# Platform Architecture

## A Two-Level Optimization Approach

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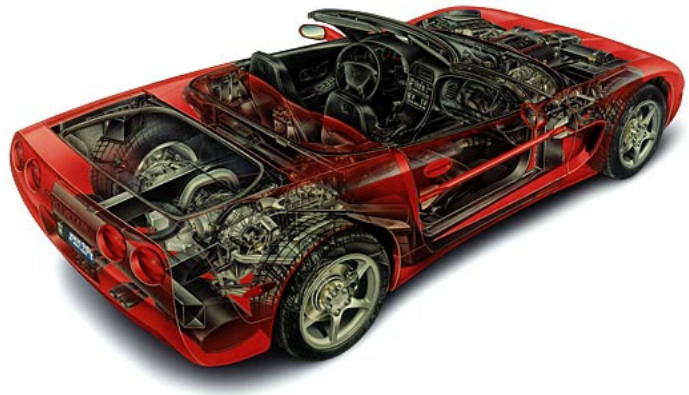
# Outline

1 - Introduction to Platform Architecture in Products

**GM Corvette**



2 - Automotive Platforming Example: A Two-Level Optimization Approach

**VW Golf**

3 - Discussion

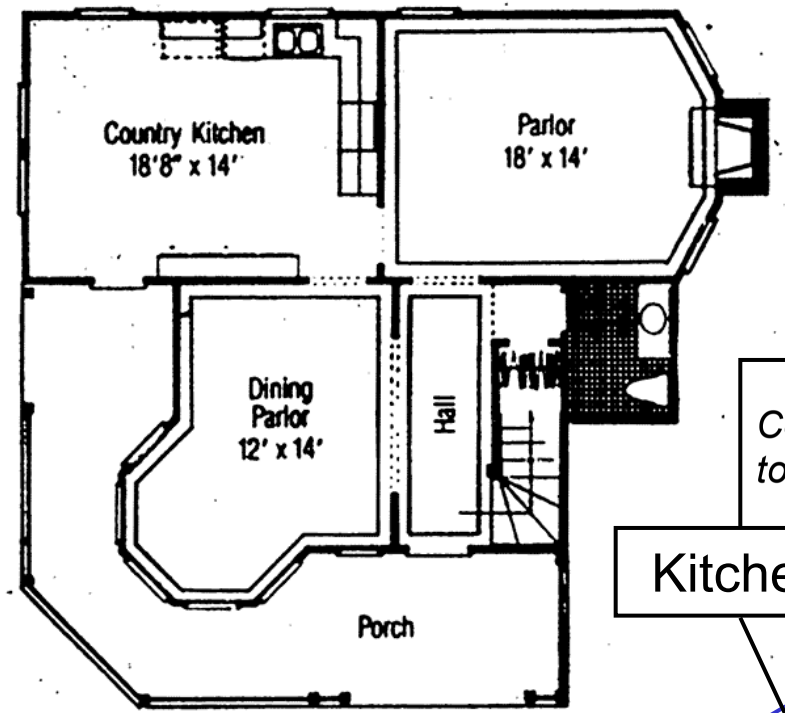
# 1 - Introduction to Platform Architecture in Products

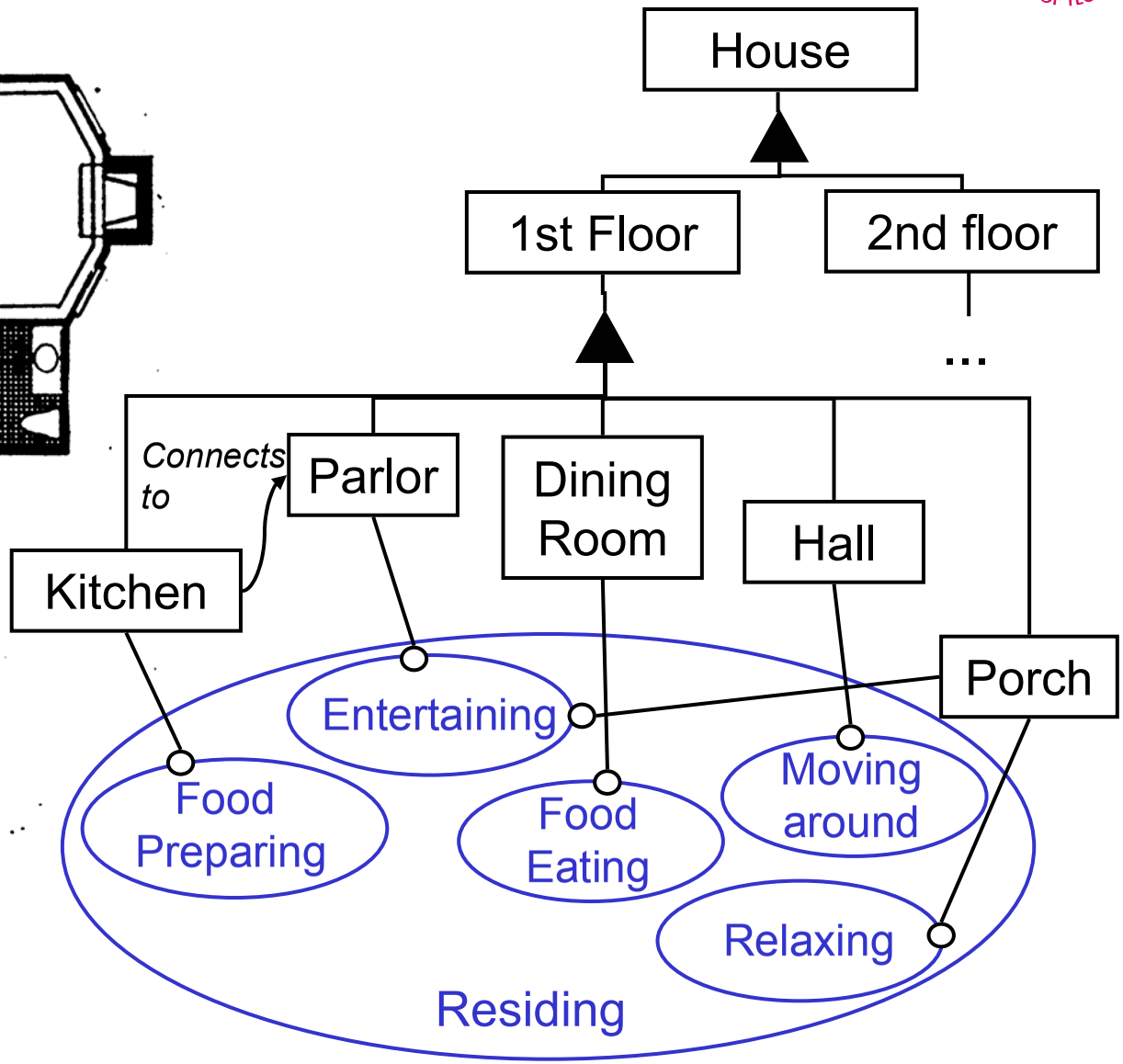
# Definition of Architecture

The arrangement of the functional elements into physical blocks. (Ulrich & Eppinger)

The embodiment of concept, and the allocation of functionality and definition of interfaces among the elements. (Crawley)

# Example: Private Residence

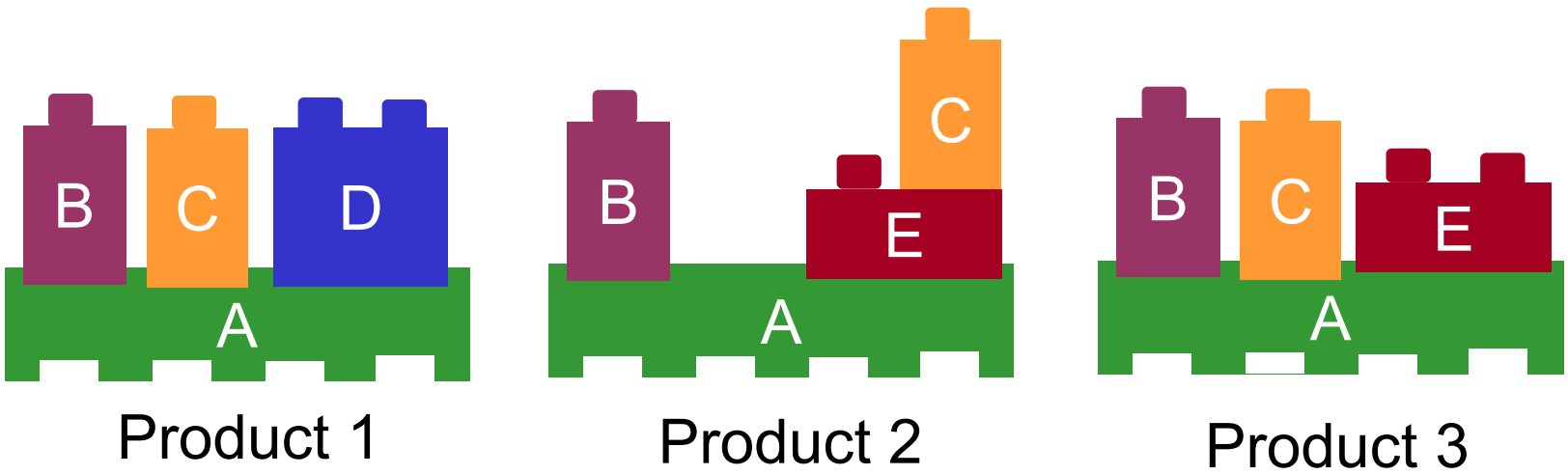


# Definition of Platform

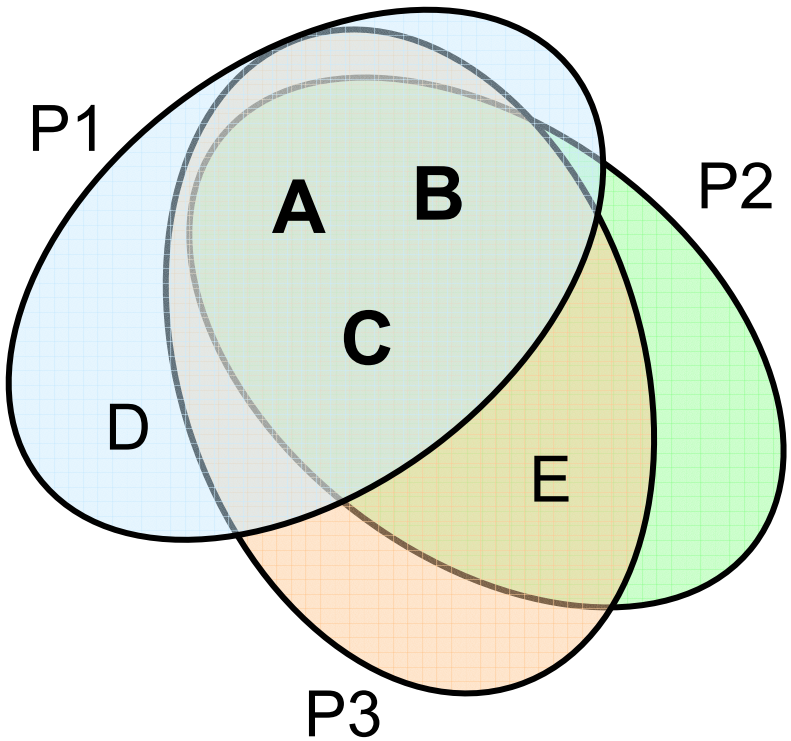
**Platform =** **A defined set of common or shared elements and its interface definition**

