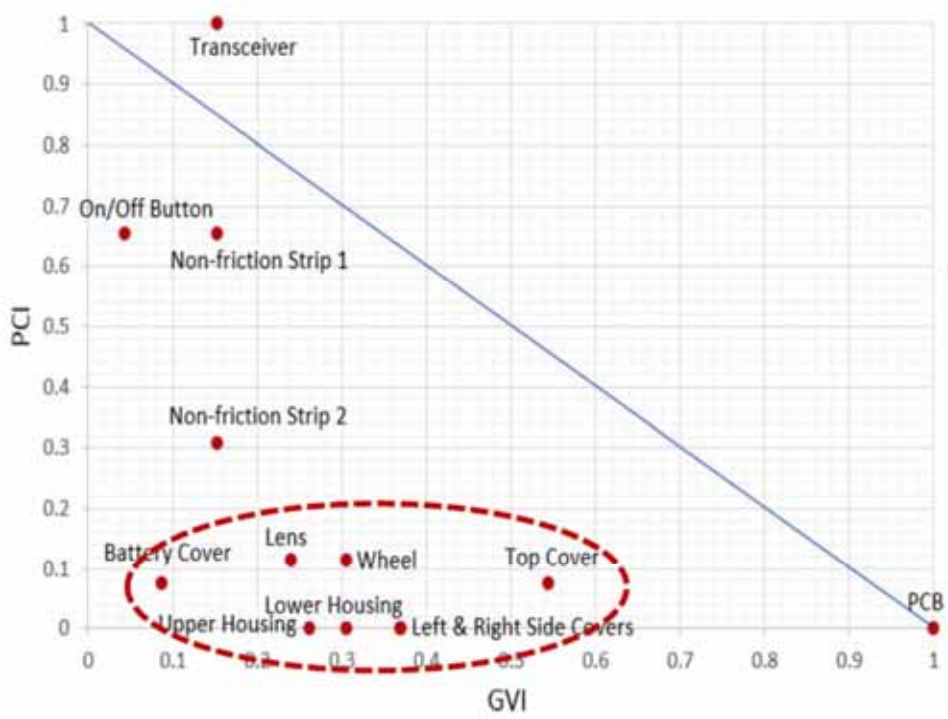
Released in 2013-2014

	Product		
			
	Wireless Mobile Mouse 1850	Sculpt Mobile Mouse	Sculpt Comfort Mouse
MSRP	$14.95	$29.95	$39.95
Release date	Jun. 2014	Aug. 2013	Sep. 2013

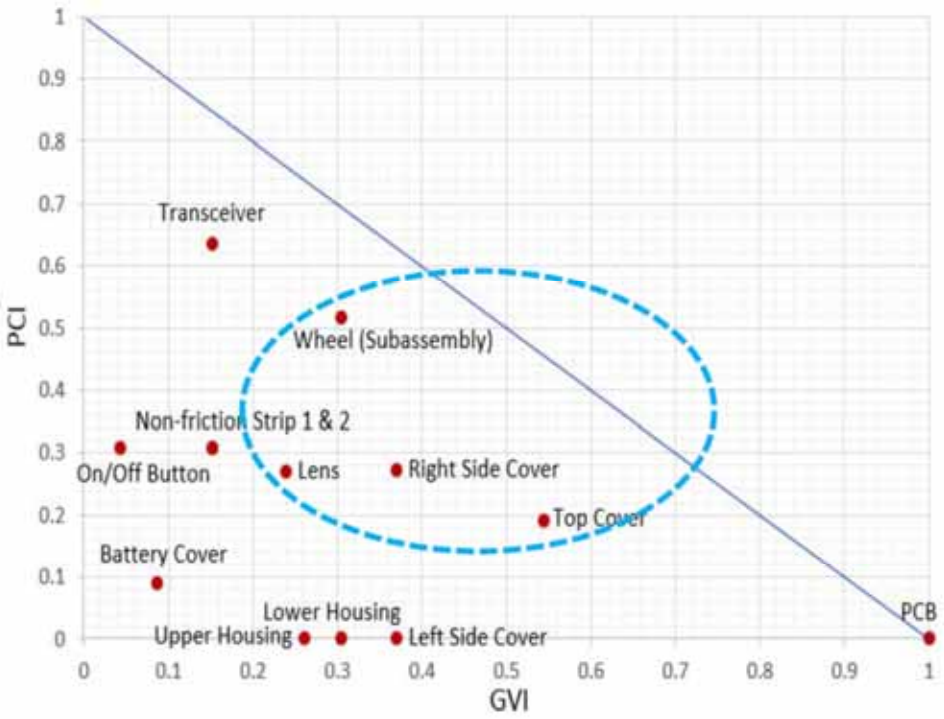
For more info, see: S. Jung and T. W. Simpson, 2016, "An Integrated Approach to Product Family Redesign Using Commonality and Variety Metrics," *Research in Engineering Design*, 27, 391-412.

