ANIMATION TOOLS FOR THE MICROSIMULATION OF A PUBLIC TRANSPORT NETWORK

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ABSTRACT

Numerous technological advances have made possible the microsimulation of large samples of travel demand on sizeable networks. To effectively explore, analyze and communicate the voluminous results of a microsimulation, an animated sequence or movie can be a helpful though challenging approach. The objective of this paper is to describe the techniques necessary to produce an effective animation with a large set of data and objects using well-known widely-used software. Following the dynamic disaggregate assignment of approximately 193,000 origin-destination trips (derived from smart card transactions) to the four-line, 68-station Montreal subway network coded using a general transit feed specification (GTFS), we propose a visualization solution in which the output data file is processed using MS Excel. The object-modelling required for the animation yields a data structure that facilitates a detailed characterization of network usage patterns. While standard animation tools can express the same dynamic transport network phenomena, they generally provide few, if any, numerical indicators. The Excel animation, however, can serve as a dynamic dashboard for microsimulation results for specific vehicle trips or for the network as a whole. The methodology has the potential to contribute to the analysis of daily transit system operations by effectively visualizing the variations over time of important productivity indicators and as such represents a useful synthesis of a large and detailed datasets.

Keywords: visualization, microsimulation, public transport, smart cards, GTFS

INTRODUCTION

In many urban areas around the world, transit ridership has increased significantly over the past few years. The growing importance of public transit usage and the associated emergence of new challenges relating to crowding and congestion ensure the continuing evolution of methodologies for operational and strategic planning of public transit services.

Contributing to this evolution are new sources of public transit data, notably smart card transactions and standardized electronic schedule formats such as the general transit feed specification (GTFS). These data sources have the potential to permit the systematic analysis of transit systems at an unprecedented level of detail although the sheer volume of information they contain present a challenge with respect to the construction of knowledge and the search for meaning. The development of methods for visualizing these data constitutes an important step in addressing this challenge. Similarly, advanced simulation techniques such as agent-based microsimulation also benefit from visualization tools to synthesize and communicate their outputs which, like smart card data and GTFS, generally take the form of large and complex databases.

Because of their fine spatiotemporal resolution, dynamic microsimulation models are especially interesting subjects for a visualization tool that includes animation. The moving image on its own, however, does not necessarily provide sufficient information for planning or operational purposes. The goal of this paper is to develop an animated visualization tool that, in addition to portraying dynamic phenomenon, also includes numerical indicators of the performance of the system and some of its components. A well-known software package, Microsoft Excel, is used to implement the design. Ideally, the tool would be of practical use to researchers and transportation system planners engaged in the exploration of large quantities of data generated by measurement or by simulation. A microsimulation of the Montreal subway system serves as example application.

The paper has the following structure: The first section reviews the objectives and methods associated with the visualization of spatiotemporal phenomena; the second section presents an inventory of tools developed for the visualization of public transit systems using GTFS or smart card data; the third section briefly describes the data and methodology used to conduct a microsimulation of the Montreal subway system; the fourth section deals with how the results of this simulation can be rendered into an enhanced animation sequence. The final section offers a few concluding comments.

VISUALIZATION OF SPATIOTEMPORAL PHENOMENA: OBJECTIVES AND METHODS

Obtaining a meaningful synthesis of large quantities of data representing complex phenomena presents a constant challenge to transportation analysts and modellers who must communicate the significance of their methodology and their discoveries. Visualization techniques are adopted for this general purpose. The criteria for good design of a particular visualisation tool, however, are not always obvious.

A useful reference for determining appropriate objectives for a visualization strategy is a map use cube (MacEachren, 1994) which evaluates visual representations along three independent axes: task, interaction and users. The task axis represents the visualization’s purpose ranging from “knowledge construction” to “information sharing”. The interaction axis measures the degree to which the user can control the what, when and where of the visualized phenomenon. Finally, the user axis represents the nature of the target audience which varies between a unique individual (typically the analyst) and the general public. The space formed by these three axes (the map use cube) generates a spectrum of possible objectives for a specific visualization effort: exploration, analysis, synthesis and presentation. For example, at the purely exploratory stage where knowledge construction is the task, the visualization must be highly interactive and destined to a very limited and specific audience. At the opposite extreme, the task is the communication of a specific message. In such cases, the audience could be members of the general public and the level of interactivity is low. This range of applications is evident in transportation planning practice where there exists a wide variety of graphs, three-dimensional drawings, geographic information systems and animations used for purposes ranging from project design to public consultation (Hixon, 2006).

