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A Preliminary Assessment of Activity Analysis and Modeling for Homeland Security Applications

Authors
Henson, Kriste M.
Goulias, Konstadinos G.

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Kriste M. Henson *(corresponding author)*
Los Alamos National Laboratory
Decision Applications Division
P.O. Box 1663, MS F604
Los Alamos, NM 87545
Tel (505) 667-0933
Fax (505) 665-5125
kriste@lanl.gov
and
Department of Geography
University of California at Santa Barbara

And

Konstadinos G. Goulias
Department of Geography
University of California at Santa Barbara
3611 Ellison Hall
Santa Barbara, CA 93106
Tel (805) 893-4190
Fax (805) 893-3146
goulias@geog.ucsb.edu

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ABSTRACT: A review of 46 activity-based models is conducted, detailing features that are required for homeland security applications. Two examples of homeland security studies are included to highlight these needs. This review demonstrates that only a few of the models have the desired characteristics of fine spatial and temporal resolutions. Because the criticality of locations varies due to time and/or the day of the week depending on the presence of individuals and the fact that potential targets are specific locations within a city, data needs for modeling these types of scenarios exceed typical planning and forecasting modeling as well as research modeling. A discussion of a homeland security-related modeling application conducted by Los Alamos National Laboratory (LANL) using TRANSIMS for the Department of Homeland Security (DHS) is included to demonstrate the level of detail that is achieved using nationally available data sources. In addition, the literature contains many data and information gaps including virtually non-existent models of security, identifying and inventorying residential locations, inclusion of more time constraints in models, modeling short-term changes in land use, carefully identifying and filling in missing sub-populations in surveys, accounting for fleets, services, and goods in models, better modeling of inter- and intra-household interactions, including weekly and seasonal variations in travel behavior, and developing a new paradigm for activity scheduling in panic and emergency situations.

INTRODUCTION

In this paper, we examine the plethora of activity-based approaches as candidates for homeland security applications. These methods contain by design some of the most attractive features available because they could be used to predict the presence of a city's population at specific locations and at explicit times of a day. Our assessment aims at identifying key features of homeland security applications, conducting a review of existing activity analysis methods and their fundamental building blocks, and providing a broad brush identification of gaps to build repeatedly running homeland security applications.

According to Ettema and Timmermans (1), "activity-based approaches typically describe which activities people pursue, at what locations, at what times and how these activities are scheduled, given the locations and attributes of destinations, the state of the transportation network, aspects of the institutional context, and their personal and household characteristics." Activity-based models have been developed to create activity patterns that more accurately reflect how people plan and organize their days. This is important so policy changes can be evaluated to determine how these will affect transportation networks. Although the temporal and spatial resolutions utilized by the numerous models developed in the past 25 years vary greatly, these may be adequate depending on the policy application at hand. However, when these models are viewed though a filter of homeland security application requirements, only a handful of the models have either the time and/or space resolution to reasonably provide useful results.

As with using activity-based modeling to evaluate policy changes, applying the same models to homeland security problems requires more sensitivity that can be obtained via the typical four-step model. However, we believe that the majority of the activity-based models may not be able to sufficiently answer these questions without further work to improve the current time and location resolutions being utilized. As examples we use two homeland security studies in this paper that highlight this inadequacy. Improvements in spatial and temporal resolution, reliability of land use and population information, and improving activity schedule creation by including time constraints and better understanding of inter- and intra-household interactions seem to be the most important improvements required.

The next section provides an overview of homeland security applications needs and two examples. Immediately after that we offer an overview of a large a sample of activity-based models we could identify and review using criteria directly related to homeland security. Then, specific gaps left by all these models are described and the paper concludes with a summary.

HOMELAND SECURITY AND TRANSPORTATION MODELING

Homeland security applications aim at developing scenarios of events, consequences, and strategies to minimize the impacts of consequences. Minimization of the consequences, however, requires that we also account for limited resources and rely on cooperation from a variety of individuals and groups.

