ECONOMICS OF AUTOMOBILE RECYCLING

The recycling of automobiles in North America represents one of the most successful -- if not the most successful -- examples of material recovery. This activity is sustained by a large industry constituted by several parties: consumers, dismantlers, remanufacturers, transportation companies, material recycling companies, metal recovery enterprises, landfills, and to certain extent, the automobile manufacturers.

It is estimated that approximately 94% of the vehicles being retired are processed by the recycling industry. From these, approximately 75% of the total mass is recovered. The other 25% is normally sent to the landfills. These recovery rates are even more impressive considering that approximately 10 million cars are disposed yearly in North America. This is an industry that processes almost ten million tons of material per year.

The fundament of this industry is that it works purely on the basis of economics. It is argued that the success of the industry is based on the structure of the system; parties taking profit self-optimizing decisions, are capable to efficiently deal with the recycling of cars.

However, the historic trends of reducing the vehicle weight and increasing the non-metal composition of cars pose serious doubts on the industry viability in the future. A significant portion of the economic benefits associated to automobile recycling comes from the recovery of metal materials. In addition, most of the non-metals represent a double cost to the industry; they have to be processed -- increasing the transportation and operation costs -- and, at the end, are sent to landfills at an additional cost.

Automobile manufacturers are concerned about these risks because they perceive -- in countries like Germany, governments are also understanding -- that they have a major impact in the recyclability of automobiles. The automobile manufacturers determine weight and composition, as well as the level of Design for Disassembly in vehicles. These factors have a major role in defining the dismantling and recycling that will take place on automobiles.

Recycling of automobiles involves two principal stages: disassembly and shredding. This work addresses both stages and explains a systematic approach to model them. The first part is focused on the detail complexity of the disassembly problem. The second deals with the industry as a whole including the shredding operation and the price dynamics governing the systems' behavior.

In the first part, the Disassembly Model Analyzer (DMA) tool is described. This is an optimization program based on a genetic algorithm. This tool is capable of interpreting the complex economic and physical information associated to the disassembly problem of a relatively large product (more than 500 parts). The DMA interprets this information and then returns, among other information, the profit-optimizing disassembly plan. The DMA was used to determine the potential impact on several dismantling drivers -- design, prices and costs -- on dismantling practices. The potential impacts were structured in the form of empirical equations using a design of experiments procedure.

The second part of this work includes the description and use of the Automobile Recycling Dynamic Model (ARDM). This industry model captures part of the most relevant interactions among parties in the industry and evaluates the effect of policy changes (such as weight, and vehicle composition), in the environmental impact of disposing and recycling automobiles. The

ARDM uses the empirical equations generated by the DMA to model the dismantlers' behavior. In this sense, the ARDM includes optimization decisions (profit-maximizing) within a dynamic context. The ARDM has to be dynamic because prices depend on the different industry participants' decisions, which in turn, depend on the prices.

In the ARDM, the environmental impact of disposing automobiles is traced by determining the Automobile Shredder Residue (ASR) generation and the number of cars being left out of the recycling loop (abandoned cars).

The DMA and the ARDM are used to answer two fundamental questions: "Is there a major threat in the future for the industry recycling automobiles in North America?"; and "Is there something the automobile manufacturers can do to improve the situation?"

The answer to both questions is "Yes." Significant changes in vehicle weight and composition trends, or major changes in the industry structure have to be made if the industry recycling automobiles in North America is to exist in the future. However, automobile manufacturers have a good opportunity to deploy, in conjunction with other interested parties, a well-orchestrated strategy to sustain, at least, the current level of automobile recycling.

Sound strategies in this sense are not necessarily intuitive. Increases in the level of Design for Disassembly (DFD), for example, will not completely result in more recycling. This work shows how a structure based on parties seeking self-maximizing monetary goals will fail to convert DFD increases into additional recycling. The pollution externality argument is supported. It is also explained that certain types of coordinated intervention might be the optimum way to proceed.

Finally, this work explains how the DMA and the ARDM can be used inside the automobile manufacturers' organizations to evaluate and give relative priority to alternative projects in technological development and automobile design.

