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TPASS - DYNAMIC, DISCRETE-EVENT SIMULATION AND ANIMATION OF A TOLL PLAZA

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ABSTRACT

This paper describes the development of a software package that simulates and animates the operation of a toll plaza. The Toll Plaza Animation/Simulation System (TPASS) gives transportation authorities the ability to experiment with various toll plaza configurations and traffic characteristics in order to determine the resulting queuing, wait times, and toll revenue.

TPASS was designed to consider all of the important operating parameters of a toll plaza. All of these parameters can be varied by the user via a complete, menu-driven user interface.

The combination of simulation and animation in TPASS provides transportation engineers and planners with a well-rounded engineering tool. The simulation portion allows them to make quantitative comparisons of experimental data sets while the animations present information that is visual and allows them to evaluate the "reasonableness" of the simulations.

TPASS is being used by transportation authorities in the New York and New Jersey region. One recent application involved studying the Verrazano Narrows Bridge Toll Plaza in order to determine the plaza's impact on the air quality.

1 INTRODUCTION

Transportation agencies and authorities in the United States and worldwide face growing pressures in the 1990's. One pressure is due to increased traffic volumes that cause unprecedented congestion on roadways. A second pressure is restrictive legislative requirements that have come from the need to reduce dangerous emissions from vehicular exhaust. Third, the cost of new construction of roadway has skyrocketed. Finally, new technologies that promise increased efficiencies in the operation of roadways are being developed but are largely untested. Choosing the best technological options can be challenging since the state-of-the-art is changing almost daily.

Recent passage of the Inter-modal Surface Transportation Efficiency Act of 1991 (H.R. 2950) has opened up opportunities for transportation authorities to study and implement new technologies, including Intelligent Vehicle Highway Systems (IVHS), and specifically, Automatic Vehicle Identification (AVI).

Science Applications International Corporation (SAIC) has been developing systems devoted to increasing the efficiency of roadways since 1985. These systems include toll collection systems that use AVI. In parallel to this effort, SAIC has been developing a dynamic, computer-driven simulation of the operation of a toll plaza. This software tool, the Toll Plaza Animation/Simulation System (TPASS), is used by SAIC and its customers to increase the efficiency of current operations and to assess the benefits of new transportation technologies.

An earlier description of the TPASS model was reported at the 1990 Winter Simulation Conference (Junga, 1990). The current paper summarizes that work and presents an up-to-date description of the on-going development and application of the software package.

2 MODEL DESIGN CONSIDERATIONS

TPASS was designed for use by traffic planners and engineers that most likely have no previous experience with simulation. Ease of use, performance, flexibility, and a suitable hardware platform were the dominating criteria in the specification process.

During early development work with the product (Junga, 1990), a high-end IBM PC compatible was the predominant choice of hardware. The PC's popularity, availability, and user familiarity ranked it highest among other choices. In addition, the cost of high-end machines (based on 80386 and 80486 processors) and software has fallen rapidly. This selection eliminated

the need to train a user already well acquainted with a PC and DOS to use a more costly work-station and UNIX.

In terms of the model's flexibility, there are many variables that can be measured and, in some cases improved, with the processing of vehicles through a toll plaza. To be a truly useful product, TPASS had to have the capability to model a multitude of plaza configurations, traffic patterns, and behavior.

Finally, the capacity to run useful simulation experiments incorporating all of the relevant criteria could not be accomplished at the expense of the simulator's speed.

3 MODELING APPROACH

Furnishing the modeler with a product that was not only capable but easy to use created some unique challenges in the product's design. A user-interface insulates the modeler from the actual model source code, provides ease in data entry and edit, and performs all of the other necessary functions to run, view, and analyze the model. A configuration check prior to run-time prevents many errors attributed to simple oversights in the configuration of the plaza, further increasing the efficiency of the modeler.

The general approach to implementation of TPASS required the use of a high performance simulator and animator. The assumption of an 80386 (with a 80387 math coprocessor) or 80486 processor allowed for use of recently released software that took special advantage of the processor and the inherent added memory capability for large models. GPSS/H 386 discrete-event simulation language offered not only the capability of these features but has unsurpassed performance at model run-time for this type of application. GPSS/H 386 also provides mechanisms to easily read/write external files and the means to secure the model source code. The former permits all user input variables to be placed outside of the model and facilitates the implementation of customized output reports and animation while the latter assures the integrity of the model logic itself by not allowing the user to make any changes to it.

Proof Animation was selected for its run-time performance and its ability to execute animations by reading ASCII files. Motion control is maintained by the animator, further reducing the burden on the simulator. Since no proprietary simulation software is required to drive Proof Animation, it can be used for presentations as well. It is a vector-based animator, allowing full zoom, pan, and rotational control by the user. Available utilities permit the rapid layout creation for customized plazas (see "PACKAGING" below) by converting existing AutoCAD files to background layout files used by the animator.

The enormous volume of variable data required by the model to ensure total flexibility demands that it reside in several external data files. Four data sets exist to drive the model and are grouped as plaza, traffic, global, and experiment. To manage all of this data, entry/edit screens are provided. In addition to allowing for ease in adding and changing data, these screens provide a mechanism to check data validity (range, format, etc.) prior to its submission to the model. In addition, context-sensitive help is available at all data fields to assist in training of new users.

Several standard output files are also created with a TPASS model run. Since standard GPSS-type output would be of little or no use to a non-simulationist, a special results file is created that is more beneficial to the traffic engineer. This file contains the extracted statistics of interest summarized in several fashions to provide a comprehensive evaluation of the simulation run. A "snap-shot" queuing file is also created that is useful in the calibration of the model to existing data. An animation event file, if so requested, is generated to be used by Proof Animation to display graphically the results of a run.