As a result, homeland security modeling applications contain many unknowns. For example:

- What is the purpose of the model?
- Will a scenario be written and executed?
- For scenarios, how detailed do they need to be?
- How large of an area will be included in the model?
- How detailed do the models need to be?

- How do people reschedule their immediate actions in panic situations? For example, are parents going to pick their kids up from school in the event of an emergency?

On July 15, 1996, President Clinton signed Executive Order 13010 establishing the President's Commission on Critical Infrastructure. The Commission's mandate was to develop a national strategy for protecting the country's critical infrastructures from numerous types of potential threats and assuring their continued operation. This council recommended that complex subjects, including the nation's transportation system, undergo threat and risk assessments (2). According to the Government Accountability Office (GAO) in testimony given on February 15, 2005 before the Committee on Commerce, Science, and Transportation in the United States Senate, the Transportation Security Administration (TSA), which is responsible for the security of all modes of transportation as outlined in the Aviation and Transportation Security Act (ATSA) (Pub. L. No. 107-71), needs to implement a risk management approach for prioritizing efforts and focusing resources (3). This includes conducting criticality assessments to evaluate and prioritize assets and functions in terms of specific criteria, such as a structure's significance as a target, the importance of it to accomplish a mission, and the ability and potential cost to repair or replace this capability, as a basis for identifying which structures or processes are relatively more important to protect from attack. For example, key bridges might be identified as "critical" in terms of their importance to national security, economic activity, and public safety. Or, large sports stadiums, shopping malls, and office towers might be considered more of a substantial target when they are in use, but not when they are empty. Criticality assessments would provide information needed to determine which structures and assets are most important to protect from an attack and need to have resources allocated for special protective actions (4).

The key aspects emerging from this are: a) criticality of each location changes with time of day and/or day of the week depending on the presence of persons in and around the location; and b) potential targets are specific and distinct locations that are major attractors of activity. Both aspects require fine modeling and simulation resolution in time and space.

TOPOFF 2

TOPOFF 2, conducted in 2003, was the largest and most comprehensive terrorism response exercise ever completed in the United States. This Congressionally-mandated national terror exercise, conducted by federal, state, and local response organizations, depicted a fictitious foreign terrorist organization that detonated radiological dispersal device ("dirty bomb") in Seattle, and released the Pneumonic Plague in several Chicago metropolitan area locations (5). The simulation began when patients began arriving at Chicago-area hospitals with flu-like symptoms on the first day. On the second day, the dirty bomb was released in Seattle. Finally, the drill ended three days later in Chicago with a plane crash, a building collapse, and the capture of a terrorist cell in the city's South Side (6).

FHWA disaster scenarios

In 2003, a study completed for the Federal Highway Administration (FHWA) analyzes four different catastrophic events. These include the terror attacks in New York City and Washington, D. C., on September 11, 2001, the Northridge, California earthquake on January 18, 1994, and the Baltimore, Maryland Howard Street rail tunnel fire on July 18, 2001. The immediate and long-term impacts on each city's local and regional transportation systems are examined. Two of the documented lessons learned are important for our purposes: (a) an agency needs to learn from previous events and incorporate learning into an agency's response plans; (b) the need to practice for the expected and the unexpected. The report also noted that in each of the emergencies, transportation agencies had to work together to provide alternate travel options to the public and that these alternatives shifted over time in response to changes in travel behaviors of the public (7).

To conduct these types of scenarios, different types of data are needed to run a simulation. To start, a base transportation network is required. A synthetic population will need to be created and assigned to locations on the base network. Depending on the time of day to be modeled, the population will have to be given home, work, and other locations to perform activities such as grocery shopping, attend school, or visiting the dentist. In the case of the dirty bomb, its location of release in the scenario must be predefined. While this is a point location, its area of influence, decreasing in strength as you move away from the impact location, must be overlaid onto the network. From this, you can see who in the population will be affected. At this point, travel restrictions can be imposed on the network. As with any emergency, first responders will want the danger area cordoned off so that people involved in the incident can be helped and any crime scene information will be minimally impacted. Also, with this type of incident, the need to minimize contact between uncontaminated persons and radiation is required. Victims who come in contact with radiation need to be directed to decontamination areas. These efforts will require parts of a city to be closed off from the transportation network. Other bystanders, if needed to be evacuated, must leave the area while no longer being able to use certain local and arterial streets. The locations of network routes must also be modeled. For example, the Twin Towers destroyed in the September 11, 2001 bombing had a subway station located directly beneath them. Knowing approximately where on the network transit vehicles have been traveling is very important in estimating the number of people who may be affected by radiation or a chemical or biological release when traveling through a contamination plume before a release is discovered.

