

## **TOWARD INCREASED USE OF SIMULATION IN TRANSPORTATION**

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### **ABSTRACT**

The validity and usefulness of system simulation has been well-established for decades in areas such as computer and communications systems, general manufacturing systems, and military systems along with many other areas. Recent years have seen the technique become entrenched in specific areas such as automotive manufacturing, semiconductor fabrication, and automated warehouse design.

Transportation simulation also has a long history as evidenced by publication of numerous transportation simulation papers in the Winter Simulation Conference Proceedings and other publications over the years. During the past few years the number of transportation simulation applications presented at WSC has increased, to the point that in WSC'98 for the first time there is an entire track – 24 presentations organized into eight sessions along with this panel session – devoted to transportation simulation applications.

Is transportation poised to be the next big growth area for discrete-event simulation? Is it already a major area, left relatively unnoticed over the years due to the number of different application subareas? Is the growth already happening? What are the opportunities, and what are the barriers? This panel will address these and other questions.

### **1 INTRODUCTION**

We simulate all manner of systems that move people and goods. For people there are street crossings, escalators, elevators, moving sidewalks, urban street traffic, limited-access highway traffic, buses, subway and other commuter trains, ferry boats, inter-city passenger trains and airplanes. For goods there are air freight, inter-city rail and trucking, transfer yards, ships and marine terminals, river barges, intermodal networks, private road and rail networks, local street delivery systems, and so forth. Goods can be bulk material, in cartons, on pallets, in containers, or could be letters, magazines, or small bundles or parcels (postal type applications), or passenger baggage, or many other things.

Warehouses and distribution centers are often an integral part of a transportation network.

Does the air transportation industry (and its government counterparts) simulate local and national airspace, flight schedules, airport terminal operations of all types as much as it should? Can we have better street and highway systems through simulation? Will buses and passenger trains be more punctual if timetables are always simulated? Can goods be moved faster and at lower cost through simulation in situations where it is not being used today?

Simulation of transportation systems is strong and appears to be growing. What is the future for transportation simulation?

Our panelists will attempt to answer these and other questions using the following suggested framework:

1. Please briefly describe some transportation simulation applications with which you are familiar. For each one, was it a success or a failure? Why?
2. Have you seen a specific transportation situation where you thought simulation should have been used but wasn't? What was the situation? Why should simulation have been used? Why wasn't it? What were the consequences, if any?
3. Can you name at least one significant barrier to wider use of simulation in the problem domain in which you work? How could this (these) be overcome?

## **2.1 Gary Cross, IBM Corporation**

In the Fall of 1996, IBM Research and IBM's Worldwide Travel and Transportation Industry Solution Unit began exploring the application of simulation modeling techniques to the airport terminal congestion problem. The IBM team evaluated several simulation products on the market, including a software application developed by IBM several years prior. The objective was to combine in-house knowledge and experience with emerging technologies to develop a simulation application that could accurately replicate existing customer processes and provide a precise visual and statistical representation for the end user. Hence, the "Journey Management" project was formed to address the need for a tool to allow airlines and airport authorities to deliver a positive experience to airline passengers as they proceed through airport processes. The resulting "IBM Journey Management Library" is a set of building blocks and templates, for use with a simulation tool, to describe airline processes (e.g. check-in) and related new technologies. The IBM JML can be efficiently reused both to model multiple airport environments under variable local conditions and to serve as the core engine for the expansion of simulation models

into other related airport activities, such as baggage handling and ramp services.

Air Canada, a commercial airline based in Montreal agreed to serve as the test site. The leadership, knowledge, and skills provided by their Operations Research and Business Innovation Solutions (ORBIS) organization was vital to the development of the Library. Toronto's Lester B. Pearson Terminal 2 was selected as the evaluation site for modeling. The terminal operations for domestic passenger processing at that facility provided the greatest variations of interactions between passengers and Air Canada's processes where process capabilities were both integrated and segregated in the form of check-in, ticketing, and baggage handling. Domestic departures operations were also determined to be the best source of significant amounts of reliable information in the form of collected statistical data, quality assurance, and contemporary databases. Starting in early 1997 the Journey Management Library project was on its way to success.

Key challenges in this simulation effort were:

1. Accurately capturing the complexity of the passenger mix and its impact on the requirements for airport services. For example, a different distribution of number of bags needed to be applied to business and leisure passengers.
2. Deriving representative arrival patterns for the customers.
3. Incorporating variable resource schedules to model the assignment of agents to counters. Both full-time and part-time agent schedules were phased in and out over the course of the day to maximize productivity by approximating the peaks and valleys in passenger activity. The result was a resource profile that can vary significantly in each fifteen-minute interval throughout the workday.

These and other challenges were fully addressed by leveraging the experience of our cross-functional team. The team included representatives from airport operations, IBM Research and representatives from the software developer. Frequent team meetings were held at critical junctures of development along with periodic "proof of concept" testing which helped the team to arrive at a successful conclusion.