Elements can be all kind of architectural elements , e.g. parts, components, systems, processes, organizations - objects or processes

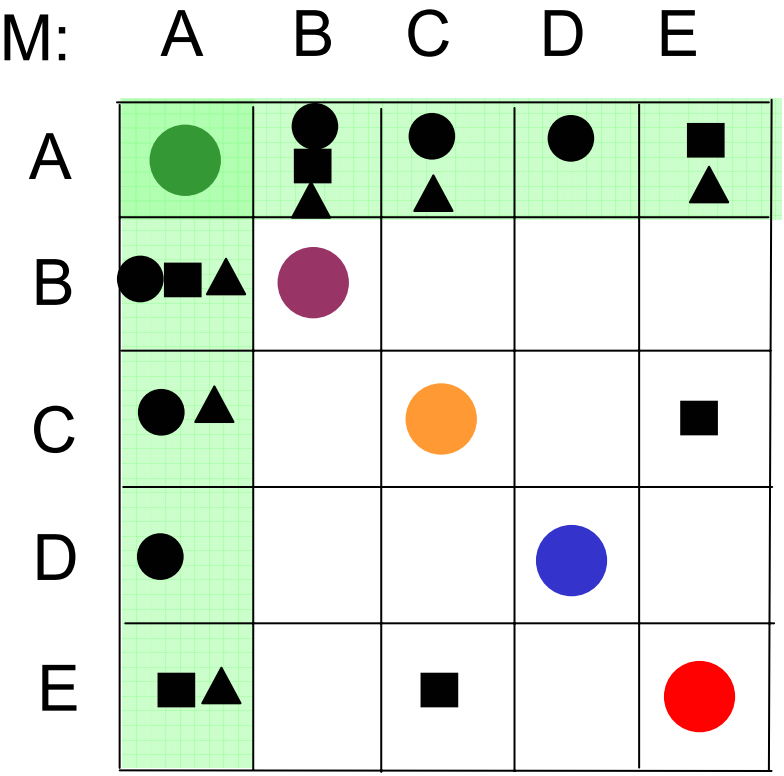


# Set Theory - DSM

Set Theory:




DSM:




P1 ● P2 ■ P3 ▲

$$P1 \cap P2 \bigcap P3 = \{A, B, C\}$$

Platform = common set= ABC

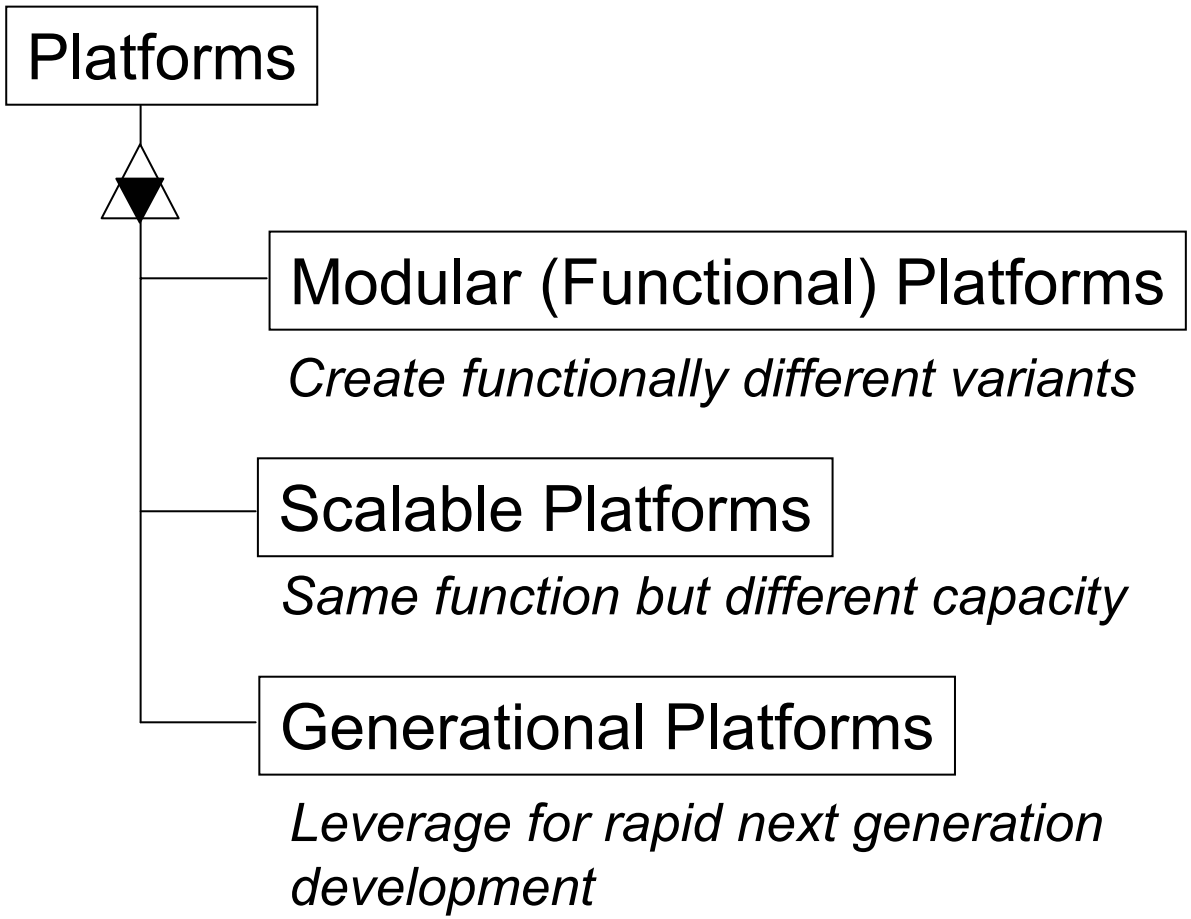
Interconnections: A

# Platforming - VW Example

| | VW | SKODA | SEAT | AUDI | |
|---|---|---|---|---|---|
| Segment E "Upper Class" | Concept D*** | | | A8 | Platform D (D1) (incl.Bugatti EB118) |
| | new W8 model? | | | A6 | |
| Segment D "Medium High" | Passat | new W8 model? | new W8 model? | A4 | Platform B(C?) (B5, C6?) |
| Segment C "Medium" | Beetle Bora Golf | Octavia | Toledo Leon | TT A3 | Platform A (A4, A5) |
| Segments A&B "Small Class" | Polo Lupo | Felicia | Cordoba Arosa | A2** | Platform A0 (A00, A01, A02, A03) |
| | | Fabia* | | | |

Ca. 65% common parts

# Classification of Platforms




Examples

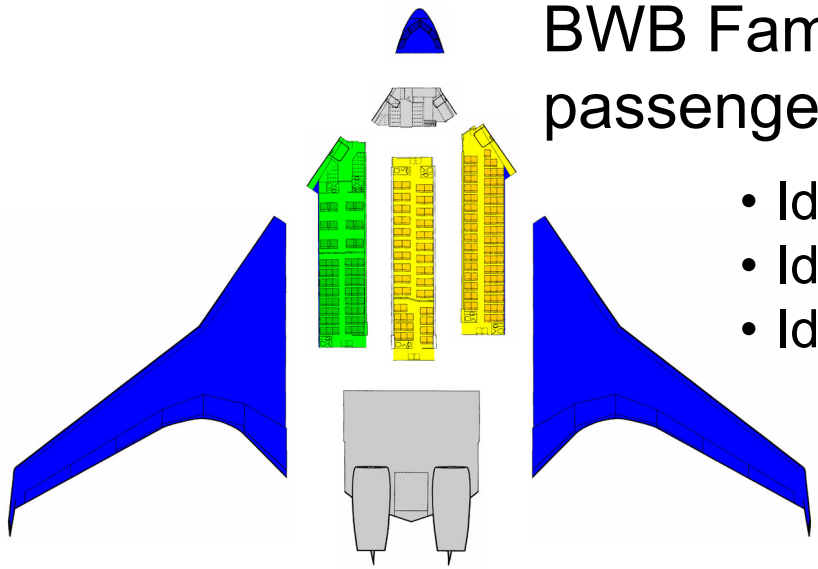
BWB

BWB
Photo Films

Computers

*Ref: K. Otto*

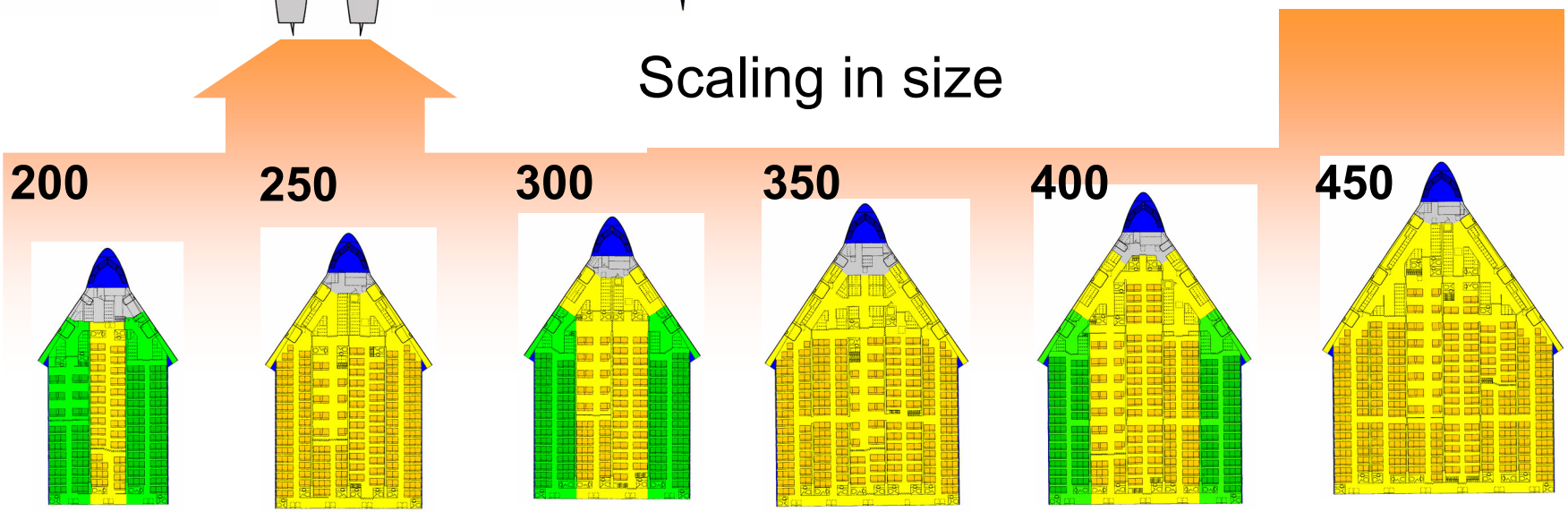
# Boeing Blended Wing Body - 1



BWB Family covering 200-450 passengers with:

- Identical Wings
- Identical Cockpit
- Identical & Similar Bays

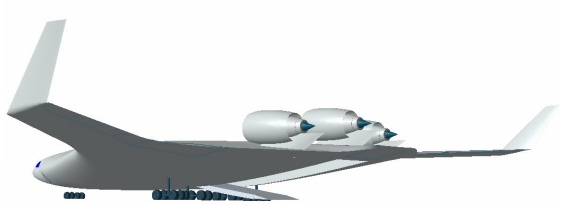
Scaling in size





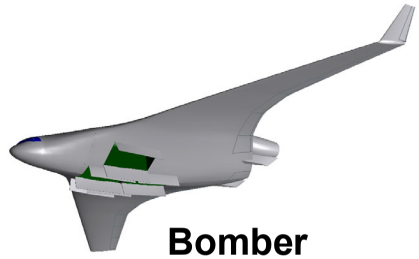

Source: Boeing

# BWB Common Fleet



Global Range Transport/Tanker

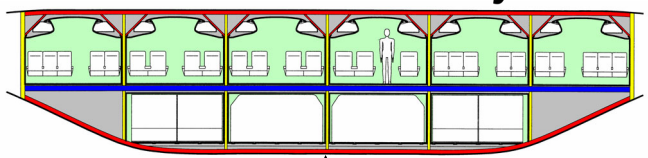
Tanker

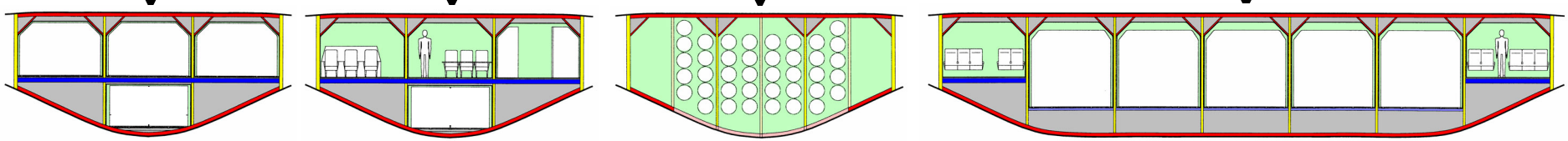


Bomber

***Representative Cross Sections***

***Commercial Family***





***Tanker*** ***$C^2$ISR*** ***Bomber*** ***Global Reach Freighter***

**Share Common Wing, Cockpit and Centerbody Elements**





Source: Boeing

# Platforming makes sense

When we have ….

- Systems with common basic sets of attributes
- Long lifecycle, distributed ownership
- Highly interconnected systems with need for future growth
- Products in rapidly changing environment
- Products that include “fast clockspeed” technologies
- Products with stable core functionality but variability in secondary functions and/or external styling
- Products with peripheral customization architecture

… based on empirical evidence

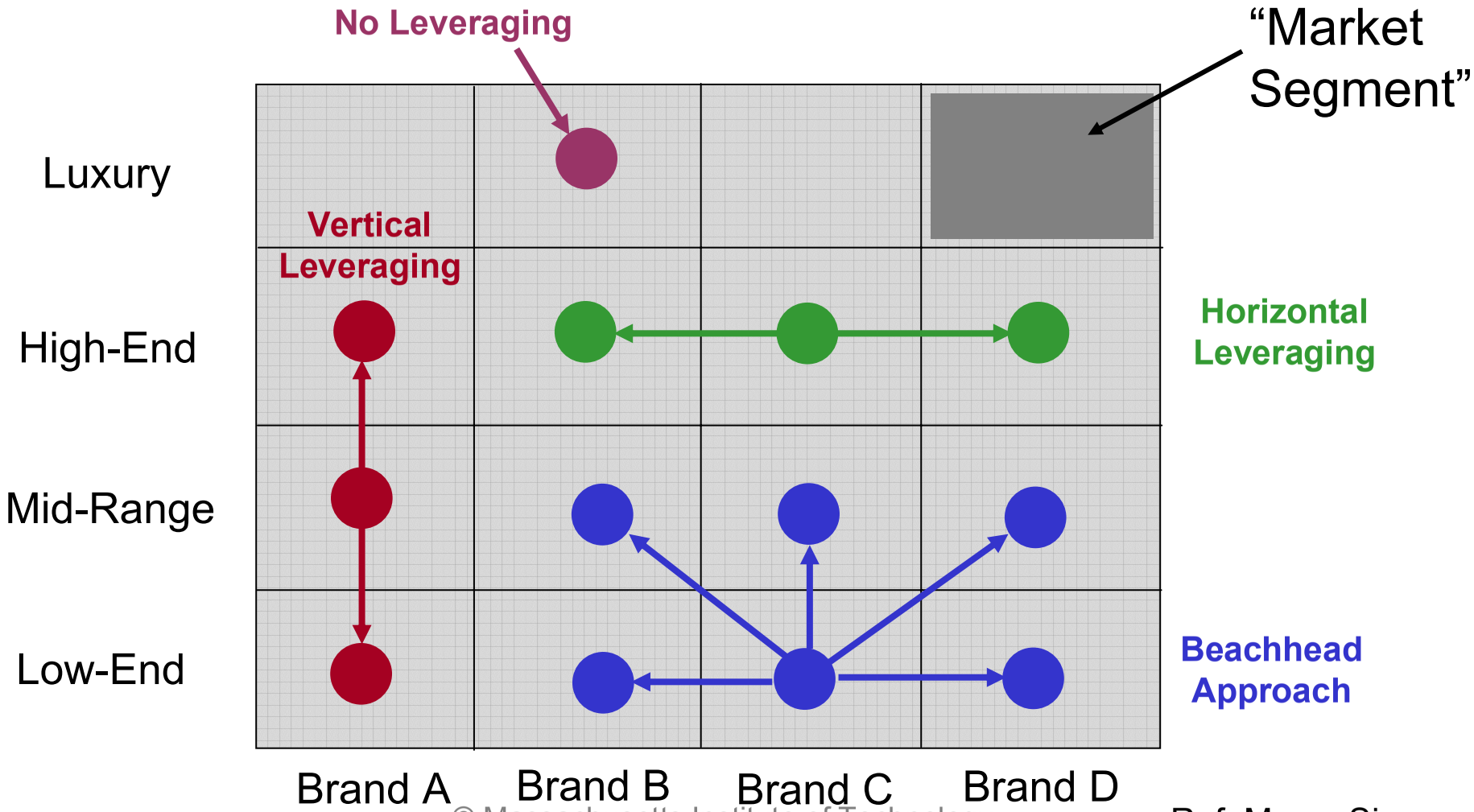
# When to avoid Platforming

- Single-use or short lifecycle products without need for product variety - commodities
- Systems insensitive to change over time
- Single function products
- Stable, unchanging packaging or design
- Slowly changing markets
- Ultra-high performance markets with no performance loss allowables

Ref: E. Fricke

# Platforming Strategies

Usually start with some market segmentation grid






Ref: Meyer,Simpson

# MIT esd Advantages - Reported Benefits

- Reduction of inventory *(Baker et al. 1986)*
- More standard parts *(Martin and Ishii 1996)*
- Shortening product design lead times *(Ulrich 1995)*
- Easier coverage of market niches *(Meyer and Lehnerd 1997)*
- Reduce design risk and cost
- Faster response to changing market needs (always?)
- Standard manufacturing processes and tooling

# Disadvantages - Potential Downsides

- Introduction of undesirable functions and unexpected technical problems in different variants based on the same platform (e.g. Audi TT problems with rear wheel pressure)
- Cannibalization of high end products by low end products of the same platform product family, when customer awareness is high (e.g. Golf versus Skoda)
- Loss of performance competivity if degree of commonality is chosen too high and market segment is price insensitive
- Effect of platforming on long-term product innovation

# Interesting Research Questions

(1) Given a product family with *N* products to be placed in *M* market segments - how many platforms to use?

(2) What is the right trade-off between degree of commonality between variants and loss of distinctiveness (performance compromise)?

(3) How does the competitor's position affect the platform strategy?

… there are many more

# 2
# Automotive Platforming Example:

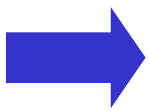
# A Two-Level Optimization Approach

# Problem Setup

We are a (new) automotive manufacturer and want to compete successfully in these market segments:

| Symbol | Name | #vhc | Size | Mean Price |
|---|---|---|---|---|
| LOWC | Compact Car | 30 | 2,357,802 | $13,427 |
| MDSD | Medium Sedan | 33 | 4,198,028 | $19,844 |
| LXSD | Luxury Sedan | 65 | 1,591,438 | $34,238 |
| SPTR | Sports-Roadster | 34 | 514,837 | $23,424 |
| SUVC | SUV | 56 | 3,519,461 | $25,146 |
| PUPT | Truck | 51 | 2,800,104 | $22,805 |
| MVAN | Van | 24 | 1,589,958 | $24,986 |
| | | | 16,571,628 | |

Total U.S. Market 2001 ca. New Vehicle Sales: 16.8 M/year



What is the right strategy?