To truly prepare for the unexpected by running scenarios of terrorist attacks or ranking assets to determine more sensitive areas, activity models that do not operate at fine levels of spatial and temporal detail may be too coarse to gain any insight and practice for the unexpected. For example, as in TOPOFF 2, if a dirty bomb were released at a sport's stadium or on an elevated train station, how would this be simulated at a traffic analysis zone (TAZ) level? How would you define a contamination zone? How would you model the evacuation of these areas since time in these situations is critical, especially if the only lowest available time unit was a 3-hour block? If an agency is to practice for the unexpected and incorporate lessons learned into response plans as highlighted by the FHWA, a different sort of strategy is needed to conduct homeland security-related exercises. A variety of innovations in travel demand modeling and simulation may offer new options for homeland security models.

ACTIVITY APPROACHES REVIEW

The first models that began to incorporate behavioral processes into the methodologies were published in the late 1970's and early 1980's. Many of these models either utilized time-prism constraints, such as PESASP (8), BSP (9), and the Computational Algorithms for Rescheduling Lists of Activities (CARLA) (10), or data-driven statistical distribution utility-maximizing models, including the Adler and Ben-Akiva model (11) and the Kawakami and Isobe model (12).

The Simulation of Travel/Activity Responses to Complex Household Interactive Logistic Decisions (STARCHILD-13, 14) applied both these mechanisms in a utility-based model with constraints. SCHEDULER (15) was the first model framework to incorporate a computational process model (CPM), adding a psychometric cognitive basis first proposed by Hayes-Roth and Hayes-Roth (16). In SCHEDULER, activities, selected from the long term calendar that represents a person's long term memory, comprise a schedule that is "mentally executed". Each of these models generate activity patterns, with either no actual time-of-day estimate or, as is the case with CARLA, each activity to be considered by the model is required to have a duration and a time window in which the activity needs to occur supplied as an input. Spatial information such as specific locations where activities are pursued is not considered as part of these models.

The first model to include a microsimulation in its paradigm is ORIENT (17). This methodology was proven in a real application for the Netherlands in 1992 when Goulias and Kitamura built the longitudinal econometric model called the Microanalytic Integrated Demographic Accounting System (MIDAS-18 and 19, and converted for the US by 20), which simulates the evolution of households along with car ownership and travel behavior. The Activity Mobility Simulator (AMOS) (21), which uses a neural network to identify choices and a satisfying rule to simulate schedule changes, is also a microsimulation that uses a different modeling paradigm. While MIDAS is a strictly longitudinal process econometric model progressing one year at a time, AMOS is constraint-based model designed for finer temporal resolution.

