Globally, transportation systems have been designed to help ensure economic prosperity and high quality of life through efficient movement of people and freight. It is also one of the primary forces behind the two major global crises of today’s world, namely energy scarcity and climate change. Under the current global concerns of energy scarcity and climate change, there is increasing realization that a transition from a petroleum-dependant society to one fueled by alternative clean energy sources, more efficient vehicles, and a more efficient transportation network is required for a prosperous sustainable future. The consumption and dependence on petroleum are directly proportional to the time and distance traveled by individual passenger and freight vehicles. Thus, a plausible strategy to reduce energy dependence is to minimize the required travel distance and time for routine daily activities. Without significant constraints in land availability and low cost of gasoline, land transportation planning, which is typically done at a local to regional scale, has not been traditionally driven by priorities other than to energy conservation.

In order to reduce a nation’s oil dependence, environmental impacts, and congestion, a number of alternative energy supply, distribution, and end-use transportation systems, technologies and policies are presently being explored. However, it is still unclear when and in what precise combination these sources and technologies will emerge as successful and sustainable solutions. Ideally, future plausible development and implementation strategies for alternative energy resources and technologies will secure and support a societal system in which energy, environment, and mobility interests are simultaneously optimized. Given the intertwined nature of such a system across wide geographic scales, assessing the effectiveness of possible planning strategies and discovering their unanticipated consequences require data collection, modeling, and simulation at the finest data, process, and societal response levels coupled with the system’s behavior over large spatial and temporal scales. Traditional transportation analysis has been rooted in linear interpolation of average energy technology usage efficiency and average emissions. Other than a very high level distinction between “city” and “highway” driving, individual vehicle and driver behaviors have been largely ignored.

For knowledge discovery, characterization of the interaction between the human dynamics and transportation infrastructure is essential and requires integration of three distinct components, namely, data, models and computation. Previous research has attempted to develop simulations to address scenarios regarding the relationships among energy, emissions, air quality, and transportation. These include detailed physical models of transportation engineering, including CORSIM, TRANSIMS [2, 3, 1], VISSIM [4], PARAMICS and OREMS [5]. Very recently, few models have started addressing the human dynamics of physical and social systems, such as

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SEAS [6] and Repast/Mason [7] and others [9]. However, none has been able to successfully integrate both the physical as well as behavioral aspects to characterize the interdependencies within the US transportation system and can address the interplay between energy, environment, and quality of life. Progress has also been limited by data and computational challenges necessary for accommodating the required high resolution along spatial, temporal and behavioral dimensions [12]. Integration of high resolution socio-demographic data and models bring much promise for capturing the social/behavioral dimension [13, 14, and 15]. This dimension is essential in enabling us to characterize the interplay and interdependencies between (transportation) technology and societal features that are likely to: (i) have an impact on the success of future technologies and (ii) be overlooked by current approaches of modeling at aggregated scales. For example, efficiency obtained from conventional hybrid vehicles are expressed in miles/gallon. However, common tendency to linearly translating that to energy efficiency, even at a county scale, by transposing an assumption of spatially uniform hybrid ownership is potentially misleading because total miles driven by hybrids are very likely to be a smaller than anticipated percentage of total miles driven. This is because current ownership of hybrid vehicles are spatially skewed resulting from factors such as differential economic affordability, environmental consciousness, level of education that are very reflective through the residential distribution of the owners.

In this paper, we describe the development of a geospatial modeling, simulation, and visualization framework of regional transportation processes with high resolution geographic, demographic, socio-economic data and behavioral characteristics and allow judicious evaluation of the impacts of multiple transformational mobility/energy/environment optimizations. This knowledge discovery framework is primarily driven by:

i. LandScan USA, a multi-dimensional dasymetric modeling approach, which has allowed the creation of a very high resolution population distribution data both over space and time (16). At a spatial resolution of 3 arc seconds (~90 meters), the LandScan USA database contains both a nighttime residential as well as a baseline daytime population distribution that incorporates movement of workers and students (figure 1).

ii. Oak Ridge Population Dynamics Simulator (ORPDS), a transportation simulation engine that utilizes the open source agent-based traffic simulation model, TRANSIMS, as the basic development platform. TRANSIMS has two major parts which are Router (a trip assignment model) and a Micro-simulator (a microscopic cell-and-agent based traffic simulation model). The module Router has been modified so it generates trip chains that are statistical sound based on the National Household Travel Survey. The Micro-simulator is computationally intensive and time expensive for large geographic data sets (17). To evaluate an alternate approach, a new event-based mesoscopic traffic simulation models is also developed to compare with the Micro-simulator (Figure 2). The ORNL Meso-simulator is an implementation of a discrete event model of traffic moving on a network of roads is closely based on Burghout's Mezzo model (18).

We provide example case studies where such high resolution data provides unprecedented advantages for multi-resolution (mesoscopic to microscopic scales) transportation modeling and simulations. These examples include newer approaches for:

a) Evacuation modeling of a large chemical facility for enhanced evacuation time estimation;
b) Daily school commutes of approximately three hundred thousand school children in the city of Philadelphia, USA for estimating street level environmental exposure analysis.

c) Daily work-related commute of approximately two hundred thousand in Knox County, TN for assessing potential deployment strategies and energy impact of alternative fuel and vehicle technologies.

We have developed these activity pattern models in LandScan USA using the existing data sources (American Community Survey from US Census Bureau) and previous literature on purpose specific trip rates, trip lengths, and number of stops per day/per circuit, etc. The modeling and simulation results are translated into quantified impacts on energy use, the environment (e.g., criteria air pollutants, greenhouse gases), economics, mobility, and other societal factors from local to regional and national scales. In addition, we discuss the utility and limitations of scalable spatio-temporal visualization approaches that are necessary for understanding temporal dynamics that describe observed and/or predicted physical and socioeconomic processes using vast volumes of observation (imagery and video) data from remote sensor networks and simulation results.

Figure 1. LandScan USA nighttime and daytime population distributions for San Francisco, CA.

Figure 2. UML diagram of the classes that are specific to the mesosimulator.

* Research sponsored by Laboratory Directed Research and Development program of Oak Ridge National Laboratory (ORNL), managed by UT-Battelle, LLC for the United States Department of Energy under contract no. DE-AC05-00OR22725. This manuscript has been authored by UT-Battelle, LLC, under contract DE-AC05-00OR22725 with the U.S. Department of Energy. The United States Government retains and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.
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