

A Review of Gaming Simulation in Transportation

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Abstract. Gaming simulation has proven to be an invaluable method for experimentation and learning and exploring scenarios in various fields of policy making. In this paper, we present a case for the use of gaming simulation in transportation analysis. We also present a review of games and gaming simulation in transportation analysis. We observe that *gaming simulation is not widely used in transportation, despite its wide use in associated fields.*

1 Introduction

Simulation games can be defined as experiential, rule based interactive environments where players learn by taking actions and by experiencing the effects through feedback mechanisms built into the game [1]. With their roots in war gaming, simulation games have a long history of being used for policy analysis. They have also been extensively used as business simulation games. They have been used in studies on human cognition and behavior, and as training and pedagogical tools.

In the transportation domain, understanding travel behavior and activity is a crucial prerequisite for transportation analysis and planning, urban planning and infrastructure investment decisions. Understanding travel behavior means understanding the movement of people and goods based on preferences, activity and demand.

In the last decades many techniques to aid decision-making have been developed. Within these, there are two major styles. One has its foundations in applied mathematics, operations research and systems analysis, and focuses on formal methods and algorithms to aid the decision maker. The other set has its foundations in cognitive and social psychology and focuses on intuition, creativity and communication to aid the decision maker. While both sets of techniques have their own problems, gaming simulation is considered a hybrid of these two, borrowing the best from both worlds [2].

Transportation systems are complex in nature. They are characterized by emergent properties from the interplay of a large number of actors. These actors could be users, planners and managers of a number of transport modes within geography, linked to global transport flows of people and goods. This means that planners have to take into account all the uncertainties that result from these complex, dynamic and socio technical systems.

Gaming simulation is therefore particularly suited to transportation analysis, providing the ability to ask a range of questions on individual decision making, interaction of individuals, and the behavior of organizations across institutional levels.

To further strengthen the case for gaming simulation in transportation, there is a rich history of the use of these methods in disciplines closely aligned with transportation, such as logistics and supply chain management.

In the following sections, we describe the use of gaming simulation in logistics research and the linkages between logistics and transportation. We then present a review of simulation games in transportation, and some future directions for research.

2 Gaming Simulation in Logistics

Broadly, there are three categories of simulation games. From a historical perspective, war games are among the oldest categories of games. Following World War 2, games were used widely in training exercises in business. Later, games were used in a number of areas, such as education, urban planning and so on [1,3].

Simulation games in logistics fall under the category of business games. Their history begin in the year 1955, when RAND corporation developed a business simulation game on the U.S. Air Force logistics system. The simulation, called MONOPOLOGS, required players to take the role of inventory managers of the Air Force supply system [4,5]. A popular educational game is the MIT Beer Game, which illustrates the bullwhip effect in supply chains [6] Business games have since been employed extensively and effectively as teaching tools in both management sciences and operations research [5].

Simulation games have also been used in the transportation and logistics fields, for future asset management and road maintenance tendering [7], to explore the nature of trust and bargaining power in supply chains and networks [8,9] and so on. The design methods for these games have also been generalized [10].

The development of a city economy depends on an efficient logistics service. Urban freight transport policies have significant impact on the efficiency, safety and environmental aspects of a city. Further, given that most freight nodes, distribution centers and intermodal transfer points are located in urban areas, the impact of logistics on a city's environment, congestion and livability is immense. A majority of freight is transported by road, placing further emphasis on the integration of city logistics and transportation planning [11].

3 Gaming Simulation in Transportation

In this section, we present a review of simulation games in transportation analysis. A broad search was conducted using the keywords *transportation*, *traffic*, *mobility*, *logistics*, *urban planning* in the journals *Simulation and Gaming*, *Games and Culture*, *Journal of Artificial Societies and Social Simulation*. Similarly, the gaming keywords *gaming*, *simulation gaming*, *virtual reality*, *experimental simulation* were used to search in the journals *Transportation Research*, parts A through F and Google. Combinations of the gaming and transportation keywords were used to search through the Scopus database. A broad web search was also conducted using Google. Results of

the search on the keywords *game/games* were too broad to be of any relevance, due to their different meanings, for instance in game theory and political games.