In the mid-1990's, a large number of activity pattern models were released utilizing a wide variety of paradigms. Ettema, Borgers, and Timmermans released the Simulation Model of Activity Scheduling Heuristics (SMASH) in 1995 (22) and COMRADE in 1996 (23). SMASH is a CPM and data-driven statistical distributions hybrid microsimulation that focuses on the pre-trip planning process. The Model of Action Space in Time Intervals and Clusters (MASTIC-24), which uses data-driven statistical distributions, Household Activity Pattern Problem (HAPP-25), an optimization model, the Prism-Constrained Activity-Travel Simulator (PCATS- 26), a utility-based model, and the GIS-Interfaced Computational-process modeling for Activity Scheduling (GISICAS- 27), a simplified CPM, all utilize time-space constraints from time geography. Ma (28) also developed a model system that combined long term activity patterns (Long-term activity and travel planning – LATP) with a within a day activity scheduling and simulation (Daily Activity and Travel Scheduling – DATS) incorporating day to day variation and history dependence. However, the theory behind each of these models varies greatly. MASTIC identifies clusters in the action space to perform and schedule activities. HAPP, a variant of the pick up and delivery time window problem, optimally creates activity schedules. PCATS applies time-space prisms as constraints to generate activities and trips for individuals. GISICAS, a simplified, operational version of SCHEDULER, employs a Geographic Information System (GIS) to incorporate spatial information into the model to create individual schedules, starting with high priority activities. Other models also attempt to recreate personal schedules such as Vause's model (29), a CPM that creates a restricted choice set for creating activity patterns, a model by Ettema, *et. al.* (30), and VISEM (31), a data-driven statistical distributions model that is a part of PTV Vision, an urban and regional transportation planning system, that creates daily activity patterns for behaviorally homogeneous groups within the population. Similarly, two new modeling frameworks were also proposed. Stopher, Hartgen, and Li proposed the Simulation Model for Activity Resources and Travel (SMART- 32) in 1996. SMART, using a time geography framework, envisions creating activity patterns for households based on three types of activities – mandatory, flexible, and optional – inside a GIS environment. Another framework, the Daily Activity Schedule model was published by Ben-Akiva, Bowman, and Gopinath in 1996 (33). This model, used to create the Portland Daily Activity Model (34), advocated modeling lifestyle and mobility decisions on a scale of years. These influence daily activity schedules, which are comprised of primary and secondary tours constrained in time and space.

Microsimulations continued to be developed during this same time period. In 1995, the TRansportation ANalysis SIMulation System (TRANSIMS), a data-driven cellular automata microsimulation, was developed at Los Alamos National Laboratory (35). It was one of the first simulation packages to contain models that create a synthetic population, generate activity plans for individuals, formulate routes on a network based on these, and execute the activity plans. Another microsimulation, SMASH (22) was released the same year. SMASH models the pre-trip planning process and outputs a list of activity/location pairs. In 1997, another daily activity-travel pattern model was estimated using the 1990 Southern California Association of Governments (SCAG) travel dairy. This data-driven statistical distributions model, created by Kitamura, Chen, and Pendyala (36), is a sequential approach for creating activity-travel patterns for a synthetic population. A year later in 1998, ALBATROSS was released by Arentze and Timmermans (37, 38). ALBATROSS is a CPM that predicts the time, location, duration, and with whom activities occur as well as the type of mode utilized. The Regional planning Model Based on the microsimulation of daily Activity Patterns (RAMBLAS), published in 1999 by Veldhuisen, Timmermans, and Kapoen (39), is a data-driven statistical distributions microsimulation that applies time-space constraints. Simulated individuals are assigned activity patterns and modes based on representative population groups formed from socio-economic demographic data. Similarly, SIMAP (40) divides a survey population into groups, based on representative activity patterns (RAPs). These classifications are used to create full day activity patterns. Like SIMAP, DEMOS (41), also released in 2000, is a microsimulation that utilizes data-driven statistical distributions. DEMOS is designed to simulate the evolution of people and their households using the Puget Sound Transportation Panel. It also simulates activity participation, travel, and telecommunication market penetration using a few representative patterns.