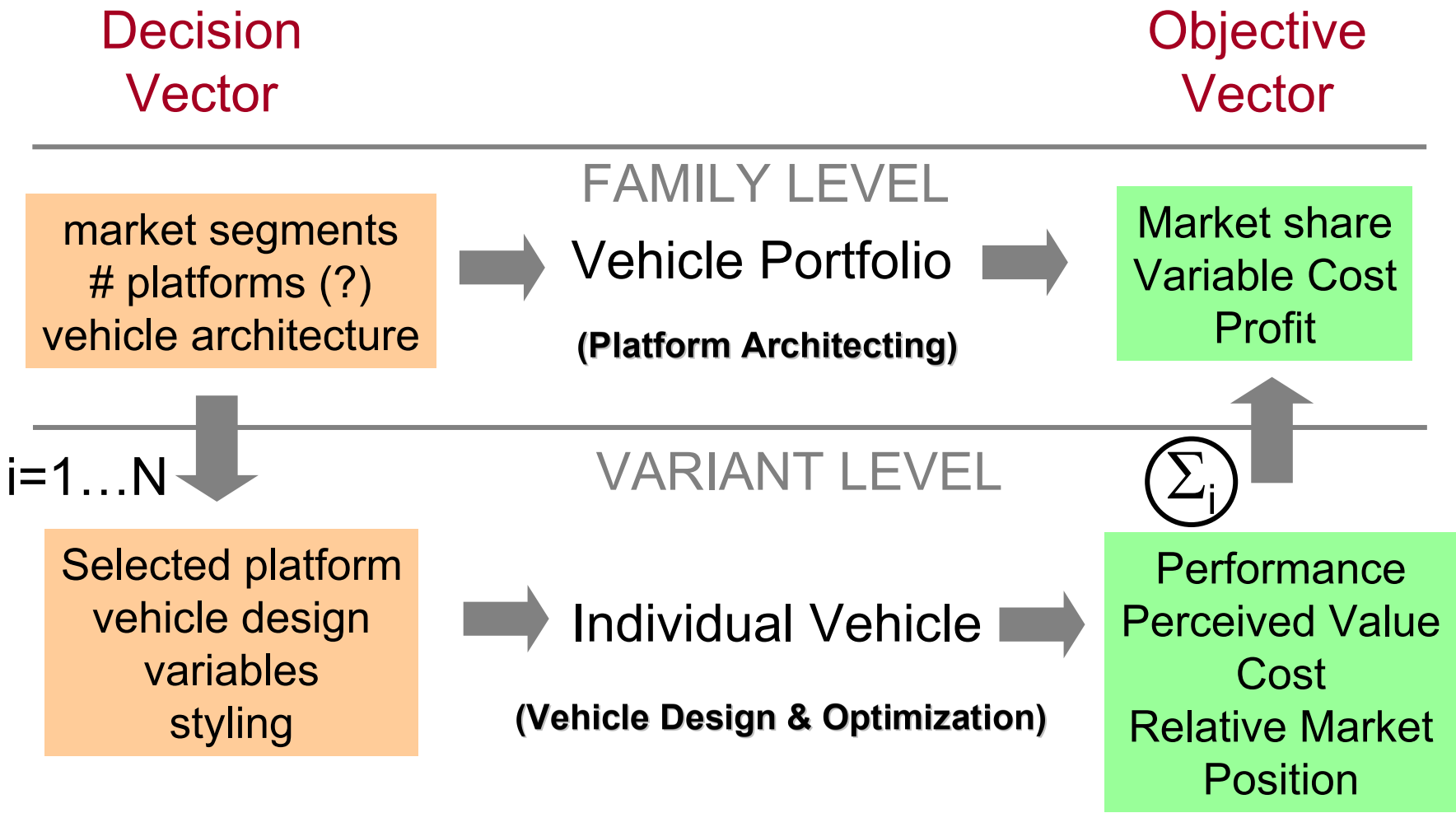


Source: NIADA National Market Report - 2002

# Simplifying Assumptions

- The targeted market segments are known
- One product (vehicle) per market segment
- The basic vehicle architecture is given
- Market segments operate independently
- Competitors continue to offer the same
- The fixed operating cost per year is $B 4.0
- MSRP corresponds to actual sales price
- Offer at the same price as market leader

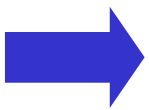
# Two Level Approach



# Vehicle Segments

| | | |
|---|---|---|
| LXSD | SUV | TRCK |
| MDSD | | VAN |
| LOWC | SPTR | |
| Sedans | Sports | Utility |

N=7

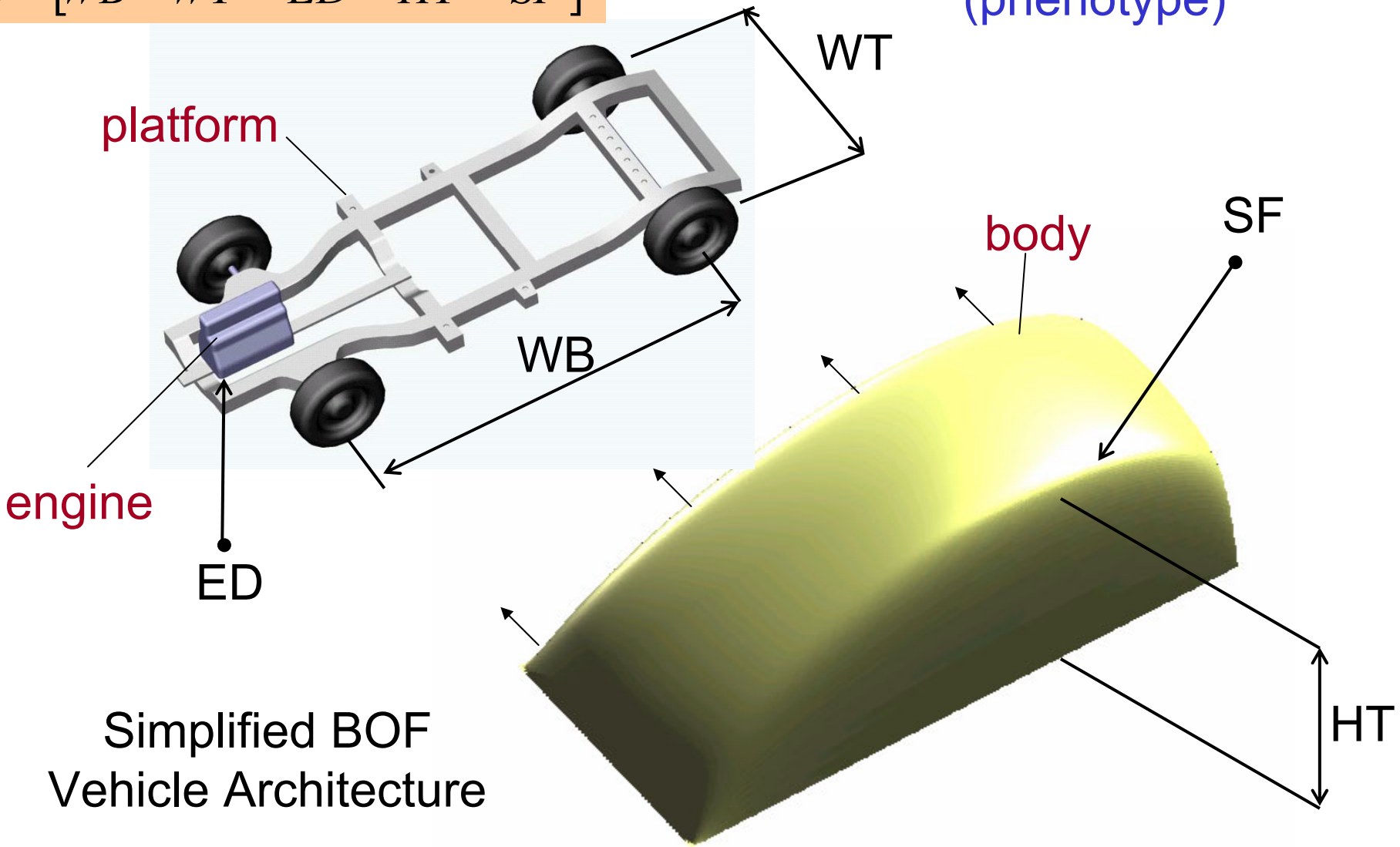


7 Variants, but how many platforms?

# Vehicle Architecture

$$\vec{x} = \begin{bmatrix} WB & WT & ED & HT & SF \end{bmatrix}^T$$

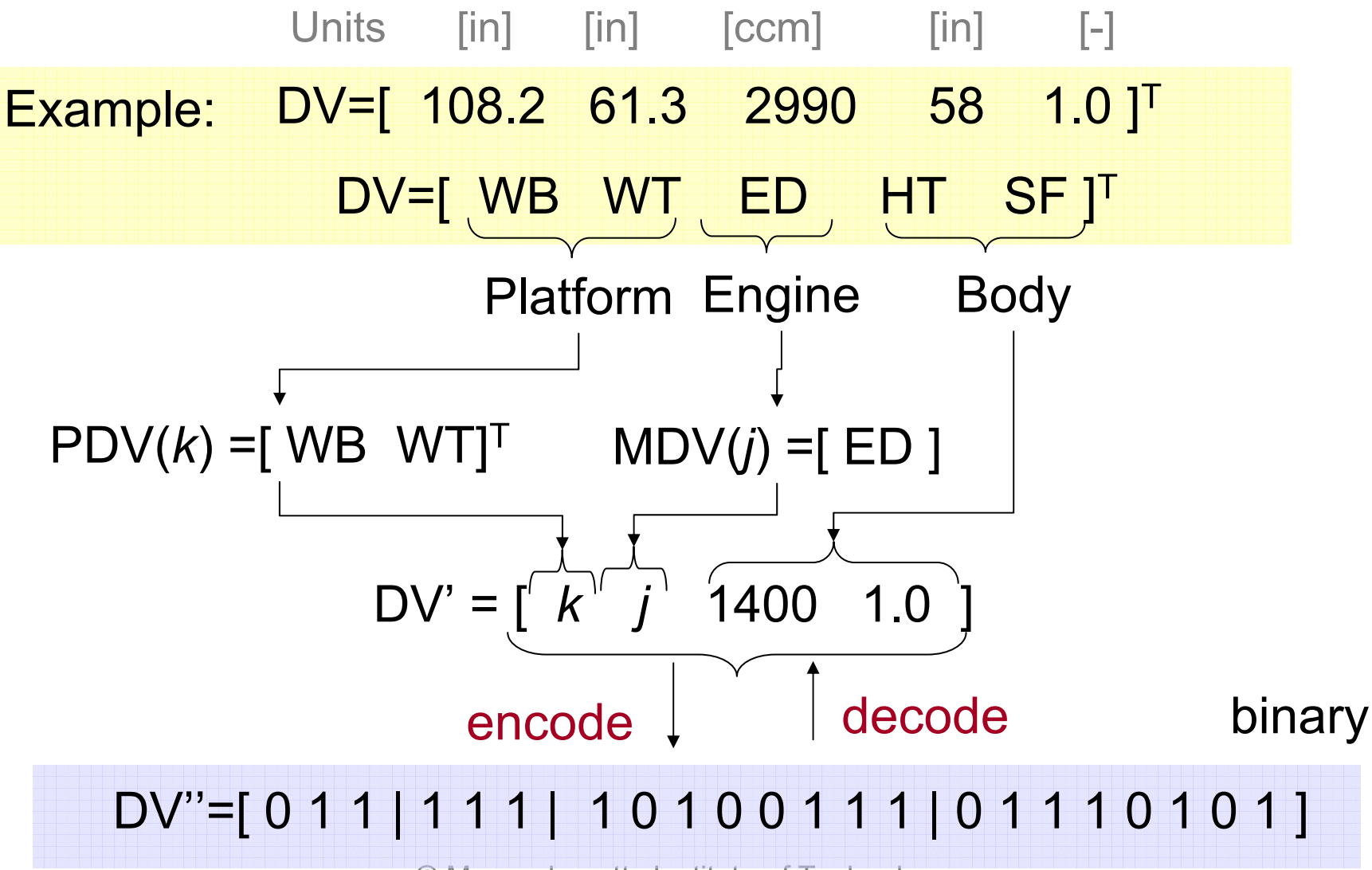
(phenotype)