The results of the searches are described below. There are quite a few entertainment games that focus directly or indirectly on transportation. There were very few games described in the literature to draw any patterns or comparisons. Game theoretic and other simulation models are being used extensively, providing scope for future development of simulation games based on these models.

3.1 Commercial and Open Source Games

Below is a brief comparison of popular commercial and free games on transportation. Most of them deal with the construction and evolution of transportation networks, based on simple economic models. These networks then have to be managed by the players.

Table 1. Popular Entertainment Games on Transportation

| Game | Goal | Transport Modes | Realism |
|---------------------------------|--|---|---|
| Transport Tycoon | Make as much profit as possible, transporting passengers and freight by road, rail, sea and air. | Rail, Monorail, Road, Sea, Air | Some features, such as signaling and the evolution of new modes of transport are realistic. The economic models are not. |
| OpenTTD [12] | Make as much profit as possible, transporting passengers and freight by road, rail, sea and air. | Trucks, Buses, Trains, Monorail, Airplanes, Ships | Some features, such as signaling, evolution of new modes of transport, and the construction of networks are realistic. The economic models are not. |
| Simutrans [13] | Run a successful transportation company transporting people, mail and goods | Rail, Road, Tram, Monorail, Ship, Air | Not realistic. However, the extensible design of the software means that it can be made to be. |
| Railroad Tycoon | Build and manage a railroad company | Rail | Not realistic |
| Airport Tycoon | Build and manage an airport | Air | Not realistic |
| SimCity [14] | Build an entire city from scratch | Road, Rail, Monorail, Elevated Rail, Ferry | Some features such as policy options and environment effects of building will be realistic, in the new version of the game scheduled for release in 2013. |
| Microsoft Flight Simulator [15] | Mission Oriented Goals | Air | Realistic |

Games in the transportation domain fall mainly into two distinct categories. Most games are business simulations, with goal being building and managing transportation networks and companies of different modes. The first game in this genre was *Transport Tycoon*, and it has spawned different game series' over the years, both open

source and proprietary. Airport Tycoon and Railroad Tycoon are both game series' similar to Transport Tycoon. Simutrans and OpenTTD are open source extensions of Transport Tycoon. The gameplay of these games are similar, with the player asked to build large transportation networks of different modes to transport passengers and freight. While some aspects of these games may be realistic, most of them are not. In particular, the economic and ecological models are not realistic, but the transportation aspects, such as network characteristics, scheduling and signaling tend to be realistic. However, none of these models are validated. Other games not mentioned in the comparison are Locomotion, Transport Giant, Cities in Motion [16] (unreleased) and so on.

The second category is one of simulations, primarily flight simulations. These games involve the player flying a plane. The game play is very realistic, as is the terrain which is based on actual geographies. The planes in the game are existing and previous models of aircraft. These games also involve some aspect of traffic management, simulating the functions of air traffic controllers.

The third category is one of urban planning, or city building games in virtual environments. SecondLife [17], IBM's CityOne [18] and SimCity are all city building games. These games do not directly study transportation, but it is an essential components in all of them. Compared to the other games, SimCity has been used more often for research purposes, as a pedagogical tool for urban planning [19,20] and in envisioning sustainable cities and so on. [21]

3.2 Simulation Games

Despite the benefits of simulation games for transportation, they have not been used widely in trying to understand transportation issues and solutions. Very few examples of the use of simulation games in transportation exist.

These games have been used for a range of purposes, with very little overlap among them. Backlund et al [22] studied the effectiveness of a simulation game in enhancing learning in driver education. Games have been used to collect data and conduct research on travel behavior and adaptability when fuel prices increase rapidly, and to investigate adaptive capacity in the same situation [23, 24]. Games have also been used to assess the environmental and health impacts of different modes of transportation [25]. They also been used to create appropriate traffic behaviors in various situations. Renaud et al used simulation games to train children in appropriate traffic safety behaviors [26]. Meijer et al used simulation games to explore alternative modes of organization for rail cargo management [27]. In a similar vein to the entertainment games described above, Lardinois used a simulation game to aid decision makers in the planning, management and operations of an inter city transportation system [28]. There have also been attempts at building a generalized traffic simulation game that can be used for different purposes. [29]

Simulation games have also been used in situations where transportation is not the main focus, but an essential component of the problem being addressed. A common use case is one of emergency management training, where the management of various transport modes becomes essential [30,31]. Another use case is that of urban

planning, where transportation is an essential component. Reckien et al used a game to study the effects of urban sprawl [32]. King et al posit the need for a simulation game approach to regional and urban planning in third world countries such as India [33]. CARamba, a game for the Dutch road network makes clear the effects of measures on the road network.