Non-microsimulations continued to be formulated from the late 1990's. As previously mentioned, the Portland Activity Schedule Model, based on the Daily Activity Schedule Model framework, uses integrated disaggregate discrete choice models to determine an individual's demand for activity and travel as an activity pattern and set of tours. PETRA, another data-driven statistical distributions model, was formulated by Fosgerau in 1998 (42, 43). This model utilizes a less complicated paradigm that only models home-based tours for the purpose of work, errands, and leisure. A model with high spatial resolution, the Alam Penn State Emergency Management model (Alam-PSEM, 44) is a building-by-building simulation of activity participation and presence at specific locations of the University Park campus for each hour of a typical day. In 1999, Bhat and Singh (45, 46) estimated the Comprehensive Activity-Travel Generation System for Workers (CATGW), a series of econometric models that replicate a commuter's evening mode choices, number of evening commute stops, and the number of stops after arriving home from work. Another econometric model, the Conjoint-Based Model to Predict Regional Activity Patterns (COBRA), developed by Wang and Timmermans (47), generates general patterns of stops for specific activities using a conjoint-based model with stated preference data. The Wen and Koppelman model (48) utilizes three layers of decisions that are influenced by exogenous variables to generate activity patterns. Another data-driven statistical distribution model, the CentreSIM regional model (49, 50, and 51) uses time-of-day activity and travel data for different market segments to predict hour-by-hour presence at locations and travel between zones. A complementary model to ALBATROSS, AURORA (52, 53) is a utility-based system that models the dynamics of activity scheduling and rescheduling decisions as a function of routine and unexpected events. In 2004, Pribyl and Goulias (54) extended CentreSIM (medoid simulation) to derive a few representative patterns and simulate daily schedules.

Microsimulations continued to evolve in another direction. The Integrated Land Use, Transportation and Environment (ILUTE) model (55) is designed to simulate the evolution of people and their activity patterns, transportation networks, houses, commercial buildings, the economy, and the job market over time. Another model developed by Miller and Roorda (56), the Toronto Area Scheduling model for Household Agents (TASHA) is a hybrid of CPM and data-driven statistical distribution paradigms. This model uses projects to organize activity episodes into schedules of persons. Schedules for members in a household are simultaneously generated to allow for joint activities. A microsimulation that uses econometric models to simulate daily activity travel patterns for an individual, the Comprehensive Econometric Microsimulator for Daily Activity-travel Patterns (CEMDAP) model (57) is based on land use, socio-demographic, activity system, and level-of-service (LOS) attributes. MERLIN, a CPM and data-driven statistical distributions model from Van Middelkoop, Borgers, and Timmermans (58), estimates leisure and vacation activity travel patterns on an annual basis. Another model that utilizes constraints is the Florida Activity Mobility Simulator (FAMOS) (59). FAMOS encompasses two modules, the Household Attributes Generation System (HAGS) and PCATS. Together, they comprise a system for modeling the activity patterns of individuals in Florida. The output is a series of activity-travel records. Microsimulations have continued to gain in popularity in the activity-based modeling universe as they move from research applications to practice. New York’s "Best Practice" Model (60) and the Mid-Ohio Regional Planning Commission (MORPC) Model (61), both developed by Vovsha, Peterson, and Donnelly, and the San Francisco model (62) are currently being utilized by their respective metropolitan planning organizations (MPO).

As can be seen in Table 1, the majority of the activity-based models have undefined or large time resolutions. With the exception of STARCHILD (1986) with a temporal resolution of 15 minutes and TRANSIMS (1995) with the time increment of one second, it isn’t until 1999 with the release of the Alam Penn State Emergency Management Model (Alam-PSEM), which models one hour intervals, that more and more models have been published with smaller time intervals, down to the resolution of one second. Currently, CentreSIM (regional) and MORPC also have a temporal resolution of one hour. SIMAP utilizes a 10-minute interval. TASHA and CentreSIM (medoid), have five and one minute increments, respectively, while ILUTE, in theory, varies depending on what type of simulation is being run. Besides TRANSIMS, RAMBLAS, CEMDAP and FAMOS are the only other models that can be run on a second-by-second basis. When evaluating spatial resolution, even fewer models are able to process data below a zonal level. ALBATROSS and MORPC both can operate at the sub-zone level. Alam-PSEM, SIMAP, RAMBLAS and TRANSIMS are the only models able to utilize data at the building or point level.