The IBM JML, given its ease of use, allows airlines and airport authorities the ability to easily represent multiple service configurations and quantifiably (e.g. either by economic or statistical measures) choose between alternatives. The value to the organization is that the template can be quickly assimilated, re-used, and repeated with minor parametric changes by other field locations and

used to improve customer service and enhance productivity.

The IBM JML also has applicability to other travel-related service providers. In the competitive travel and transportation environment, rail, lodging, rental car, and cruise line companies are planning and preparing for ways to handle the increased volumes of passengers as the millenium approaches.

## **2.2 Jack Levis, United Parcel Service**

United Parcel Service will continue to use simulation as part of a suite of tools to measure, plan, and analyze our transportation systems. Simulation combined with optimization, time study, ergonomic evaluation, and other analysis methods is used to provide operations planning tools that integrate with corporate decisions on methods and procedures.

Our approach is to move from the general to the specific. Simulation is best used to answer the high level policy questions:

- What should the job setup be?
- Where should work be performed?
- What type of conveyance is best?
- What are the proper methods and procedures?

By using simulations, multiple operating scenarios are evaluated. The simulation generates more questions than answers and is used to formulate top down decisions from a global perspective. When the “best” operating methods are determined, a sensitivity analysis is run to determine the bounds under which the operating plan remains valid.

For example, a simulation for the loading of our trailers would show in detail how the job is to be performed and the interrelation of time dependent activities. This is more robust than the traditional work measurement approach. The simulation may show that additional resources must be made available to best service all packages. These additional resources would be accounted in final work measurement allowances.

The completed simulation is then appropriately summarized and used in work measurement, control systems, and planning systems. Once operating methods and procedures are established, the flexibility of a simulation is no longer needed, and features such as animation begin to lose their value. For day to day planning, we have found optimization to be best. The questions are now more specific and the operating

conditions are more narrowly defined. Optimization is used to answer:

- How many people are needed?
- When should they begin work?
- How many hours should I budget?

The output of the optimization goes to control and analysis systems to compare the planned versus actual statistics. If the variance between planned and actual is large, the simulation is used to validate conditions and determine where discrepancies exist. In this way, simulations become a training and troubleshooting tool also.

Of course, the recipe outlined is not always appropriate. Sometimes a problem cannot be properly defined, and a simulation is used directly as a planning tool. In these cases, business rules and goals are not clearly understood. A business manager would take a simulation and iteratively vary the input until a reasonable compromise plan is created.

There are other times when the operating scenario is so well defined that there is no need to run through simulations. An optimization would be built directly from existing work measurement information. The scheduling of our tractor trailer movements fall into this category. The work is well understood and the process is mature, the only question is what is the best way to schedule the activities.

United Parcel Service has completed many simulations and optimizations for nearly all parts of our business. These include:

- Tractor Trailer Scheduling
- Aircraft and Crew Scheduling
- Hub Internal Flow Balancing
- Network Package Routing
- Delivery Routing and Scheduling
- Inside Operations Package Handling

These systems have had varying degrees of success, with success being measured as their impact on the operations in reducing cost and / or improving service. Some of the factors that determine successful vs. unsuccessful systems are listed below.

**Alignment of goals:** The goal designed into the system must match the goal of the manager using the tool. A tool designed to reduce cost may not be well received if the operator’s goal is maintain status quo. A flexible simulation that allows many what-if scenarios will seem clumsy if the goal of the user is to quickly get tomorrow’s plan.

**Ease of use:** Similar to above, a system must be easy to use in order to gain acceptance even if it produces a good solution. A system that works well for an engineer in the lab may not meet usability requirements of a business manager.

**Availability of Data:** Simulations and optimizations are only as good as the data that is provided to them. A tool that requires data that is not available or cannot be accurately obtained is doomed for failure. During the design of the system, data availability and accuracy must be addressed. Simplicity is important.

**Top Down Support:** As with all systems designed to improve operations, the more support from the top the higher the likelihood of success. Of course, support from the top is most likely to be received if the system provides operational benefit and meets the other three criteria mentioned.

Simulations, optimizations, and other tools are only worthwhile if they are used to change something and provide business benefit. This must be kept in focus throughout the process of development. The end game is implementation, and this must be planned from the beginning.

### **2.3 Catherine McGhee, Virginia Department of Transportation**

The Virginia Department of Transportation has been expanding its use of simulation in recent years. Recognizing the need for a means of analyzing the operational characteristics of complex transportation networks, the Department began investigating the use of simulation models. Simulation models have been applied to both arterial and freeway networks to develop near term improvement strategies as well as longer term plans.

For example, the Department currently has a number of consultants under contract to develop plans for the expansion of Interstate 81 throughout the state. The need for an accurate analysis of the weaving sections along the corridor as well as the potential impact of exclusive truck lanes resulted in the requirement that the simulation model CORSIM be used for the operational analysis. This represents a significant change for the Department where analyses have traditionally been conducted using the methods provided by the latest edition of the Highway Capacity Manual. It is also a new way of doing business for many consultants. The I-81 project is a good example of this. The consultants were already under contract when the decision was made to require the use of CORSIM and many of them had no prior experience with the model. The Department has therefore expended a significant amount of effort providing training and technical support in the use of CORSIM.

