Recycling Infrastructure Stability: Transfer Pricing Analysis

Frank Field
Materials Systems Laboratory
International Motor Vehicle Program

Recycling Initiatives, Again

- In the Early 1990s, The German Recycling Initiatives Were Established
- A Wide Range Of Motivations Suggested
  - Landfill Use Reduction
  - Market Protection; Transplant Limitation
  - Rationalization of the Secondary Infrastructure
  - Part of a Recycling Sequence - Packaging, Electronics, etc.
- The Original Initiative Slowed By Other Political Events
- But, It Now Has Returned
  - European Commission Initiatives
  - Ultimate Objective - 95% Recycling Of The Automobile (varying timetables)
**Consequences**

- Automakers Are Confronted With A Slippery, But Potentially Onerous, Target
- Definitions Are Going To Make Or Break This Initiative
  - What IS "Recycling," Anyway?
- Current Political Pressures Keep Putting Off Implementation
- Aspects Of The California Electric Vehicle Initiative All Over Again

---

**Automobile Recycling Infrastructure**

- System is propelled solely by profitability of each business
  - NOT by government policy intervention
  - "Pushing a rope at each end"
- How robust is this system to pending changes in
  - Vehicle materials
  - Regulatory / economic constraints

![Diagram of automobile recycling process](image)
Key Economic Drivers

- Shredder Extracts The Bulk Of Recycled Automobile Value
  - Ferrous Scrap
  - Non-Ferrous Blend

- Dismantler Extracts Parts
  - For Resale
  - For Remanufacture
  - For Material Recovery
  - For Regulatory Reasons

- Transaction Prices Are Key To Understanding System Stability To Change
  - Acquisition of Deregistered Vehicle: Cost (?) to Dismantler
  - Transfer of Hulk To Shredder: Income to Dismantler, Cost to Shredder
  - Sale of Recovered Metals: Income to Shredder
  - Disposal of ASR: Cost to Shredder

- Policies focus on the "ends of the rope" - deregistered vehicle cost and ASR

---

How Much Value Is In the System?

- Magnitude Determines Degree Of "Wiggle Room" For Policymakers and Industry
- Regulations Are Not Directed Toward Adding Value
- Issue Is Extent To Which Additional Costs Can Be Managed And Distributed
- Examination Of Economics Depends On Assessment Of Transfer Pricing
Options To Increase Materials Recovery

- Technical Options Exist To Increase Recovery
- Costs and Their Distribution Key To Viability
- Modeling Issues

1. Dismantler + Shredder + Landfill

2. Dismantler + Shredder + Pyrolysis

3. D + S + Mechanical Separation + Selective Precipitation

Key Systems Investigated For Improving Recovery

1. Dismantler + Shredder + Landfill

2. Dismantler + Shredder + Pyrolysis

3. D + S + Mechanical Separation + Selective Precipitation
Dismantler Modeling Goals

- To what extent should a vehicle be disassembled
  - Dismantler attempts to maximize profits
    - Part can be sold for revenue, but...
    - Parts cost to remove

- A part is removed if
  - Value of Part \(>\) Cost of Removing Part.
  - Value, = Maximum of (Part sale price or Material value of part)
  - Cost, = Removal Labor + Sorting Labor \(\cdot\) Value in the Hulk
    - What is the "Value in the Hulk"

- For convenience, define
  - Intrinsic Buoyancy, = B, = Value, - Cost,
  - Remove if \(\Rightarrow\) B, > 0

Which Parts to Remove: Sequence Matters

- Parts do NOT exist in isolation & are NOT randomly accessible
- Each part can only be reached by through certain paths

For example
- To get to D \(\Rightarrow\)
  - A & B must be removed
Individual Model Results
Revealed Economic Drivers

- Each model reveals profit determining assumptions

<table>
<thead>
<tr>
<th>Dismantler</th>
<th>Shredder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>Composition</td>
</tr>
<tr>
<td>Hulk Price</td>
<td>Hulk Price</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pyrolysis</th>
<th>Mechanical Sep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill Price</td>
<td>Landfill Price</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>Capital Cost</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selective Ppt.</th>
<th>PUF / ABS Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill Price</td>
<td>PUF / ABS Price</td>
</tr>
</tbody>
</table>

Massachusetts Institute of Technology
Cambridge, Massachusetts

Testing System Performance:
Vehicle Composition

- Mixtures of three different vehicles designs were used

- Steel: 2.3% Ferrous, 6.4% Aluminum, 12.6% Polymer, 24.5% Other NonFerrous, 72.1% Other
- Aluminum Intensive: 2.6% Ferrous, 7.3% Aluminum, 14.3% Polymer, 51.4% Other NonFerrous, 49.9% Other
- Composite Intensive: 14.2% Ferrous, 2.5% Aluminum, 26.2% Polymer, 7.2% Other NonFerrous, 49.9% Other