The detail and spatial accuracy required for homeland security applications by far exceeds the examples reviewed above. Below we review briefly an example application from a project at Los Alamos National Laboratory (LANL) that has been working with the Department of Homeland Security (DHS) to model some of these types of situations using TRANSIMS. TRANSIMS has the capability of simulating movements of individuals around a network on a second-by-second basis between parcel-level locations. LANL has been utilizing this capability while running scenarios and ranking assets for cities around the U.S. For several cities, including Chicago and most recently the Los Angeles metropolitan area, transportation networks are created using the NavTeq NavStreets Premium Dataset, provided to LANL via a federal-use only license through the National Geospatial-Intelligence Agency (NGA). The NavTeq network is a highly accurate representation of roads, from local streets to large arterials and freeways, and contains many of the necessary road attributes, including speed limit, functional class, and types of vehicles allowed (www.navteq.com). Therefore, it is ideally suited for use as a base network. For example, the Chicago network contained approximately 150,000 street segments in just Cook County. On the network, individual activities are located on the links. Dun & Bradstreet data, again provided by NGA, were utilized to create activity locations. These data, which contain actual business locations, addresses, numbers of employees, and the business types by Standard Industrial Classification (SIC) codes, are utilized to create trip attractors. Public schools, private schools, and colleges or universities, updated semi-annually, are geocoded onto the network using addresses obtained from the National Center for Education Statistics website (nces.ed.gov). Hospital data, including locations and bed counts, were obtained from the Emergency Response Services dataset, provided again by NGA. Home locations have been estimated using several different methods. For Chicago, electronic phone books and home mailing lists generally utilized by marketing businesses were obtained and geocoded. However, the drawbacks for this method are that people who do not own phones, are unlisted, or do not have a physical address were missed. When modeling Los Angeles, GeoLytics block boundary shapefiles containing the number of households from the 2000 Census, were used. The household counts were then allocated to generalized activity home locations, two per street link (one on each side of the street). With the exception of this last methodology, the activities were left for the majority of the metropolitan areas as individual points. For example, all of Cook County in Chicago contained individual houses, apartment complexes, businesses, schools, and hospitals. This resulted in the creation of approximately 823,500 activity location points in this county alone.

DATA AND INFORMATION GAPS

Although substantial progress is observed in the activity-based travel demand forecasting methods and in the integrated land use transportation modeling arenas, we still have many critical areas for further improvement. The list below is developed with focus on homeland security applications.

Research

According to http://www4.trb.org/trb/homepage.nsf/web/security/#trbppmonth, the majority of the general transportation security activities have been exclusively confined to operations. Very little, if anything, has been devoted to applying activity-based models in homeland security applications.

Identify and Inventory Residence Locations

Complete coverage of all the locations in the US can be achieved when we use multiple source of information and databases that are available in the public domain (e.g., excluding tax records and original Census data). For complete coverage, the ideal and most detailed geographic unit is a parcel of land. Public records of parcels exist in tax assessments and they are becoming more available on the internet (e.g., http://gis1.co.lake.il.us/mapsonline/default.asp - accessed July 2005). These records contain details about the parcel and the buildings within it including sizes and building characteristics. Contrary to what one would expect, this information is not commonly used either as the primary source of data or as a validation and verification tool. For example, the value of the properties in each parcel and its general neighborhood characteristics can be used to more precisely "allocate" households to specific geographic locations as residents.

Include Time Constraints

When formulating activity schedules, many of the models do not utilize the constraints of operating cycles for businesses. Since the time of day being modeled, or even the time of year, will result in great differences in activity patterns, this type of information must be evaluated. For example, doctor's offices are only open for patients during the day. In smaller communities, they may close early a few afternoons a week. The constraints of operating cycles for businesses must therefore be included.

Modeling Short-term Changes

While long-term modeling has received a great deal of attention, short term modeling of changes in business locations and land use has been neglected. Many of the existing datasets are only updated annually, so determining the types of changes that occur on a monthly basis may be important in homeland security modeling. For example, a doctor office moves to a new location and another business moves in. Unless the same mix of businesses is maintained in the area, research has shown that traffic patterns could change. The same issue exists for residential changes – if a house is sold, is the buyer following the same activity pattern as the original owner? Research concentrating on updating or forecasting changes in small increments is needed.