In terms of technology, the games presented in the literature are similar. There is a wide spectrum of technological use, from paper based table top exercises, to computer aided immersive gameplay and physical cars. Most games use a combination of paper based table top exercises combined with simulations run on a computer and/or visualizations of data and results. Wood et al, Storshcnider et al, Reckien et al used simple paper based table top games to simulate their scenarios, with a few other artifacts to describe other objects in their games [30,31,32]. Renaud et al created a controlled environmental setup, with mock ups of physical layouts [26]. Meijer et al used paper based instruments, aided by computer simulations [27], while Watcharasukarn et al, Johansson et al, Lardinois et al used purely computer based gameplay [23,24,25,28]. Backlund et al used a physical car in a controlled environment to play the game [22]. Kutz et al are trying to construct a generalized immersive 3d environment, supported by computer graphics and a physical object to simulate the effect being in traffic [29].

Little attention has been paid to the validation of these simulation games. Most approaches rely on earlier work or on empirically collected data during the game sessions to validate their approaches.

3.3 Game Theory

Game theory provides transportation analysts powerful tools to solve many problems. There are a lot of examples of its use in transportation analysis, from analyzing vehicle routing problems [34] to transportation network reliability [35], to optimal parking policy [36], and so on. Zhang et al and Hollander et al present a comprehensive reviews and classification of game theoretic applications in transportation analysis [37,38]. It is observed that there is wide use of game theoretic models in transportation analysis, but simulation games remain relatively unused. It should be possible to convert the same game theoretic models into simulation games, to ask certain questions that will not be possible with the purely mathematical formulations of game theory. It should also be possible that the same models can be used as simulations to support game play.

4 Future Work

- Validation: Little attention has been paid to the validation of the simulation games. Validation methods from the gaming literature could perhaps be used to validate the games developed so far, which might lead to more interest in the use of these games in transportation analysis. These methods generally measure the correspondence between the reference system and the simulated system[39], and measure the validity of the process, structure of the model, gameplay and so on.

- Entertainment Games: Some of the entertainment games can easily be modified for realism and real world use. These games are generic and flexible enough to fit a variety of different uses without significant effort. Once validated, these games can be easily used for the same purposes as the games presented in the literature.
- Game Theory: There is a wide use of game theoretic models in transportation analysis. These models can be used to develop simulation games, so as to ask certain questions not otherwise possible. The same models can be simulated, and these simulations can be integrated into games.
- Theoretical frame for inter-operability: We have observed three different classes of games: entertainment games which can be extended for realism, simulation games that ask very specific questions and game theoretic models that describe a wide range of scenarios in transportation analysis. There is considerable overlap in the scenarios that all of these classes of games describe, and it should be possible for some of them to be integrated. Given that they are all completely different approaches, there needs to be a theoretical frame and method developed and validated for their integration.

5 Conclusions

As the challenges in transportation grow, and become ever more complex, it is necessary to use tools that are capable of addressing these new complex challenges. Gaming simulation provides the ability to ask questions on a range of issues, such as individual decision making, institutional behavior, future scenarios and policy making. Since gaming simulation has a lot of potential for use in transportation, it is important to provide an overview of its use so far in the transportation domain, and therefore set up a general research process and a future research agenda.

This paper first attempts to make a case for the use of gaming simulation in the transportation domain. We then provide a review of entertainment games that deal with transportation, and then a review of games used for research purposes. We draw upon the literature to find a significant use of game theoretic models in transportation, and posit that these models can be used as a base for building simulation games. In the last section, we point out some drawbacks in currently existing examples of simulation games in transportation, and try to provide some directions for future research.

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