Simplified BOF Vehicle Architecture

# Vehicle Design Vector

(genotype = vehicle "DNA")



# Vehicle Price & Performance

| | LOWC | MDSD | LXSD | SPTR | SUV | TRCK | VAN |
|---|---|---|---|---|---|---|---|
| AC - Acceleration | 0.1 | 0.15 | 0.15 | 0.4 | 0.1 | 0.15 | 0.05 |
| HP - HorsePower | 0.1 | 0.1 | 0.15 | 0.3 | 0.25 | 0.35 | 0.1 |
| FC - Fuel Efficiency | 0.4 | 0.2 | 0.05 | 0.05 | 0.05 | 0.10 | 0.05 |
| PV - Passenger Vol. | 0.3 | 0.4 | 0.45 | 0.2 | 0.3 | 0.05 | 0.4 |
| CV - Cargo Volume | 0.1 | 0.15 | 0.2 | 0.05 | 0.3 | 0.35 | 0.4 |
| SR - Styling Rating* | | | | | | | |

*TBD

Preference weight matrix $\sum_{i=1}^{5} w_{i,j} = 1.0$

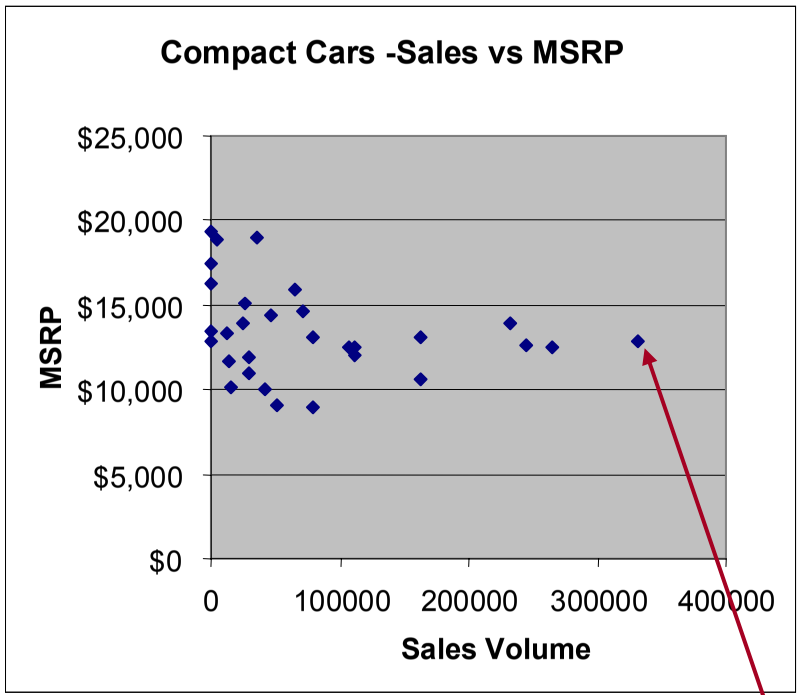
Perceived value = Aggregate performance relative to the market segment leader

Relative Performance $J_{rel,j} = \sum_{i=1}^{5} w_{i,j} \cdot \frac{J_i}{\hat{J}_{ML,i}}$

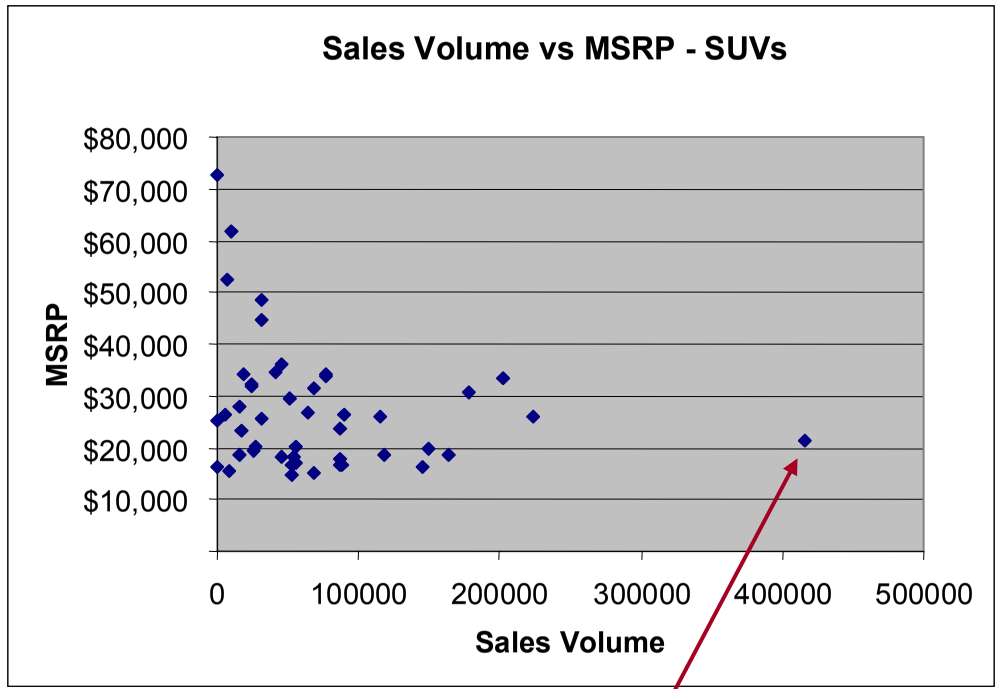
Relative Price $P_{rel,j} = \frac{MSRP_j}{MSRP_{ML,j}}$

# Example Segments

## Compact Cars - LOWC




## Sports Utility Vehicles - SUV



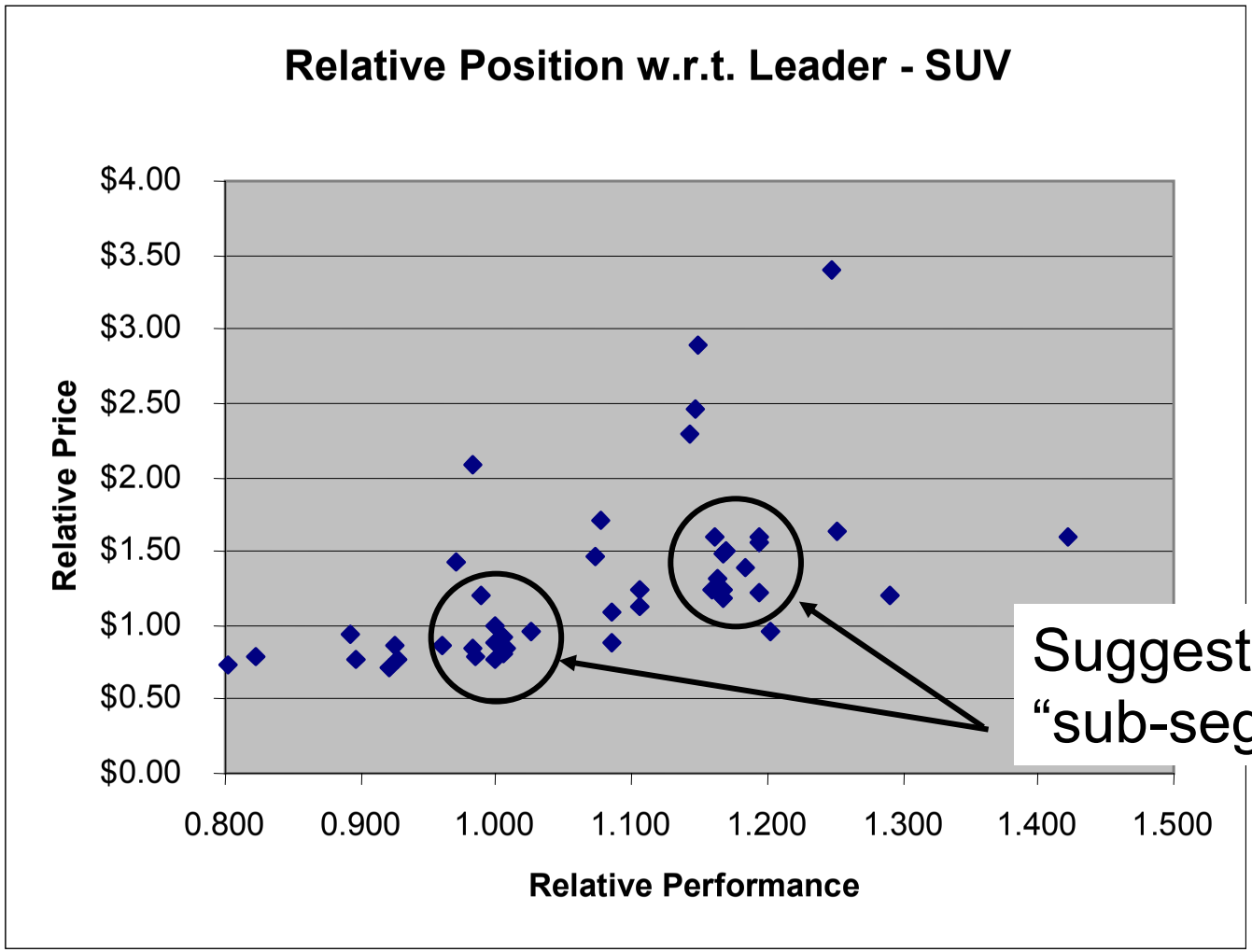

Who are the leaders?