When the purpose of the visualization is exploratory or analytical, it is desirable to have a mix of interactive visual and numerical components. Such is the design of “dashboard” visualization methods which are typically developed with the expressed purpose of providing indicators for strategic decision-making (Petit et al, 2012; Telhada et al, 2012). In the Greater Montreal Area, dashboard-type visualization tools have been developed to analyse the data collected through periodic large-sample travel surveys. These tools have been designed to assist in the dissemination of travel survey results to local decision-makers (Chapleau et al, 1997). Also, a Municipal Interactive Leaflet (MIL) has been developed which integrates socio-demographic and travel behaviour information from the most recent travel survey, the Canadian census and GIS-T network data (Morency et al, 2010). In both cases, the visualization tools were developed under MS Excel, thereby facilitating use by a large and diversified audience.

Animation can increase the communicative power of the visualization tool but the resulting message does not automatically contribute to improved understanding. Indeed, the complexity associated with the visualization of spatiotemporal data (whether measured or synthesized by some modelling process) lies in enriching something that is above all analytical. The next subsection constitutes a sample inventory of visualization methods, including animation, that make use of the primary informational ingredients of the present study: archived smart card transaction data and GTFS transit schedules.

SAMPLE INVENTORY OF VISUALIZATIONS OF PUBLIC TRANSIT SYSTEMS

The enormous quantities of data generated by smart-card transactions offer the possibility of constructing very detailed visualizations conditional on the source data being effectively analyzed beforehand. In one application, PowerPoint was used to animate travel demand on an urban bus network using smart card transactions (Chu et al., 2009). Another example of the results of such an exercise is provided by “A Week in the Life of London’s Public Transit System”, (Reades, 2012a) which shows 10-minute interval entry volumes at every subway and light rail station in London. The image was generated using Oyster (smart card) transaction data and some Python code. The result is a non-interactive static image with a level spatiotemporal resolution that effectively communicates the variability of travel demand in the system. The same data was also used to produce an animated sequence of the London Underground network (Reades, 2012b).

M.V. Jantzen (2012b) shows how travel survey data can be represented using an interactive visualization. This visualization method synthesizes the results of an origin-destination survey of users of the 86-station Washington DC metro system. The input data were condensed into an 86 x 86 origin-destination matrix. The author points out that the matrix itself is “hard to analyse” so he constructed an interactive map. The user can choose the station he wishes to study and can select either the origin or destination volumes which are represented by circles with diameters proportional to the demand volume. An example of the same approach applied to the smart card data of the Montreal subway system is shown in Figure 1. The large orange circle represents the origin station entry volumes and the smaller blue circles indicate the destinations and corresponding exit volumes.

