A Serious Game for the Illumination of Alternative Fuel and Vehicle Transitions

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Abstract

The transition to alternative fuels and vehicles presents many challenges that require long-range strategic thought and planning. Fuel producers must make expensive infrastructure decisions about which fuels to support years before they are sold. Vehicle producers must commit to new drivetrains on a similar long-range schedule. Whichever technologies prevail, hydrogen fuel cell, PHEV, BEV or biofuels, fuel and vehicle manufacturers must be reasonably certain that the technologies will be market mature and that consumers will be ready to support them. The cost of a misstep is large.

In order to illuminate the intricacies of an alternative fuel transition and develop optimal implementation strategies we are developing a serious game. In the game, players will represent vehicle producers, fuel producers and consumers. The players will make decisions over a 40-year time horizon with the objective of maximizing a personal utility score while meeting GHG reduction mandates. Game administrators will act as the government and impose predetermined exogenous scenarios (e.g. rising oil prices). A computer model based on current literature and expert opinion will manage the market representation.

Introduction

There are many reasons to transition the U.S. private vehicle fleet to alternative fuels and drivetrains. Petroleum based fuels are a major contributor to climate change, are becoming increasingly scarce, and the major remaining sources are located in foreign countries. Hydrogen, electricity and biofuels are potentially viable alternatives. Most likely, all of them will be put to use in the future.

The critical question is *how do we get from our current state to an alternatively fueled future?* An alternative fuel transition faces a challenging three-sided chicken and egg problem. In order for vehicle producers to commit to a new drivetrain they must believe the fuel producers will be ready to support it. Fuel and vehicle producers will need to make massive infrastructure investments many years prior to the vehicles entering the market. Consumers will then need to accept the new technologies, which may have considerable drawbacks, such as range limitations, compared to the old ones. A failure of any side of the triangle will cause the new platform to fail, at substantial cost to those who invested in it.

The size and complexity of an alternative fuel transition make it a suitable case for the use of serious gaming methods. Serious gaming allows for the examination of systems too large and complex for more conventional modeling methods (Mayer 2002). The methodology's historical basis is in war gaming, an important and longstanding part of training and preparation for the military (Abt 1971).

War gaming allows military decision makers to practice decision-making under crisis-like conditions in which decisions must be made quickly with limited information. The practice of war games has yielded not only training but effective strategies and tactics for everything from small arms combat to global nuclear war planning (Caffrey 2000).

An alternative fuel transition entails a similar set of challenges to policymakers; important decisions must be made with limited time and incomplete information. By running through simulations of this transition new strategies can be experimented with and given a rudimentary testing. The predictive power of this game is limited by the many assumptions that have gone into its creation. For that reason we have little expectation of accurate quantitative data being generated from it. This is normal for a large-scale serious game (Mayer 2002). Despite this, we do believe that pairing domain knowledgeable players with an interactive model can generate valuable qualitative information. Watching the numbers play out over a series of turns under a well-defined scenario can illustrate the potential strengths and weaknesses of many strategies: it is a valuable perspective on an intractable problem.

The game we are designing has three player roles: consumer, fuel producer and vehicle producer. The players recruited for the game will, ideally, be subject matter experts. A team of two to three people can play a role. There will be at least four teams for each player role, so a minimum of twelve player teams will participate. A team of administrators will run the game.

The administrators will run the mechanical aspects of the game and serve as referees. The administrators will interact with the players in a non-player role as the government. Each will have designated government responsibilities such as utility regulation. They will also introduce exogenous elements to further the pre-planned scenario.

Players will be located in the same room. They will make decisions about what cars to build, which fuels to produce, and which to buy using in-person negotiation. The players will enter decisions into a web-based interface using a hybrid turn-based structure. All players will act simultaneously in turns (or rounds) lasting ten to fifteen minutes.

Certain aspects of the game, such as vehicle purchases, will occur in real time on a first come first served basis during the turn. Vehicles are one of the few products that consumers expect to negotiate over. We wanted to capture some of that in the game. Fuel, alternatively, is purchased for the consumer automatically at the end of the turn. Fuel is a commodity product. Making consumers manually buy their own fuel adds tedium without benefit. At the turn's end the computer model will process the player decisions and report the results, after which a new turn will begin. A game will consist of ten to twenty turns, with each turn representing two or four years. A post analysis session will follow the game.