Comparison of Commonality-Variety Tradeoff

- Low commonality components (wheel, lens, right side cover, and top cover) are now closer to the diagonal
  - PCI_k values for the components have increased as they are more common in the newer family



PCI = 22.08%

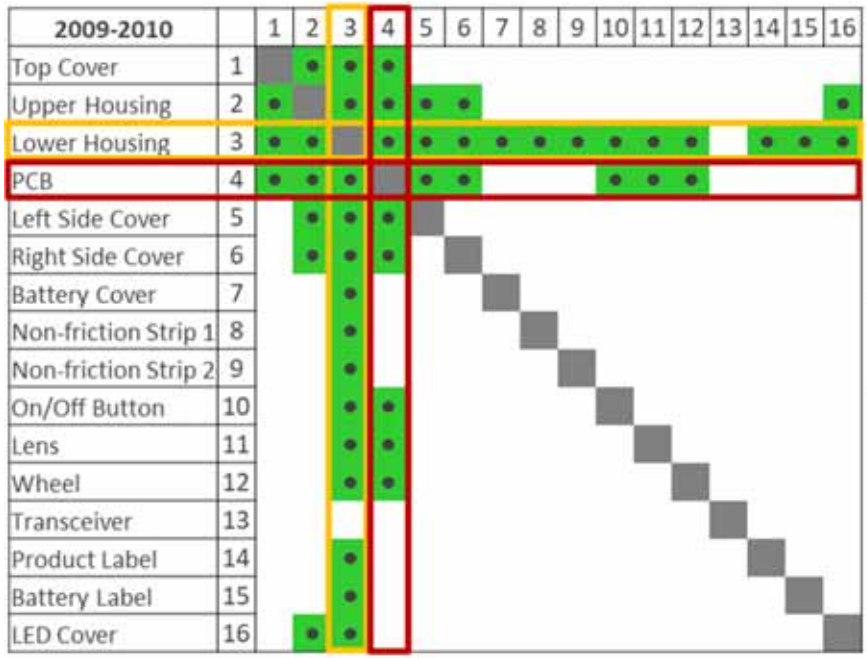


PCI = 27.46%

For more info, see: S. Jung and T. W. Simpson, 2016, "An Integrated Approach to Product Family Redesign Using Commonality and Variety Metrics," *Research in Engineering Design*, 27, 391-412.

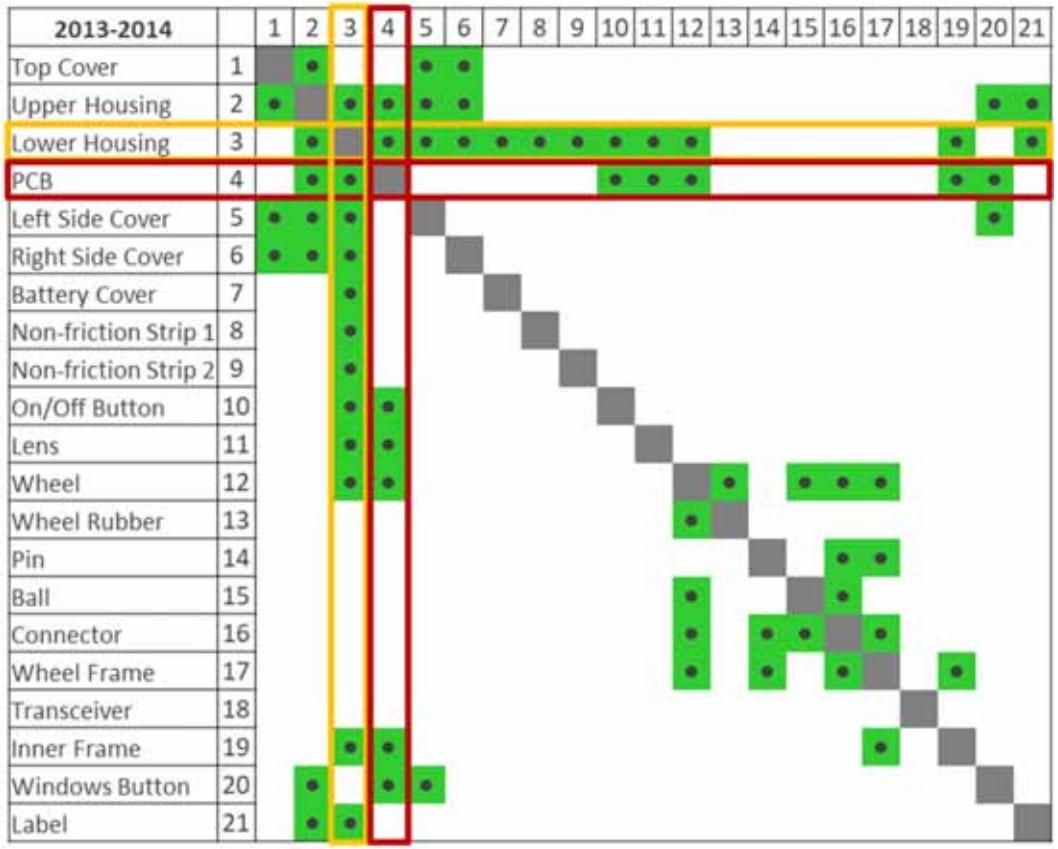
Comparison of Product Architecture

- Architecture of computer mice has also evolved similar to our proposed redesign strategy
  - # of interfaces for the lower housing: 28 → 24
  - # of interfaces for the PCD: 16 → 14



