An ABM approach for the development of an Alternative-Fuel Infrastructure

David A. Ostrowski
Ford Research and Advanced Engineering, Ford Motor Company P.O. Box 2053 SRL, Dearborn Michigan 48103, Email: dostrows@ford.com

Biography
Research Engineer, Ford Research and Advanced Engineering, Ford Motor Company; Adjunct Professor, Department of Computer and Information Science, University of Michigan-Dearborn.

Abstract-
This paper presents the application of Agent-Based Modeling to the evolution of alternative fuel infrastructures. A model is presented in which agents representing consumers and fuel station proprietors interact on a grid representing an urban landscape. Consumers make considerations with regards to the purchase or retention of alternative fuel vehicles. Fuel station proprietors make decisions on the investment of alternative fuel infrastructures. Decisions are influenced by the maintenance of the agents' utility above a threshold parameter as well as the choice between driving routes and traffic congestion. The model demonstrates the transition parameters in the acceptance of an alternative fuel infrastructure. This work is part of an on-going effort towards the support of business decisions related to alternative fuel infrastructures as well as the institutionalization of Agent-Based Modeling techniques at Ford Motor[1][2].

Introduction

Alternative fuels are defined as feasible substitutes for gasoline powered vehicles including hydrogen, electric and bio-diesel. The economies supporting their application are motivated by the concerns with global emissions, conventional fuel supplies and fuel prices. Through the application of Agent-Based Modeling techniques, there is interest into characterizing parameters that are relevant to the adoption of an alternative fuel supply. In the model to be presented, agents interact in a realistic manner on a rectangular grid representing an urban region. It is observed how an alternative fuel infrastructure might evolve as a function of agent distribution and driving habits. This characterization has a specific drawback due to it being a classic "chicken and egg" problem. [2] This is due to the reasoning that consumers hesitate to buy an alternative fuel vehicle if they anticipate difficulty in finding fuel. Likewise, fuel suppliers hesitate to invest in alternative fuel facilities if there are very few related vehicles on the road. The initial transition scenario begins with an initial "seeding stock" of appropriate vehicles and hydrogen fueling stations required to start the system. In modeling this infrastructure, it will grow in a reciprocal pattern where more vehicles will induce more fuel stations, which in turn induce more vehicles.

Early adopters of alternative fuel vehicles are considered as agents in the model. These agents weigh factors such as the distance of station, destination, traffic flow and current levels of fuel in each path decision. Information in this model is both limited and global.[4] The agents maintain a history of paths taken as well as knowledge of current fuel station locations on the grid. They employ learning through their decision process utilizing this dynamic memory. The agents make a conscience decision as to what path to take to work each day. This specific model places emphasis on the evolution of a given infrastructure with strong consideration given to the geographical areas in the model along with the interest of modeling congestion and its influence on the evolution of such an infrastructure.

Model Description

The model is represented as a rectangular grid in which drivers travel to specified locations. In each time step, the driver makes a commute. At every four month interval drivers decide between driving either a gasoline or alternative fuel powered vehicle. Agents maintain a utility function that is viewed as a residual fuel level over the average traveled distance. Agents strive to maintain their utility function over a given threshold. If the threshold is not maintained it will influence the decision of purchase or maintenance of a alternatively fueled vehicle. Agents choose between alternative paths on the grid to the specified location. Paths are designated by proximity between chosen destinations as well as the location of fueling facilities. A secondary utility is placed on the traffic congestion representing the percentage of driver agents taking the same paths. Given an acceptable recent window of acceptable residual levels, agents choose to avoid high traffic scenarios. Both utility thresholds are assigned around a random distribution between the drivers agent population.

Stations consider the investment into an alternative fuel station. This is determined through a utility function that considers the traffic threshold. It maintains that if a specific traffic level is above a given threshold, then support alternative fuels. After making an investment, they choose to maintain the infrastructure based on an acceptable utility level. If the station proprietor decides to discontinue its support, then they do not reconsider it for the remainder of the simulation.

Preliminary Results

Figure one presents output data from the agent-based model. The graph shows the ratio of alternative powered fuel vehicles along with the station proprietors supporting alternative fuels. This ratio is shown over increments in time for a period of 20 years. 1000 driver agents are applied in this preliminary investigation with 20 fuel station agents. Two of the stations are initialized with an alternative fuel infrastructure and 20 driver agents are initialized owning or leasing alternatively powered vehicles. This graph demonstrates the reciprocal growth of interest in alternative fuels between drivers and station proprietors. This is viewed as a function of the utility of the drivers being over a satisfactory level.

This paper will apply specific station grid representations with the goal of examining some of the most likely scenarios for alternative fuel adoption. Other factors to be considered will be various threshold levels among driver and station agents as well as their distribution.

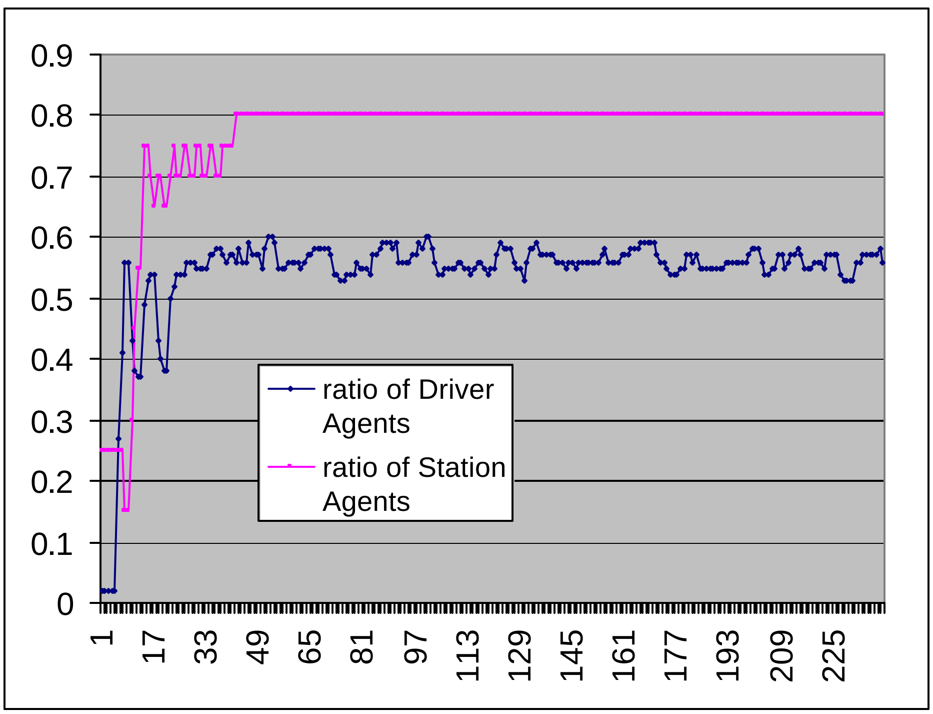

Figure 1.0 Output from a scenario demonstrating a successful transition.

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