Filling Gaps in Surveys

The majority of the activity-based models are based on survey micro-data. Therefore, missing sub-populations in surveys such as children, the homeless, and marginalized individuals, can result in large numbers of missing activity patterns. While there are methodologies to account for missing populations, how accurately are these applied? Are researchers actually spending time to properly identify these missing people? In homeland security-related modeling, missing sub-populations of people could result in misidentifying persons that could be affected in a national security event.

Account for Fleets, Services, and Goods

At any point in a day a large number of vehicles arrive to and depart from businesses and residence to deliver goods but to also deliver services (e.g., gardening, maintenance, construction). Stefan, et. al. (63) estimate these vehicles to be approximately 15% of the observed traffic. All the models reviewed here neglect this aspect of activity participation and travel as well as human interaction.

Modeling Inter- and Intra-household Interactions

Only a small number of activity-based models actually have attempted to include interactions between family members. None of them have attempted to account for activity patterns based on interactions between households or individuals in organizations.

Weekly and Seasonal Variations

The models developed for public policy suffer from the original purpose of modeling emission and air pollution from internal combustion engines at the regional level for conformity assessments. For this reason seasonality of behavior is not accounted for (although a typical summer day may not be very typical for activity and travel behavior). Recent changes in shopping behavior are also motivating analysis of weekday versus weekend travel that may help homeland security applications that require estimates valid all year.

Activity Scheduling in Panic and Emergency Conditions

As far as we are aware, no one in the activity-based transportation modeling community has ever attempted to create activity patterns based on high stress or panic conditions. Since we need to model an incident such as the release of a dirty bomb, people will no longer operate under "normal conditions". We need to understand behaviors under these circumstances. For example, more cross-over research between transportation researchers and cognitive specialists must occur in order to begin to understand this type of behavior and determine how activity patterns in this type of situation are formulated and executed.

SUMMARY AND CONCLUSIONS

Substantial progress is observed in the past 25 years in travel demand modeling and simulation and a variety of new ideas emerge as potentially useful for homeland security applications. For example, many models use hybrid paradigms that are combinations of statistical/econometric models and CPM to represent behavior. Other use statistical models embedded into microsimulation frameworks to evolve either individuals and/or households over time. Modeling and simulation appear to be concentrating at two poles. They are either designed for the long term with yearly cycles or the very short term such as within a day activity patterns. Critical gaps, however, are found in representing the entirety of our social spectrum, model capability to represent activity and travel pattern on a second-by-second basis, and modeling of people's presence at each parcel of a city. These are all potentially solvable issues using additional resources to acquire data. However, a few additional areas on inter- and intra-household interactions and activity scheduling in panic and emergency conditions are also identified as the neglected aspects in the behavioral analysis arena and they are not easily solvable by simple investments. Also, little attention if any is paid to short term changes in activity patterns (e.g., weekday versus weekend, seasonalities, and so forth) and shorter term changes in the urban landscape.

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LIST OF TABLES AND FIGURES

TABLE 1 Activity-based model spatial and temporal resolutions

Spatial Resolution	Temporal Resolution							
	Unknown/ Unspecificed	**None**	**Year**	**Blocks of Time**	**Hour**	**5 to 15 Minutes**	**Minute**	**Second**
Unknown/ Unspecified	BSP, Ettema (HCG), Hayes-Roth and Hayes-Roth, Kawakami and Isobe, Mastic, Orient, PESASP, Petra, Smash, Wen and Koppelman					Starchild		DATS, CEMDAP, ILUTE
None	Vause, CATGW, AURORA	Adler and Ben-Akiva, Comrade, Daily Activity Schedule, Scheduler, SMART	MIDAS, DEMOS	CARLA, COBRA, Synthetic Daily Activity-Travel Patterns		HAPP	CentreSIM - medoid simulation	
Region			MERLIN					
Zones	AMOS			New York "Best Practice", PCATS, Portland Daily Activity Schedule, San Francisco	VISEM, CentreSIM - regional	TASHA	RAMBLAS, TASHA	FAMOS
Sub-zones				Albatross	MORPC			
Points					Alam PSEM	SIMAP	GISICAS	TRANSIMS