SMI (Degree of Modularity): 0.158 → 0.242
NZF (Degree of Density) : 0.208 → 0.167
(Hölttä-Otto and de Weck, 2007)

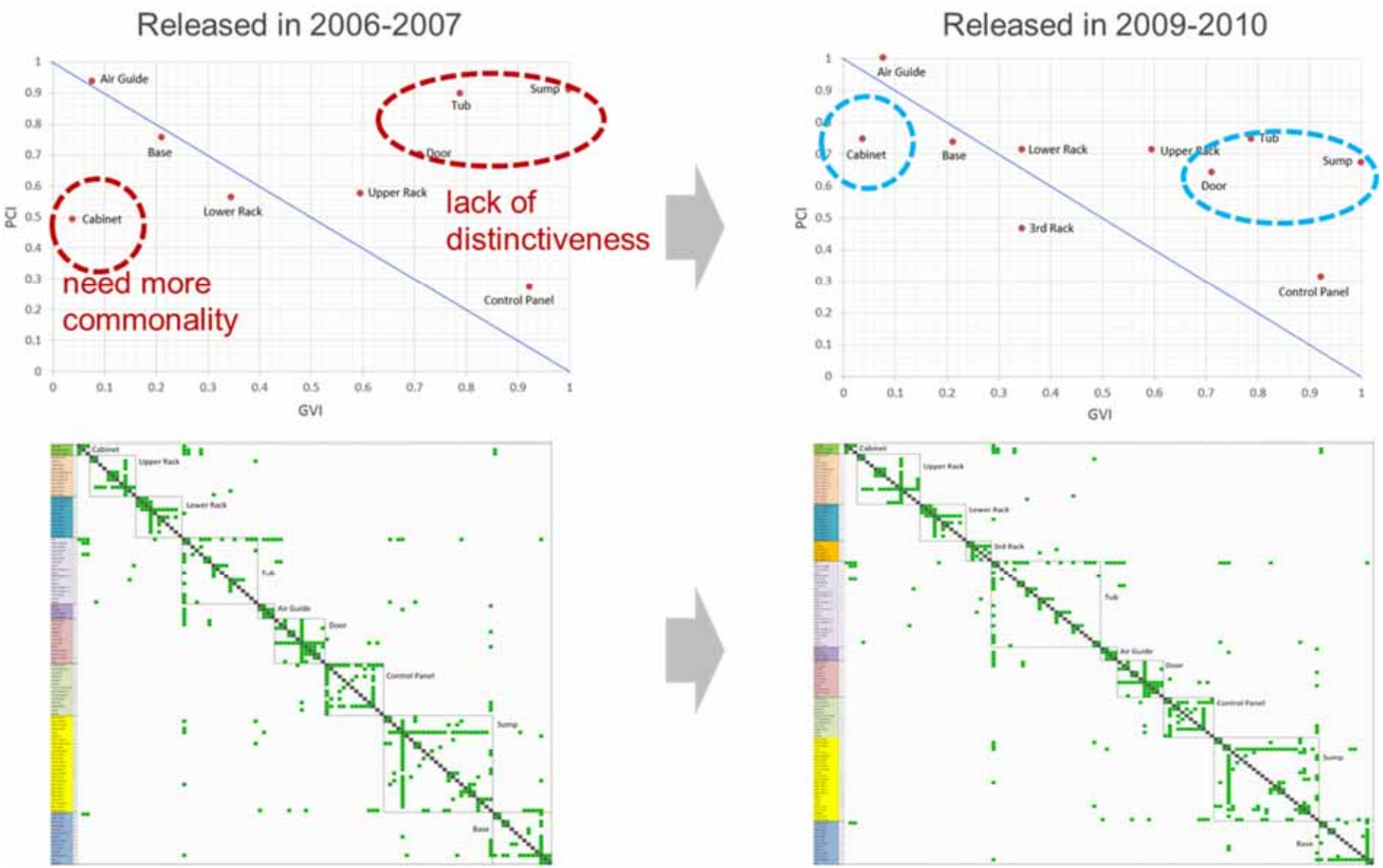
more modular & sparser



For more info, see: (Jung and Simpson, 2016)

Analyze at Module Level for Larger Products

- Analyzed family of LG dishwashers at the module level



For more info, see: (Jung and Simpson, 2016)

Closing Remarks

- Product family benchmarking and platform redesign is critical for today's competitive global marketplace
  - Cost savings opportunities through better platforming
  - Differentiation still critical for local and regional markets
- Product family benchmarking and platform redesign requires balancing commonality with variety
  - Generational variety index helps assess the degree of variety needed in the marketplace
  - Commonality indices like PCI help assess the extent of commonality achieved by design and manufacturing
- Plotting commonality vs. variety in one chart helps identify (mis)alignment between needs and variety
  - Opportunities for redesign and improvement can be found when analyzed on the component (or module) level