The results of serious games can be surprising; games often uncover unexpected results. The result of obvious interest is the dominant fuel(s) at the end of the game? Did the players achieve a significant GHG reduction? What were the policies that promoted change? Which ones prevented change? The game will serve as a policy laboratory for examining how sustained chains of decisions play out over time.

Game Description

Objectives

There are two objectives players must attempt to meet during the game. The first is a cooperative objective, the second a competitive one. The cooperative objective is to meet a mandated reduction in oil use and GHG emissions. GHG reduction goals are expected to be common in future legislation. The second objective is competitive: players must attempt to maximize a personal utility score. The utility score serves as a guide to rate the players actions and assist him in staying in character.

Player Roles

Administrators run and referee the game. Prior to the game administrators decide on the game scenario. Based on the scenario decision they configure the player roles and preset their attributes. During the game the administrators start and end turns, referee player disputes and introduce scenario elements. The administrators act as the government. Working with the other players they can implement various incentive policies to help the players achieve their cooperative goals.

Consumers represent a large class of vehicle purchasers who share common characteristics. The classes vary in size, income level, vehicle feature preferences and vehicle miles traveled per year (VMT). Each consumer has a preference profile. Possible consumer classes include *budget-style, greens, high VMT* and *premium.*

Consumers will receive a budget each turn for vehicle expenses. Subtracted from that budget will be the fuel bill for the last turn. Consumers will be able to express some preferences about their fuel purchases but the refueling itself will be automated based on the consumers' fleet makeup and VMT preferences. The consumer will also receive information on the number and types of replacement vehicles to buy.

The consumer will spend a portion of his turn shopping for and purchasing vehicles. He is free to use spreadsheet software, as are all other players. In addition to selecting new vehicles the consumer will also interact with fuel and vehicle producers to help inform their product building decisions.

Consumers will also be able to make limited changes to their VMT demands during each turn. This simulates the consumer deciding to reduce driving and/or make alternative mode choices. The consumer can choose to accept a utility penalty (or bonus) for reducing (or increasing) his VMT demand. The cost of behavioral changes will depend on the current VMT level of the consumer. Reducing VMT will lower the consumer's fuel costs on the next turn. It will also become a *learned change* for the consumer; the new VMT demand will become the consumer's new base demand on subsequent turns.

Vehicle producers represent large (quantity) vehicle manufacturers. To minimize complexity vehicle producers are limited to producing up to six vehicles all of which four to six seat passenger cars. Vehicle producers select vehicle size, performance, style and drivetrain (e.g. hybrid, battery electric, hydrogen fuel cell). Vehicle producers improve their technology by investing in drivetrain research. The drivetrain models were developed using PSAT, a research and industry standard vehicle modeling software.

Vehicle producers interact with fuel producers to make sure the right types and quantities of fuels will be available to support the vehicles they produce. They also work with consumers to develop and refine their product lines. The vehicle producer also negotiates with the government (administrators) on incentives and mandates introduced in the scenario. The vehicle producer's score will primarily be based on profitability.

Fuel producers represent large refining and distribution companies. Fuel producers buy resources such as petroleum, natural gas and biofuel feedstocks. They decide which fuels to produce, how much and by what process to produce them. They decide to build,

maintain and shut down refineries. They also make decisions on their fuel distribution networks. As the vehicle fleets transition to higher levels of electric drive fuel producers can invest in electricity production.

Fuel producers will invest in fuel production technology research in order to reduce production costs and meet government regulations. The challenge for fuel producers is the lead-time required to put a new refineries and distribution systems on line. They must make sure that consumers and vehicle producers will support their decision years in the future or they can be stuck with worthless investments.

Game Methodology

In preparation for designing and building this game I looked to the literature available on serious gaming. Most of the academic literature on serious gaming comes from researchers in Europe. The most useful reference text I have found is Games in a World of Infrastructure (Mayer 2002). This text documents provides useful theory and case studies of a number of serious games with infrastructure themes. Also of use has been the International Simulation and Gaming Association's (ISAGA) conference proceedings (e.g. Crookall 1986). A quality serious game is a labor-intensive undertaking. It is important to understand how serious games are currently used and what can and cannot be accomplished with the technique.

