Industrial Ecology of the Automobile
ESD 123

Course Introduction, Overview & Mechanics
Spring Term, 2001

Course Administration & Contacts

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**Class Resources**

- **Class Materials**
  - Handouts in class
  - Accessible from the class website
- **Will develop over the course of the term**
- **Overheads will be available after the class on the WWW**
- **WWW site:**

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<td>Automobile Manufacturing: Part Forming And Manufacturing Processes</td>
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<td>Cost Estimation; Cost Modeling; Cost of Vehicle Production; Role of Cost in Product Development</td>
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<td>Recycling of Automobiles &amp; The Other Environmental Consequences of Vehicles; Regulations in EU and US</td>
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**Introduction**

- "Conventional" Car
  - Roughly: 68% Ferrous Metal, 7% Nonferrous Metal, 7% Polymers, 8% Other Materials
  - Weight ~3000 pounds
  - Internal Combustion Engine

![US Average Vehicle Material Content](image.png)
"Super Cars" -- What Are They?

- Performance Associated With Exotic Vehicles
  - Low Weight - Below 2000 pounds
  - Specialized Powerplant
    (Note: power vs. economy is a standard automaker design tradeoff)

- Achievable Today With Specialized Materials and Production
  - Polymer Composite Vehicles
    e.g., Corvette, Ferrari, Lamborghini
  - Nonferrous Vehicles
    e.g., Acura NSX, Audi A8
  - Exotic Engines
    Titanium Componentry - Race Cars & NSX
    Polimotor - Race Cars
    Etc..........

➤ So, If It Can Be Done, What's All The Fuss About Improving Automobile Efficiency?

The Issue Is ... Cost!

- Vehicle Cost Is A Strong Function Of:
  - Material Choice, Which Influences....
  - Processing Options, Which Influence...
  - Manufacturing Methods, Which Are Driven By...
  - Market Strategies

- Underlying All This Is The Product Development Cycle
  - Car Making Is Not A Casual Endeavor
  - Product Development Costs Alone Can Be Hundreds Of Millions Of Dollars
  - Complexity Comparable To Aerospace Development
  - But Production Is Several Orders Of Magnitude Greater
    (i.e., 60,000 - 500,000/year vs. 60 to 250/year)
Advanced Materials & Automobile Development

Why Are Airplanes Made Of Aluminum & Composites, While Cars Are Mostly Steel?

- Design Processes Are Different
- Process Requirements Are Different
- Target Markets Are Different

Automobile Product Development Cycle

- Concept & Studio: Where The Car Starts
- Advance Engineering: Where The Car Takes Shape
- Product Engineering: Where The Details Are Filled In
- Production Engineering: Where The How Of Building The Car Is Worked Out
- Manufacturing: Where It All Comes Together
Vehicle Development Process

Vehicle Concept & Studio

Devise a Car Concept To Fit Within The Company's Overall Product Strategy

- Target Market - Families, First Car Buyers, Students, DINKs, Luxury, Sport Utility
- Vehicle Type - Sedan, Coupe, Van, Wagon, Truck, ...
- Vehicle Performance - Economy, Sport, ...

Fit Within Overall Strategy Important - Selling Too Many Cars Can Be As Bad As Selling Too Few

- Regulatory Issues - CAFE
- Economics
  - Expense Of Scaling Expected Low Production Design To High Volume Demand
CAFE

- Introduced To Compel Automakers To Reduce Gasoline Consumption
- Corporate Average Fuel Economy:
  \[ \text{The Harmonic Average Of The Fuel Economy Of Vehicles Sold, or} \]

\[
\text{Sum of } \frac{\text{Ni}}{\text{Sum Of } \left\{ \frac{\text{Ni}}{\text{Fuel Economy of i-type vehicles}} \right\}}
\]

- Interesting Consequences:
  If Car A Gets 20 mpg and Car B Gets 40 mpg and the CAFE Target is 30 mpg, How Many Cars Of Type B Must Be Sold For Every Car A That Is Sold?

CAFE Over Time

CAFE Statistics
NHTSA Data

Average
New Domestics
All New Cars


Massachusetts Institute of Technology
Cambridge, Massachusetts
Components of Domestic Automobile Sales
From MVMA Data Book

![Bar chart showing market share (%)]

**Advance Engineering**

- Where Concept Gets Turned Into Engineering Drawings
- Normative, Rather Than Analytical, Design Process
- Based Upon Historical Designs
- Conservative Strategy To Limit:
  - Costs
  - Risks
  - Uncertainty

Highly Effective, Particularly In Mass Production Environments

- But, Difficult To Innovate In The Absence Of History Of Past Performance
- Particular Problem For Materials
Production/Manufacturing Technologies

Automobiles Are Mass-Production Products
What Does This Mean?

- Annual Production Volumes On The Order Of 100,000
- Production Rated On The Order Of 60-75 units/hour
- Have To Be Affordable To A Large Market

Contrast With Airplanes

- Annual Production Volumes Less Than 1000
- Production Rates On The Order Of 1/day
- Specialized Markets

These Differences Lead To Different Processing Requirements

Metal Processing Requirements

Stamping

- Suitable To Sheet Metal - Aluminum Or Steel
- High Speed Process - 1 Piece Every 10 Seconds
- Expensive Tooling - $10's Of Millions Per Part
- Expensive Equipment - $100's Of Millions Per Press Line

Steel Stamping

- Steel Makers Produce Stampable Alloys
- Automakers Can Just Form And Use

Aluminum Stamping

- Similar To Steel, But
  - Not As Deep A Draw (Not As Formable)
  - Heat Treatments May Be Required
Composite Materials Processing

Variety Of Processes (SRIM, RTM, TP Sheet, SMC)

**Common Features**
- Low Equipment Costs - On The Order Of $1 Million
- Moderate To Low Tooling Costs - $100,000 To Several Million $'s
- Slow Processing Times - 1 Piece Every Several Minutes

And, Of Course, RP/Cs Are More Expensive

- Steel Sheet Starts At Around $0.30 / lb
- Aluminum Sheet - Start At Around $1.80 / lb
- Composites - Start At $1.00 / lb For Low Performance, And The Sky's The Limit!

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After Part-Making, There's Assembly

Current Assembly Plant Costs Start At About $500,000,000

- **Body Line**
  Fabricates The Body-In-White
  Welding Processes - Spot and Arc
  Adhesive Bonding
  Mechanical Attachment

- **Paint Line**
  Usually Accounts For Roughly 50% Of Plant Cost
  Washing & Drying
  Priming & Curing - E-Coat or ELPO
  Color & Clear Coats
  Final Bake

- **Chassis & Powertrain**
  Engines
  Suspension
  Transmission

- **Final Trim**
  Interiors & Finishing
  Labor-Intensive Part Of The Process
Steel Again Has Advantages In Assembly

Body Line

- Spot Welding Preferred For Speed - Works Best With Steel
- Adhesive Technologies - Required For Composites, and Probably For Aluminum
- Compliance Between Different Materials A Problem

Paint Line

- Heat & Solvents Tough On Polymers
  - Aluminum Oxide Coatings

Trim Line

- Compliance Again A Problem - Can't "Bend To Fit" When Using Composites
- Aluminum Delicacy - Easy To Mar Surface