Source: AutoPro

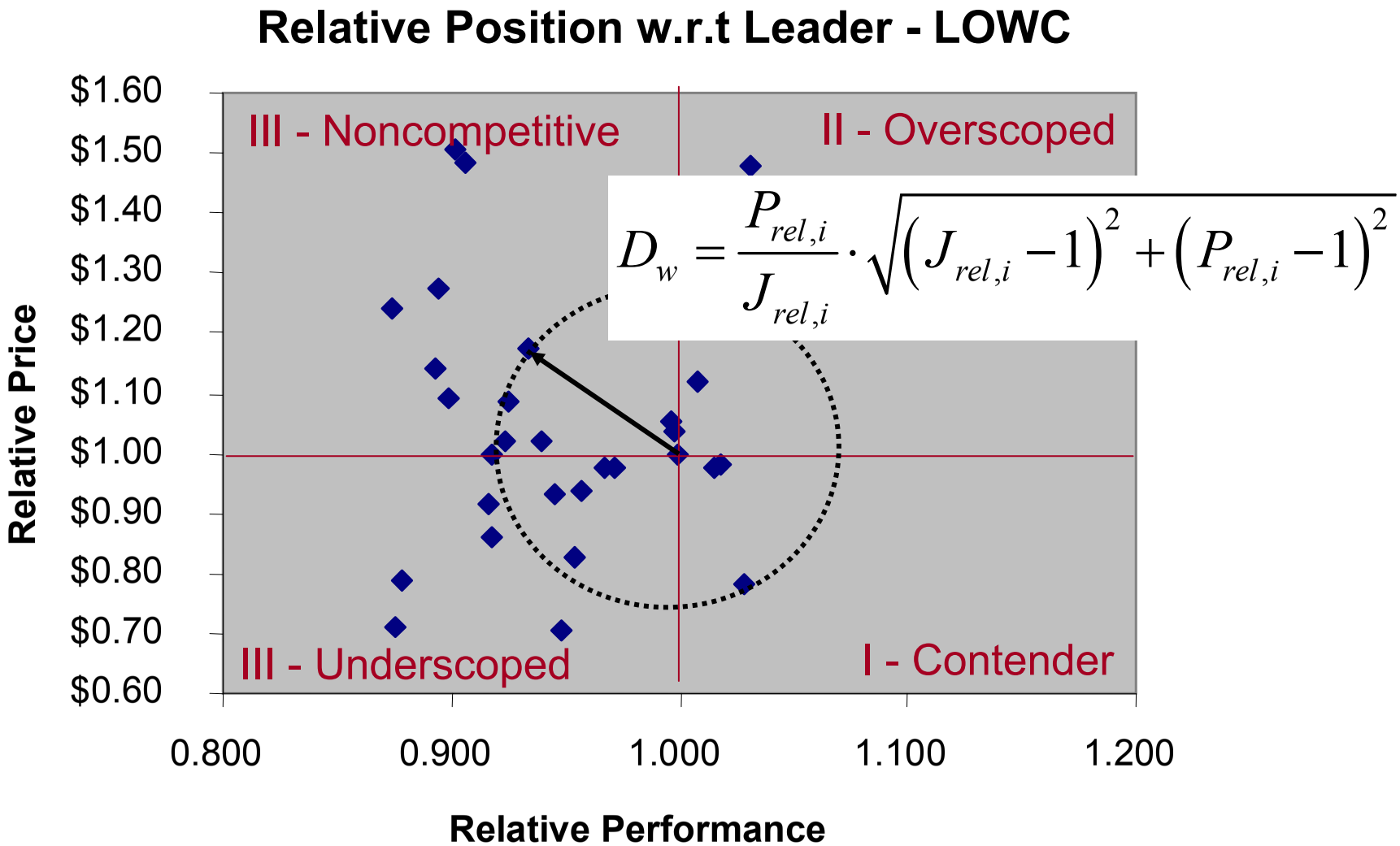
Honda Civic

Ford Explorer

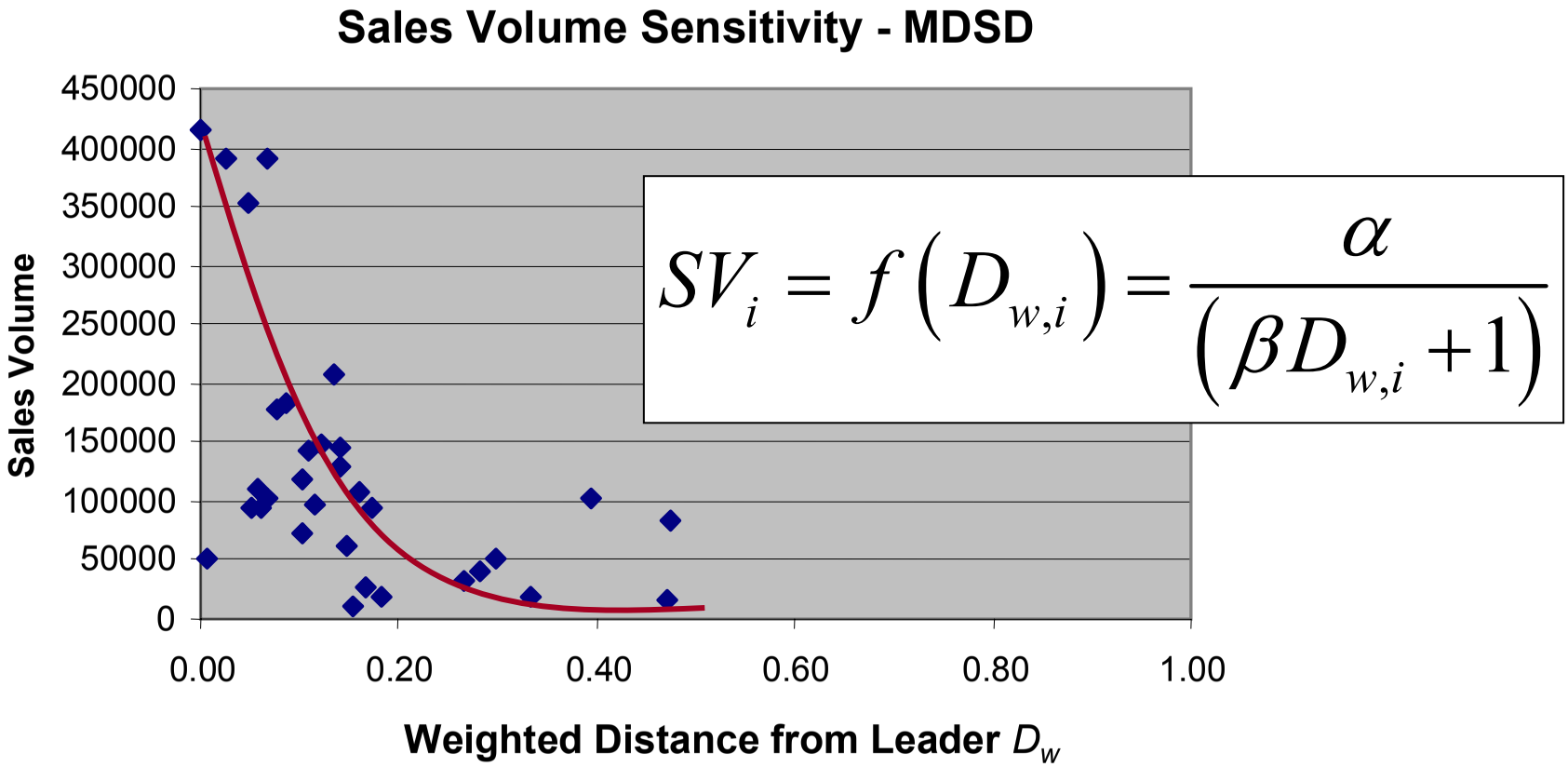
# "Sweet Spot" Hypothesis



# Competitive Position

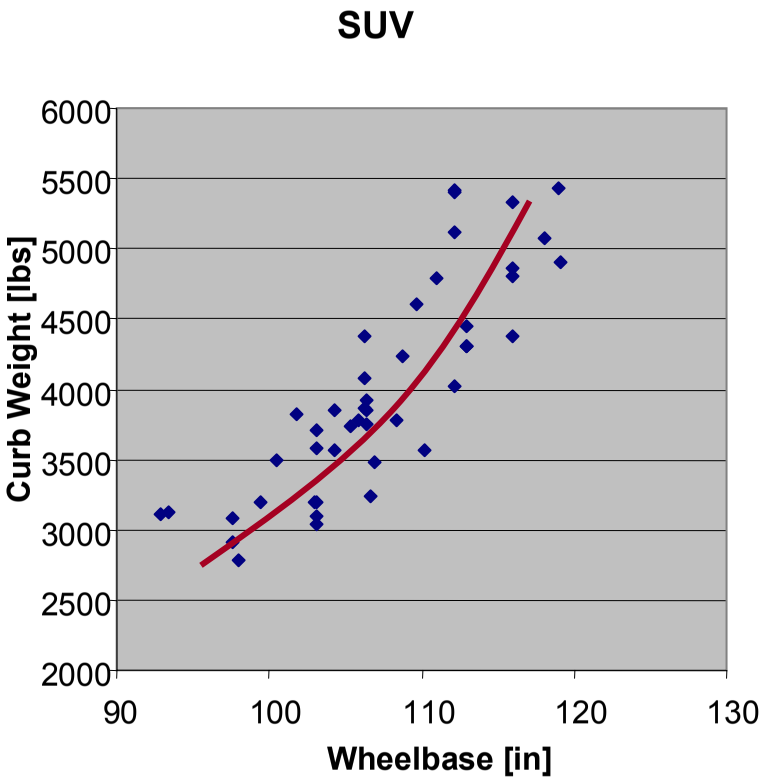


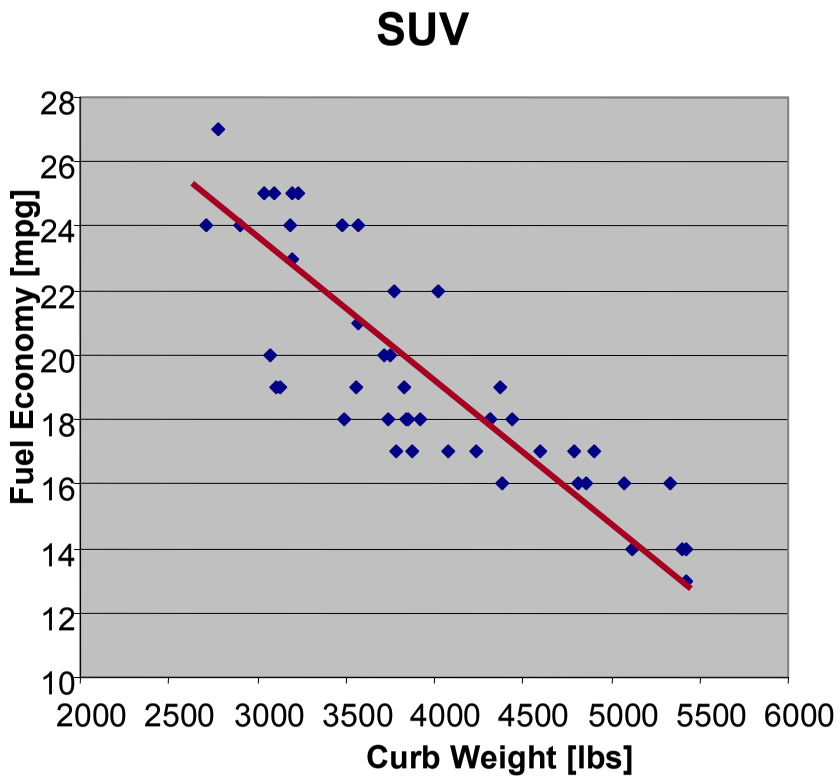
# Sales Volume Sensitivity




Establishes an estimate for sales volume penalty due to platforming/commonality effects

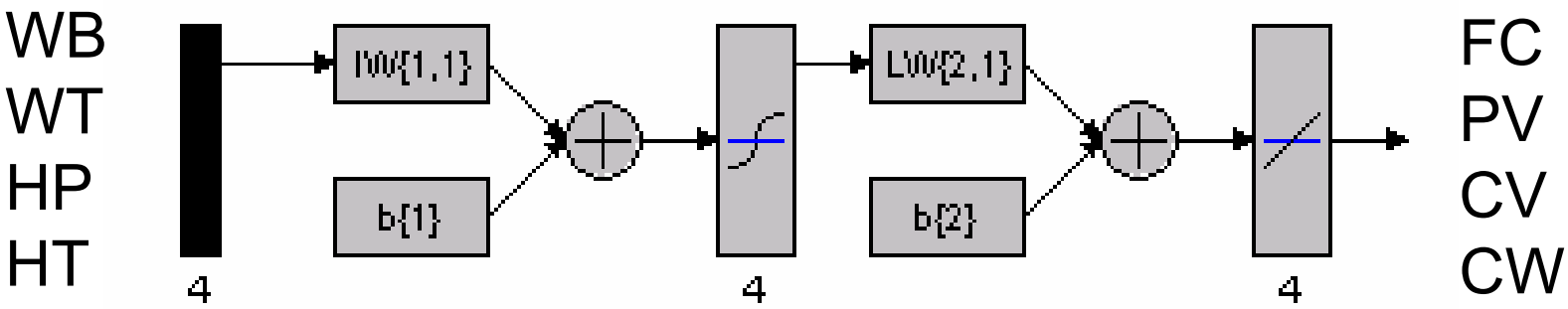
# Engineering Model




Instead of detailed CAD/CAE-simulation model,
use approximate scaling relationships for each segment.

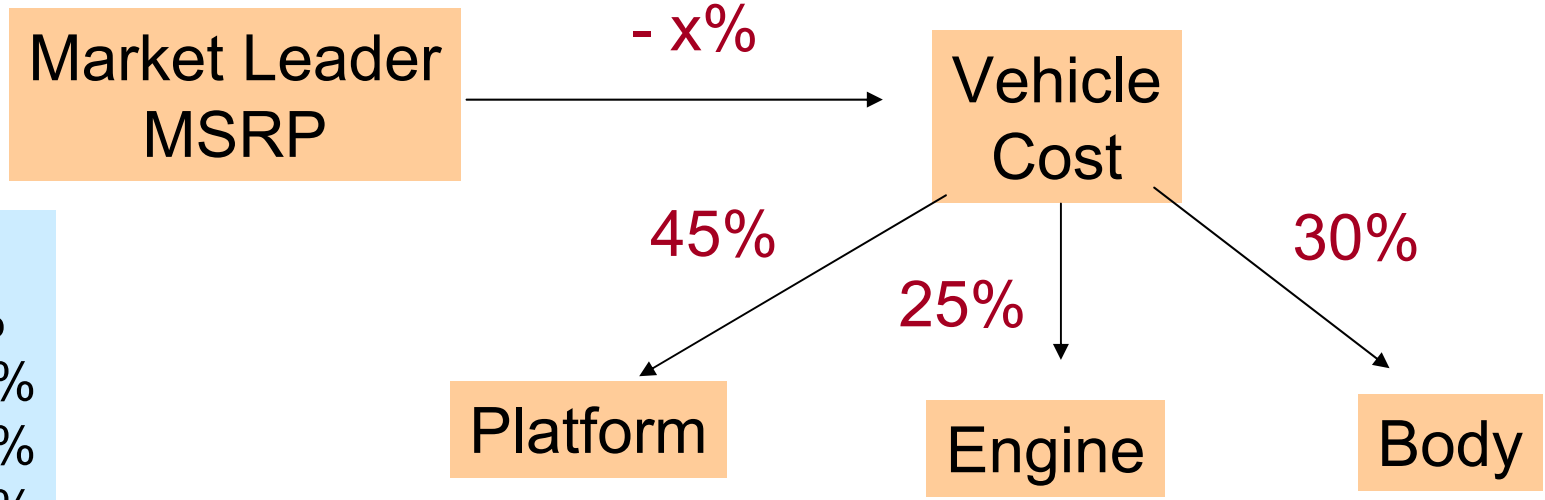
# Neural Network Model




- Multivariable function approximator