One of the biggest challenges in designing a serious game based on a large-scale infrastructure problem is model scoping. Models must be selected with care. An incorrect or overly complex model can obscure more information then it ends up providing. At this point in development there are five discrete sub-models in our game: vehicle building, experience curves, consumer fuel purchases, consumer fleet demand/attrition and fuel refining. Our strategy is to focus on accuracy and realism for these critical models and to build or include any other required models so as not to cloud the output of the critical models.

Many sub-models were considered and dropped from the design. Fuel producers were initially going to have to make decisions about oil exploration and extraction. However this subject was found to be too complex to give it proper coverage within the context of our game. The price of oil, and other fuel feed stocks, will instead be an exogenous factor. Fuel producers will compete based on their decisions regarding refining and distribution operations alone.

There is a limited amount of quality data that enters a long-range predictive system. In our game the *ordinal data* is important. We don't know what vehicles thirty years in the future will look like but we do know that certain ordinal attributes of the technologies will likely remain constant. For example, electric drive vehicles are more efficient than vehicles powered by internal combustion engines and should remain that way. The most important models should be carefully developed using available literature and expert input. Secondary models, of which there are many, should be designed with the primary goal of not distorting the output of the central models. A guiding rule for the development of secondary models is that they be *order preserving* in nature.

The Institute of Transportation Studies at UC Davis (ITS-Davis), sponsor of this project, has unique qualifications for testing and calibrating the realism of the game's models and model interactions. ITS-Davis researchers cover every aspect of vehicle and fuel markets. These aspects include consumer behavior, transportation and resource economics, vehicle technologies, fuel technologies, energy, air pollution and GHG policy. ITS-Davis is also able to recruit qualified players in industry and government once the game is completed.

The game is being implemented using Ruby on Rails (RoR), an open source web application framework. Ruby, the base language of RoR, is a popular object oriented (OO) scripting language in which it is easy to embed C for performance sensitive functions. RoR imposes a model-view-controller (MVC) structure onto projects. The combination of the OO scripting language and the MVC code structuring requirements should make maintaining and modifying the game system software as simple as feasibly possible.

Player teams will each have their own network-connected computer. They will enter their game decisions into a browser-based interface. MySQL is being used for a database. The R statistics software package is used to preprocess models where possible in order to minimize game time processing demands. Players are free to use any other software they think might assist them. Many will probably want to use a spreadsheet.

Game Goals

This is the first serious game project for ITS-Davis. As far as we know, this is also the first use of the method for studying alternative fuel transition issues. A central goal of this project is to evaluate the suitability of the method for our research field, transportation and vehicle technology. Some key questions are:

- Is the information returned worth the substantial amount of resources invested in the game?
- Can the serious game process be integrated productively into our research program?
- How can we improve the process for our purposes?

The game is intended to be a policy experimentation laboratory. Serious games should not be looked to for specific, quantitative predictions. Their results tend to be more qualitative, directions of trends rather than precise numbers. The value of a serious game is that it enables a unique type of discourse amongst a knowledgeable group of players. Provided that the game mechanics present a plausible reality players can explore the effects of a sequence of actual decisions over time. It is a different

style of interaction than reports and meetings and thus yields a different experience and outcome.

Of particular interest to us are possible solutions to the chicken and egg problems of an alternative fuel transition. Resolving this issue will likely be most efficient with some sort of government intervention since the risks are probably too large for private industry to undertake on their own. However market interventions must be handled carefully. Policy decisions on infrastructure have long lifetimes and many unforeseen implications. The game will hopefully illuminate some of the risks associated with various policies.

Feebates are one policy option that will likely be explored in the game. Feebates are a transfer tax. A fee is placed on a item that is to be discouraged (e.g. SUVs) in order to provide a rebate on an encouraged substitute (e.g. economy cars). Feebates seem like a great idea *prima facie*, however they must be implemented with care because they can have serious counteracting effects (Peters, Mueller et al. 2008).

Conclusion

We are developing a serious game to examine the subject of an alternative fuel transition. Game players will represent consumers, vehicle producers and fuel producers. Game administrators will run the game, play the role of government and introduce exogenous elements into the game in accordance with a pre-planned scenario. The game outcomes are based on player interactions in combination with computer model results.

The game is intended to be a policy experimentation laboratory. Players will be given the opportunity to test out policy options in a risk free environment. This will hopefully lead to improved policy outcomes.

The game is the dissertation project of Joel Bremson. His advisors are Joan Ogden, Alan Meiers, Cynthia Lin and others. The game is currently on schedule to begin play testing in Winter 2009.

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