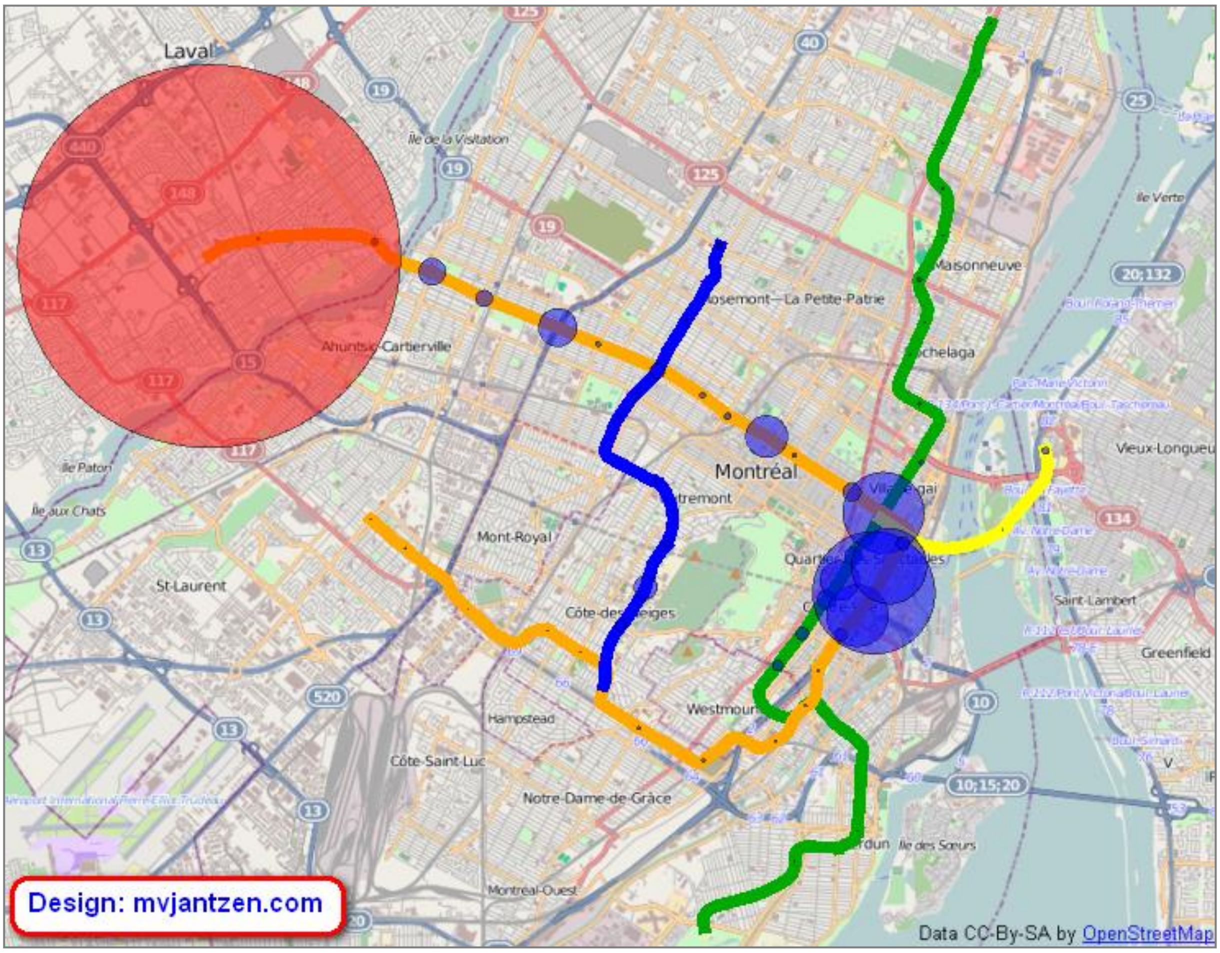


Figure 1 – Visualization of subway traveller origin-destination data

The examples presented above tend to focus on the synthesis of large quantities of data into a clear and meaningful result. However, in situations where the scope or quality of data is unknown or uncertain, it is desirable to have a visualization tool that conserves the resolution of the data and permits a maximal amount of interactivity to allow for a thorough exploratory analysis. To this end, Geographic Information Systems (GIS) constitute a highly interactive visualization tool. The GIS user can alter the presentation of the data using various types of thematic maps that reveal contrasts from the distribution of object attributes (Figure 2). In addition, the user can display in the same window the numerical values of object attributes. Finally, the user can apply filters to the data in order to isolate specific observations (see (Gatalsky et al., 2004) for a detailed discussion). Note that in any projection, some amount of distortion is necessary to ensure that the relevant components of the analysis are visible. In Figure 2, the distances between the platforms of each station have been exaggerated to better distinguish directional flows. The figure shows the various link types and indicates their directions. The passenger volume is represented by the link width. The number of boardings at each platform is indicated using circles of varying diameter.