- Trained with market segment data

| | input | | truth | | output | error % |
|---|---|---|---|---|---|---|
| WB | 103.1 | FC | 36 | FC | 33.85824 | 6.3257 |
| WT | 57.9 | PV | 85.9 | PV | 87.707918 | 2.0613 |
| HP | 115 | CV | 12.9 | CV | 11.86767 | 8.6987 |
| HT | 55.1 | CW | 2405 | CW | 2233.1235 | 7.6967 |

# Cost Model




Margins x:

| | |
|---|---|
| LOWC | 5% |
| MDSD | 10% |
| LXSD | 20% |
| SPTR | 15% |
| SUV | 15% |
| Truck | 25% |
| Van | 15% |

Include Learning Curve Effect

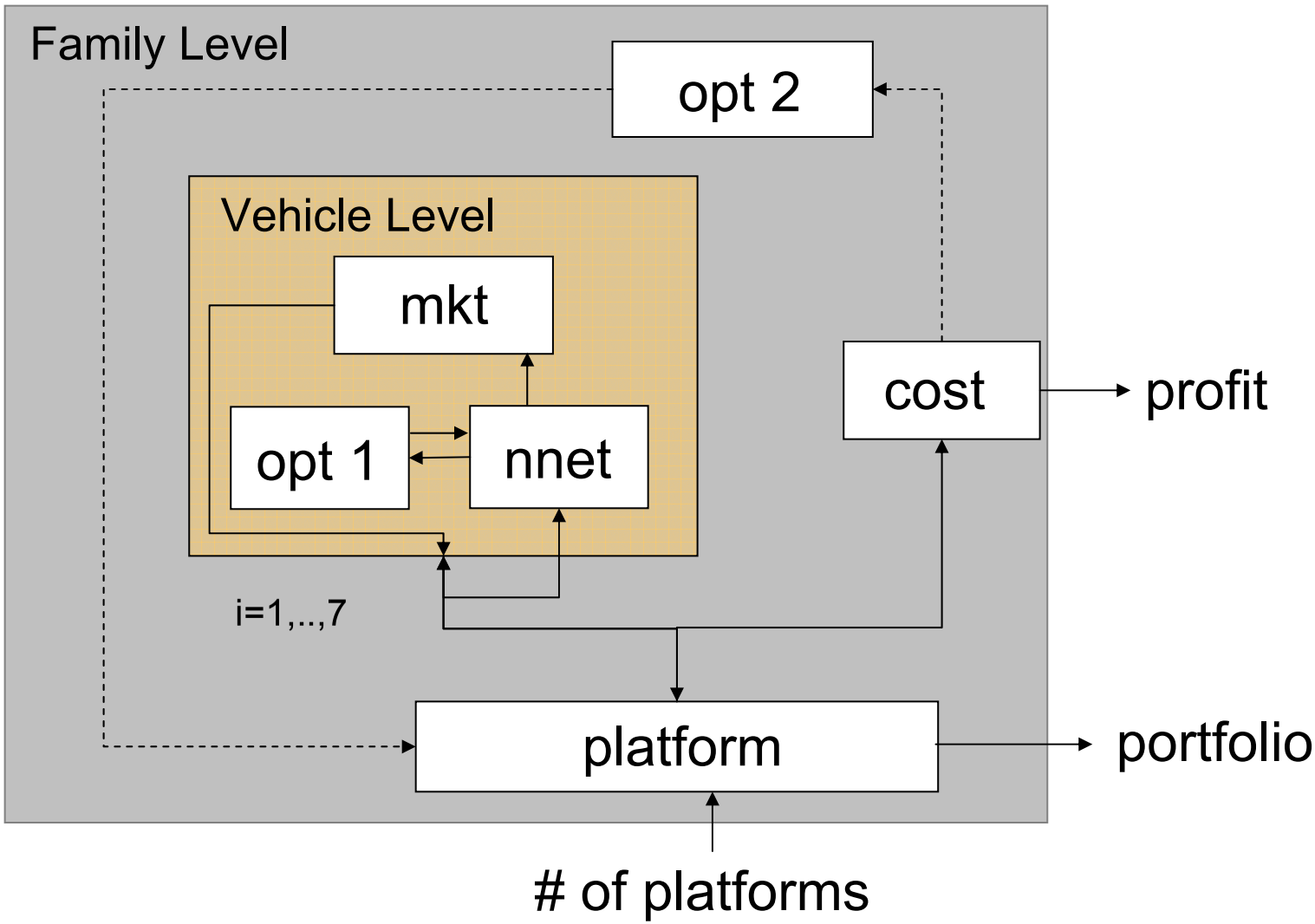
$$C = TFU \cdot \underbrace{N^B}_{L}$$

$$B = 1 - \ln(100/S)/\ln 2$$

Total Product Family Cost:

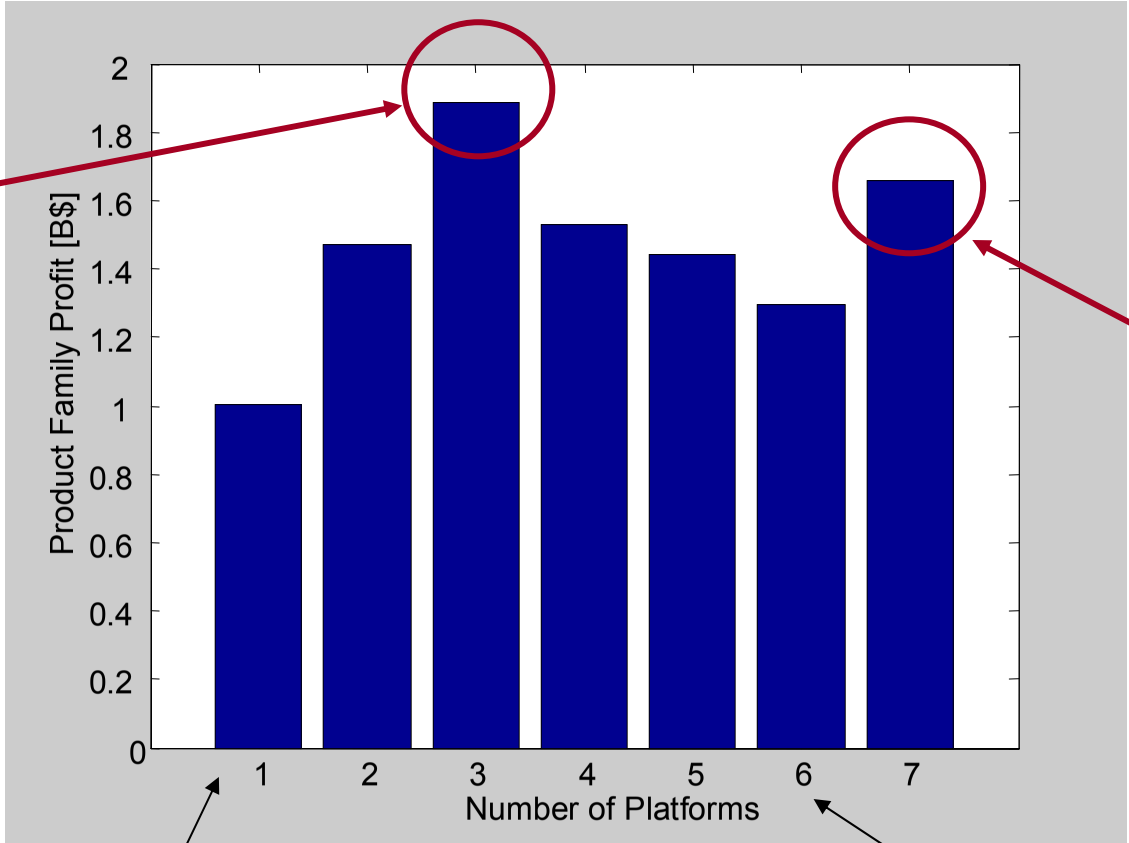
$$C_{fam} = \sum_{i=1}^{\#platform} TFU_{p,i} N_{p,i}^B + \sum_{i=1}^{\#engines} TFU_{e,i} N_{e,i}^B + \sum_{i=1}^{\#bodies} TFU_{b,i} N_{b,i}^B$$

# Simulation Framework



# Optimal # of Platforms

"Optimal" Platform Strategy




Null Platform Strategy

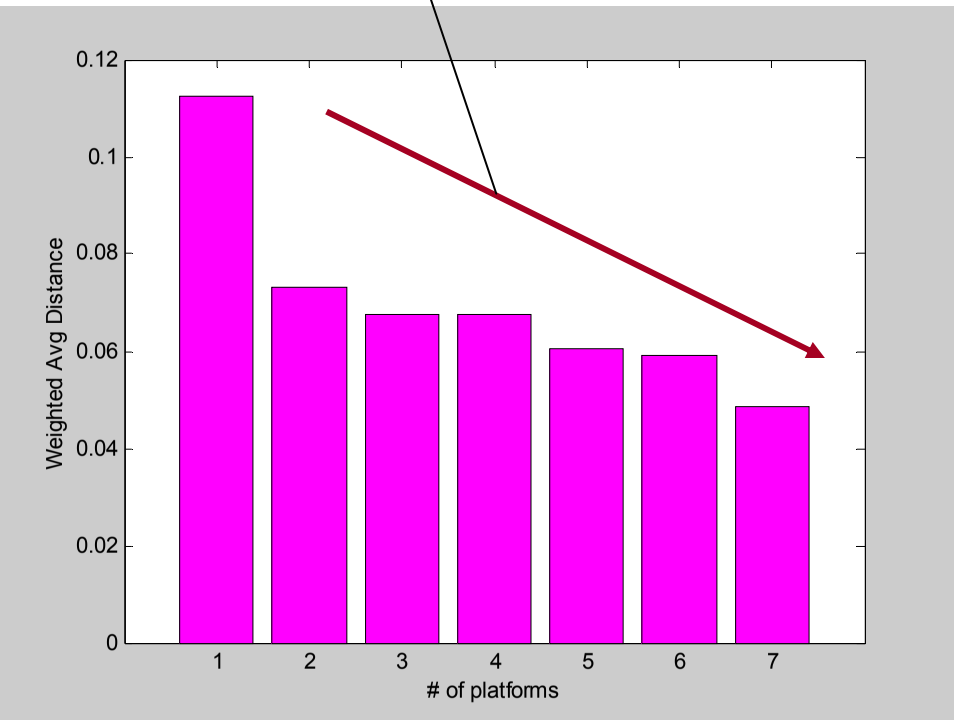
Non-competitiveness due to uniformity

cost of variety

# Some observations

Performance penalty goes down with increasing # of platforms

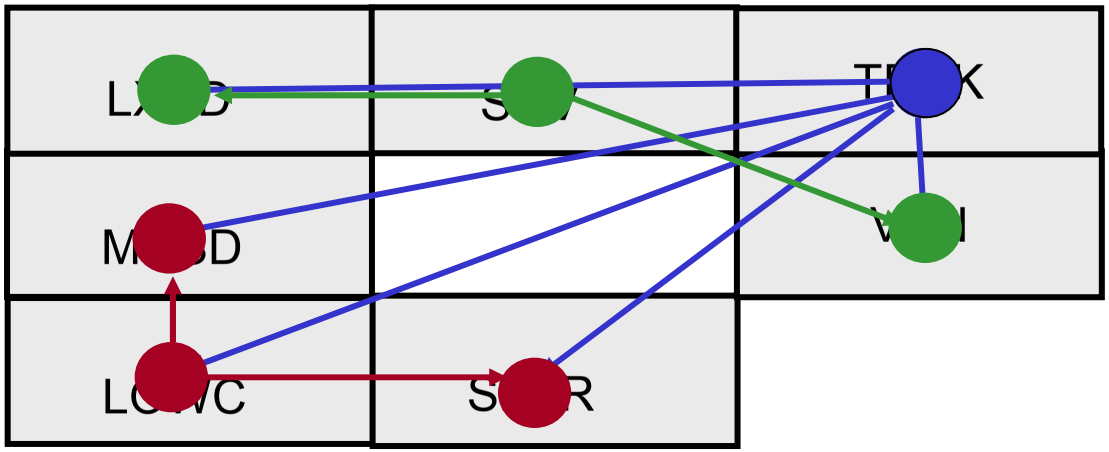
- results sensitive to learning curve *S*




Optimal - 3 Platforms

| | WB | α | β | γ |
|---|---|---|---|---|
| LOWC | 105.1 | ● | | |
| MDSD | 105.1 | ● | | |
| LXSD | 114.8 | | ● | |
| SPTR | 105.1 | ● | | |
| SUV | 114.8 | | ● | |
| TRCK | 137.0 | | | ● |
| VAN | 114.8 | | ● | |

# Resulting Strategy



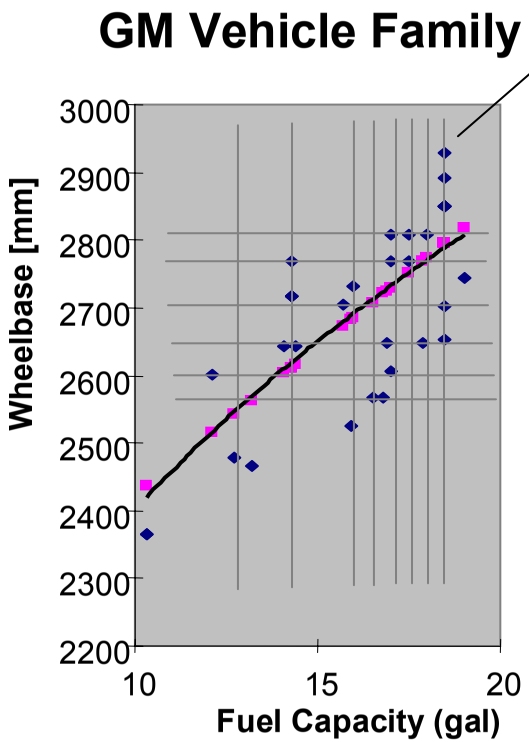
Can see the resulting strategy as more platforms are added.

| | Sedans | | | Sports | | Utility | |
|---|---|---|---|---|---|---|---|
| α | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| β | 2 | 2 | 2 | 2 | 2 | 1 | 2 |
| χ | 3 | 3 | 2 | 3 | 2 | 1 | 2 |
| δ | 4 | 3 | 2 | 4 | 2 | 1 | 2 |
| ε | 4 | 3 | 2 | 4 | 2 | 1 | 5 |
| ϕ | 4 | 3 | 2 | 6 | 2 | 1 | 5 |
| γ | 4 | 3 | 7 | 6 | 2 | 1 | 5 |

→ Beachhead strategy

→ Horizontal Levering

# Future Work




In design space one discovers grid patterns for some design variables … indicates commonality

Can one reverse engineer a competitors platform strategy based on:

- grid patterns in data?
- teardown inspection?

Attempt to apply methodology to GM vehicle family ( > 80 vehicles, >20 platforms)

# Summary

- Platform Architecture important for cost effectively creating product variety with commonality savings
- Different strategies exist, must be carefully chosen
- Include components in platform that are:
  - hidden from the customer
  - insensitive to performance
  - high value
  - technologically stable