The model was built to be flexible regarding the parameters such as the number of toll booths, speed of vehicles entering the plaza, traffic volume and distribution of vehicle classes. Other model considerations are coded to be inaccessible to the user, such as algorithms for lane selection and emulation of speed reduction. If necessary, a customized version of the model can be created to replicate a given plaza's unique characteristics should the need for further refinement arise.

4 ANIMATION

The single greatest boost to the use of simulation in recent years has been the incorporation of animation. The ability to view what is actually taking place in a simulation run not only aids in model development and verification but also serves as an effective means to communicate results. Individuals associated with simulation are all too familiar with the frustrations in conveying a point or trying to convince management of the findings of a modeling project based solely on statistical reports.

The TPASS animation background layout is dynamically created at run-time, eliminating the need for the user to spend time with this CAD-like exercise. Virtual coordinates allow for practically any size plaza, yet allow the ability to zoom-in for a close look at a single booth.

The user has full control over play-back speed, fast-forward, freeze-frame, and view angle. This control proves most beneficial when evaluating new configurations or the adoption of an automated collection philosophy. Animation is also useful for observing certain compounded effects of the plaza operation, such as the traffic platooning due to a signal light or the blocking of normally non-queued vehicles (those that may pass through automated equipment) because of excess back-ups in those lanes normally queued. Many of these circumstances would be completely overlooked with only the statistical output of a model run.

5 "PACKAGING"

The user-interface, or "front end" of TPASS is an executable file created using a high-level programming language (BASIC). This interface is graphical in nature and supports the use of a mouse for choosing menu items and data fields. The user can perform all of the tasks necessary for plaza definition, traffic input, overall data file maintenance, operation of the simulation, and display of the statistical and animation outputs, from the main menu of the interface. The user is not required, therefore, to have even a working knowledge of GPSS/H and Proof (although any added degree of proficiency is obviously never a hindrance). These programs are called from the front end automatically as needed.

This front end package contains the required GPSS/H and Proof files and is available to the user in a ready-to-use configuration. The learning curve for use of TPASS is solely based on understanding the parameters related to toll plaza operation. Knowledge about GPSS/H and Proof is not required.

Some toll plazas have unusual characteristics such as branch or satellite lanes, unusual vehicle classes, or stop lights which effect the traffic volumes. The standard TPASS model is not applicable for these plazas, but TPASS can be customized in order to take into account unusual geometry or operating parameters.

6 MODEL CALIBRATION

As with most modeling efforts, TPASS models are usually calibrated using observed data. An obvious exception would be an effort to design a new plaza for which there is no data to observe. The calibration process involves comparison of model outputs with data gathered at the plaza being modeled or from a plaza with similar input parameters. Usually, the most useful output parameter for calibration is the total number of vehicles in queue. This parameter is calculated by TPASS and plotted over time (external to TPASS) for the duration of the model run. Minor adjustments are then made to model inputs in order to close any gap between the TPASS and observed values.

7 RECENT APPLICATIONS

A significant number of transportation agencies are expressing interest in TPASS. The largest project to date was undertaken by the Triborough Bridge and Tunnel Authority (TBTA) in New York City which currently operates ten toll facilities. These TBTA facilities have limited real estate for toll plaza enlargement because of the density of population in New York. For this, as well as other reasons, the TBTA is constantly seeking ways to increase and optimize the capacity of each of the plazas.

The TBTA undertook an aggressive application of TPASS to analyze each of their ten facilities. A number of operating parameters were necessary for these analyses, including current and projected traffic volumes, changes in the toll collection methods in each lane, and the introduction of high-technology systems such as AVI. In order to allow these analyses to be performed accurately and in a timely fashion, SAIC and ASM have customized TPASS for each of the ten facilities in each direction (a total of 20 models). These models have been used to assess the effects of numerous operational changes proposed by TBTA staff and other traffic engineering consultants.

In addition to the capacity optimization study described above, TPASS was also used by TBTA to design a series of proposed changes to the Verrazano-Narrows Bridge toll plaza.

The Verrazano-Narrows connects the boroughs of Staten Island and Brooklyn. Currently, the toll for the Verrazano is collected only in the westbound direction. Proposals for changing to two-way tolls or one-way collection in the eastbound direction have been put forth. In a separate study, TBTA used TPASS to investigate the effects on queuing for each of the tolling scenarios described above. In addition, the TPASS output was used as input for an air quality model which was in turn used to predict changes to the region's air quality under the proposed tolling scenarios.

Initial runs indicated that the existing eastbound plaza could not be configured to handle traffic from one of the approach roadways. Adjustments were made to the model in order to add a "mini-plaza" to increase the number of toll booths serving the congested approach roadway. The results of this study were used to develop an environmental impact statement.

8 OTHER APPLICATIONS

The basic TPASS model can be adapted to model a number of other transportation systems such as parking facilities, weigh stations, taxi stands, fleet washing and maintenance facilities, and construction zones. TPASS places the modeling tool in the hands of the people who are best experienced and equipped to design the input and analyze the results. The engineer/user is not forced to learn a complex modeling language to accomplish the modeling task of the engineering project, but is free to easily implement the modeling task into the project at hand. The expertise and experience of the engineer/user becomes the only limit for the transportation applications of TPASS.

9 SUMMARY

Discrete-event simulation is becoming very popular for modeling transportation systems. The emergence of these modeling languages and animation packages in the PC environment has resulted in the availability of sophisticated simulation techniques to thousands of users.

This new environment has made the development of a software product like TPASS possible. While TPASS is still basically in its infancy, the package has already been applied to complex problems and has proven to be very useful. Previously skeptical users have commented that it accurately portrays what actually happens at toll facilities.

REFERENCES

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AUTHOR BIOGRAPHIES

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