Massachusetts Institute of Technology
Cambridge, Massachusetts
System Model Results
Current Dismantler + Shredder System

- Current system profitable for most cases

<table>
<thead>
<tr>
<th></th>
<th>100% Steel</th>
<th>100% AIV</th>
<th>100% CIV</th>
<th>50% Stl 50% AIV</th>
<th>50% Stl 50% CIV</th>
<th>Three-way Split</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dismantler Profit ($/Vehicle)</td>
<td>$13</td>
<td>$16</td>
<td>$11</td>
<td>$14</td>
<td>$12</td>
<td>$13</td>
</tr>
<tr>
<td>Shredder Profit ($/tonProcessed)</td>
<td>$14</td>
<td>$108</td>
<td>(4)</td>
<td>$57</td>
<td>$5</td>
<td>$37</td>
</tr>
<tr>
<td>Amount Landfilled (tons)</td>
<td>30,000</td>
<td>31,000</td>
<td>57,000</td>
<td>30,500</td>
<td>48,000</td>
<td>39,000</td>
</tr>
</tbody>
</table>

- CIV loss could be covered by reduced hulk price
- How does hulk price/composition effect these two?

Extensive Disassembly
Hulk Price and Composition Effects

- Introducing more material value prompts disassembly
  - Shredders can respond through changing hulk prices

<table>
<thead>
<tr>
<th></th>
<th>AIV</th>
<th>AIV + Al Engine</th>
<th>AIV + Al Engine + Al Chassis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hulk Price (cents / kg)</td>
<td>5</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Dismantler Profit ($/Vehicle)</td>
<td>$16</td>
<td>$105</td>
<td>$100</td>
</tr>
<tr>
<td>Shredder Profit ($/tonProcessed)</td>
<td>$108</td>
<td>$20</td>
<td>$15</td>
</tr>
<tr>
<td>Annual Huks to fill Shredder Capacity</td>
<td>125,000</td>
<td>250,000</td>
<td>500,000</td>
</tr>
</tbody>
</table>
Adding ASR Processing

Pyrolysis - Current Situation

- Pyrolysis plants must operate near capacity
  - This does not match up one-to-one with all shredder outputs

<table>
<thead>
<tr>
<th></th>
<th>100% Steel</th>
<th>100% AIV</th>
<th>100% CIV</th>
<th>50% Stl. 50% AIV</th>
<th>50% Stl. 50% CIV</th>
<th>Three-way Split</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dismantler Profit ($)/Vehicle</td>
<td>$13</td>
<td>$16</td>
<td>$11</td>
<td>$14</td>
<td>$12</td>
<td>$13</td>
</tr>
<tr>
<td>Shredder Profit ($)/ton</td>
<td>$14</td>
<td>$108</td>
<td>(4)</td>
<td>$57</td>
<td>$5</td>
<td>$37</td>
</tr>
<tr>
<td>Pyrolysis Profit ($) / ton ASR at Full Utilization</td>
<td>(10)</td>
<td>(10)</td>
<td>(9)</td>
<td>(9)</td>
<td>(10)</td>
<td>(9)</td>
</tr>
<tr>
<td>ASR Landfilled (tons)</td>
<td>7,200</td>
<td>8,200</td>
<td>24,300</td>
<td>10,700</td>
<td>7,500</td>
<td>10,800</td>
</tr>
<tr>
<td>ASR Processed (tons) would have been Landfilled</td>
<td>30,000</td>
<td>30,000</td>
<td>45,000</td>
<td>45,000</td>
<td>30,000</td>
<td>45,000</td>
</tr>
</tbody>
</table>

Adding ASR Processing

Outlook for Pyrolysis

- Pyrolysis becomes profitable if landfill prices = $50 / ton
- For shredders this translates to
  - For metal cars - a $4 cost
  - For CIV - an $8 cost
- System can bear these except for the 100%CIV scenario
  - For 100%CIV, no surplus to offer final vehicle owner
  - Other schemes might prompt proper disposal

Pyrolysis promising for near term.
Conclusions

- The automobile recycling infrastructure
  - Resilient for compositions studied
  - Could accommodate pyrolysis
    - Reduces landfill burden up to 75%
  - High Al content would force restructuring

- Stability for Higher Recycling Rates Dependent Upon Recycling Definition
  - Not A Lot Of Profit To Redistribute, Unless Vehicles Become Intrinsically More Valuable
  - With Increased Value, Dismantler/Shredder Tension Will Influence What Recycling Means - Reuse or Recovery