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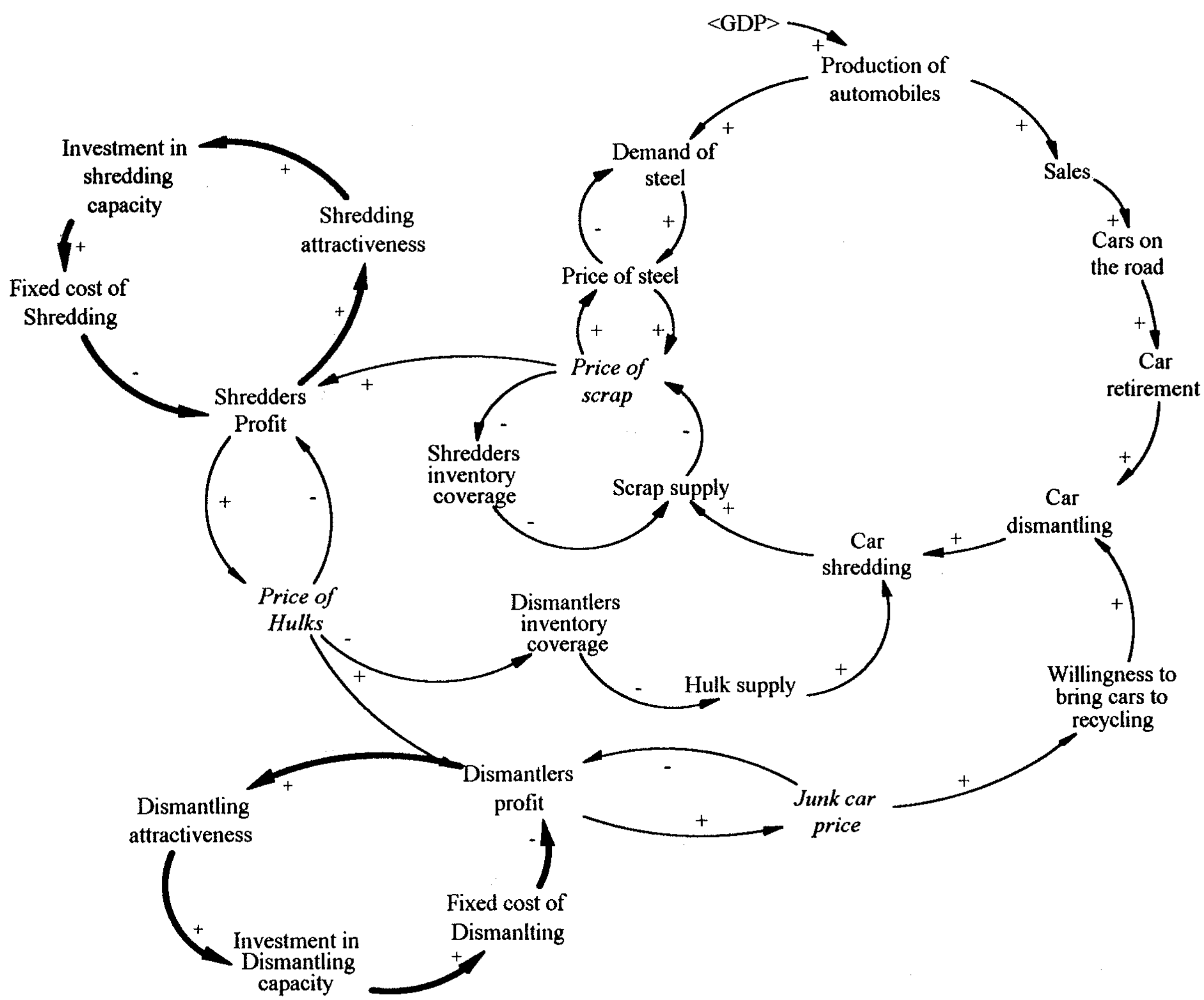
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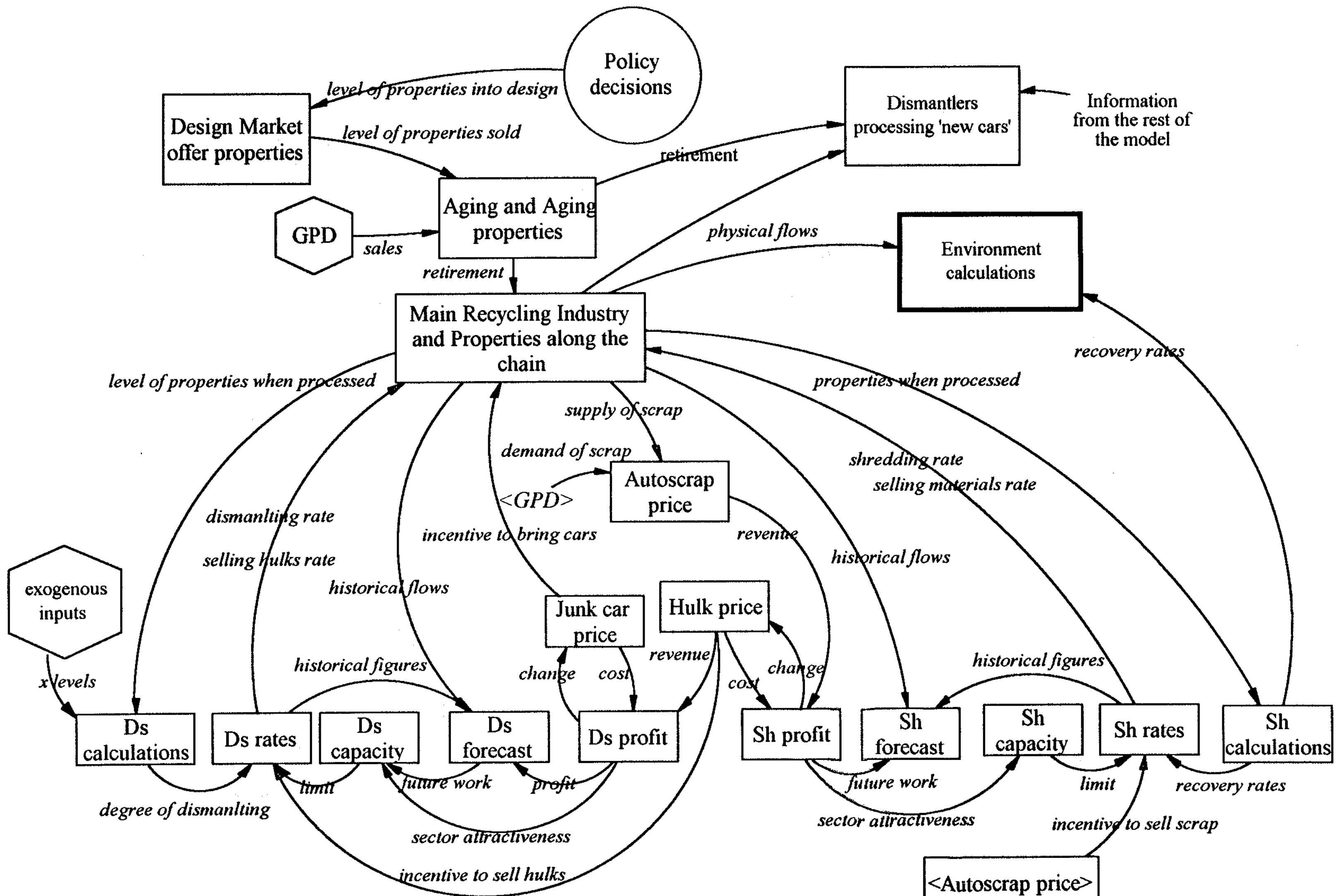
Production of automobiles
Sales
Cars on the road
Car retirement
Car dismantling
Car shredding
Willingness to bring cars to recycling
Demand of steel
Price of steel
Price of scrap
Scrap supply
Shredders inventory coverage
Hulk supply
Dismantlers inventory coverage
Junk car price
Dismantlers profit
Fixed cost of Dismanlting
Investment in Dismantling capacity
Dismantling attractiveness
Price of Hulks
Shredders Profit
Shredding attractiveness
Investment in shredding capacity
Fixed cost of Shredding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