While simulation is being applied on projects in the Central Office, the use of such models is not as common at the District level. The biggest stumbling block to more widespread use is a lack of experience with the models by Department staff. Efforts to overcome this difficulty

include a training program and efforts to increase awareness of the value of the models. Unfortunately, past experiences with consultants have, in some cases made Department staff wary of requiring the use of simulation models. High costs and project delays are not uncommon in projects that employ simulation. As Department staff gain experience and understanding of model capabilities and limitations, project management will improve and schedule and cost issues will be more easily controlled.

From a broader perspective, for simulation models to become widely accepted and applied, formal training in their use must be developed and offered at costs that are not prohibitive to public agencies and the wide range of consultants who complete work for the Department. Interaction between model developers and transportation practitioners would also benefit both groups. Often, professionals who are experts at developing models but not necessarily experts in traffic flow and operations develop these models. This results in models that do not completely meet the needs of the transportation community. By working together, model developers and transportation professionals could produce stronger models.

### **2.4 Dudley Whitney, Parsons Brinckerhoff Quade & Douglas, Inc.**

PBQD has used simulations in several different applications involving transit operations. Examples include:

- **Construction Feasibility Studies:** used to test single-track and short-turn operations during weekdays while a portion of the transit line is rehabilitated. Example: SEPTA Market-Frankford Subway Elevated, Philadelphia.
- **Signal Design:** used to test the design and operations of proposed signal systems, and/or to calculate safe braking distance and block lengths. Example: Docklands Light Rail, London; Metro North, New York.
- **Power Consumption:** used to determine the power draw from multiple light rail or rapid rail trains operating within a single or multiple power blocks.
- **Traffic Studies:** used to test the impacts on vehicular traffic from the operation of LRT and buses in-street. Examples: Hudson Bergen LRT, New Jersey; Frankford Transportation Center, Philadelphia.
- **Railroad Capacity Studies:** used to test the resulting track capacity (e.g.; trains per hour) from several alternative investment scenarios including additional tracks, improved signals and control, and

increased speeds. Example: MARC Comprehensive Plan, Maryland.

- **Train Operations Studies:** used to test the proposed operating plan for new service or changes in service. Examples: MARTA, Atlanta; MBTA Green Line, Boston.

In all cases the simulations have proven effective in either providing the required data for design calculations or providing valuable information to clients on a proposed scheme. With rare exception, the simulations, and particularly, the animations were considered by the clients to be well worth the expense.

Two examples of projects where simulations could have proven highly useful:

**Container Intermodal Facility:** though a simulation was performed for the ground-based operations (transferring containers on and off of trucks), the rail operations between the facility and the yard and between the yard and the port were not modeled. The primary constraint on the facility's capacity turned out to be the rail operations, not the ground-based operations. A simulation would have helped show the limits of those constraints and "prove" the recommended alternative.

**Railroad Operations Study For Adding Commuter Trains On An Existing Freight Railroad:** A simulation was completed for this project by another consultant, but with what turned out to be incorrect assumptions. The client did not want to spend more budget on yet another simulation, even though they could have saved tens of millions by showing that a less ambitious plan could accommodate both freight and commuter traffic.

The principal barriers to the expanded use of simulations in transit operations that I have encountered include:

- Perceived high cost - when clients are accustomed to retail software packages costing just hundreds of dollars, they frequently balk at estimates of tens of thousands to hundreds of thousands for developing and running a model. The investment is not considered cost-effective, and may not be.
- Tight budgets - a fact of life, project budgets are limited. If the client is unfamiliar with, or has not planned for, the true cost of simulations, they are unlikely to be done.
- Tight schedules - schedules are getting tighter. Clients are asking what used to take 14 months to be completed in 8. Construction of transit projects are being started just 2 years after conceptual design, where 4 used to be typical. These tight schedules sometimes preclude the use of simulations, which are seen as delaying the project.

- Inappropriate - simply put, some people do not see any benefits of simulations, arguing that the information needed to make a decision can be obtained from less costly methods.

The primary means to address these barriers is through further development of more sophisticated models. R&D funds should be allocated to develop models that are more data-driven (utilize data files separate from the core model, rather than having to alter the source code), require less time for setup, and thus cost less to use on any one project. The user interface, the data structure, and the range of real-world situations that can be modeled should be expanded to reduce the amount of time and budget spent on any one client project. In this way, more clients can afford, both in time and budget, to contract simulations. As more simulations are completed, they will become more accepted as standard tools in analyzing alternative strategies or designs rather than as extravagant toys of the most expensive projects.

### 3 SUMMARY

Simulation of transportation systems is a growing field. In order to sustain that growth and make transportation simulation more of a requirement and less of an option or an afterthought, several challenges must be addressed with each project. These include defining data requirements, capturing and analyzing data for model input, restricting simulation use to appropriate problem types, retaining focus on business goals as well as technical requirements, controlling and reducing the cost of simulation, scheduling simulation into the project so as to minimize the impact on the overall project timeline, and educating users (consumers of the information produced by simulation) and senior managers about simulation.

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