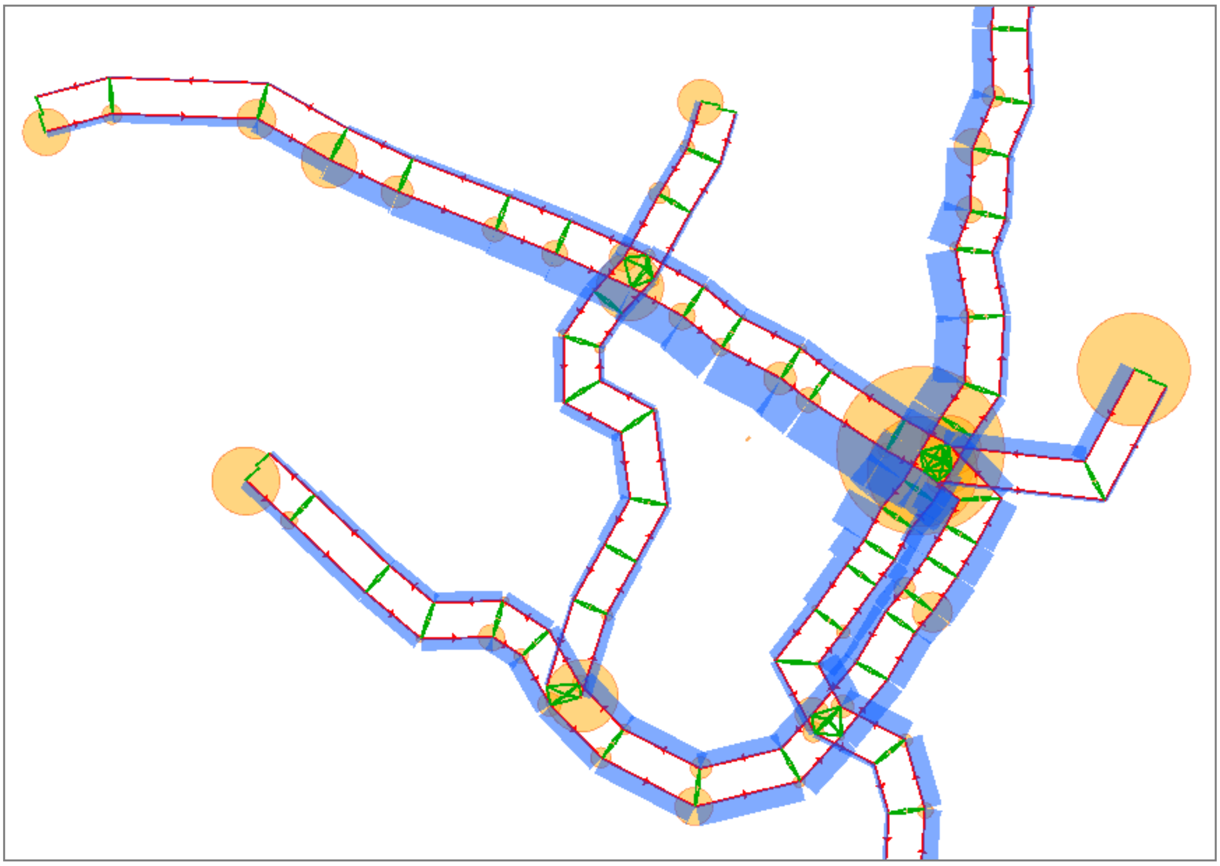


Figure 2 – Static representation of microsimulation output using GIS

A major element not incorporated into conventional GIS use is the temporal variation of a phenomenon. Animation techniques are an effective way of portraying these variations. Because of their high temporal resolution, GTFS make good subjects for animation. For example, the open-source TmsTransitAnimator software (Schedule Masters Inc., 2011) can transform a properly-formatted general transit feed specification (GTFS) into a conventional movie. The result is an aesthetically pleasing synthesis of a large quantity of detailed data describing an entire operational day summarized on a small screen and transmitted entirely in less than two minutes. A different application of GTFS data to the animation of subway trains (Jantzen, 2012a) provides an example of somewhat enhanced interactivity. Here, the speed of the playback can be controlled. In addition, some information about the simulated objects (subway train runs) can be obtained by clicking on them. The animation was constructed using a JavaScript API for Google maps.

While smart cards and GTFS represent instances of transportation data with significant visualization potential, the output of transportation models can also serve as subjects for the application of visualization tools. The TransimsVIS visualizer (Argonne National Laboratory, 2010) that accompanies the open-source TRANSIMS Studio software is one example of an interactive animation tool that uses the results of a microsimulation as input. Developed in Python, the TransimsVIS graphical interface allows the user to query different objects as well as alter the perspective and zoom of the image during the animation. The colouring and size of simulation objects such as vehicles and links can be adjusted by the user. These attributes of the animated objects can also be associated with attributes of the simulated objects. For example, the size of a vehicle can be made to vary with its passenger load and the colour of a link can be made to depend on its functional class. The dashboard elements are mostly absent however; no information on the state of the system is displayed. The freely-available Alexandria case study is a functional application of TRANSIMS microsimulation that includes an animation of the results using TransimsVIS. Moreover, a recent case study applied the same tools to the microscopic animation of the Montreal subway network (Spurr et al., 2012).

MICROSIMULATION OF TRANSIT SYSTEM DATA

This section and the next describe the methodology used to transform detailed information on the transport supply and travel demand associated with Montreal subway system into an animated sequence based on the microsimulation of assigned trips. The method, summarized in Figure 3, is based upon the microsimulation of the 68-station, four-line Montreal subway system using a GTFS containing 30,000 stop time records and detailed smart card transaction data (Spurr et al, 2012). The microsimulation is performed using the TRANSIMS activity-based modelling platform. The adopted methodology differs from standard practice in that the required synthesis of a complete population of travellers was replaced by origin-destination trips derived from archived smart card transactions. Since the Montreal subway operates using entry-only fare validation, the trip-derivation process required the derivation of the alighting station based on the locations of the sequential transactions for each individual smart card. It is impossible to enter the subway using cash. A fare (recorded on a reusable smart card or disposable plastic ticket) must be purchased. Therefore, in principle, every system entry is recorded. The boarding station where the smart card validation is recorded is considered the trip origin and the alighting station is the destination. Approximately 193,000 morning peak-period origin-destination trips are constructed in this way. Subsequently, these trips are used as input for the TRANSIMS router which uses a schedule-based algorithm to generate an optimal path (plan) for each trip based on the schedule information found in the GTFS. As such, the algorithm constitutes a totally disaggregate assignment of trips to the network. The resulting trip plans are read by the microsimulator which models the second-by-second movement of vehicles (subway trains) as cellular-automata. The boarding and alighting of passengers are simulated as well.

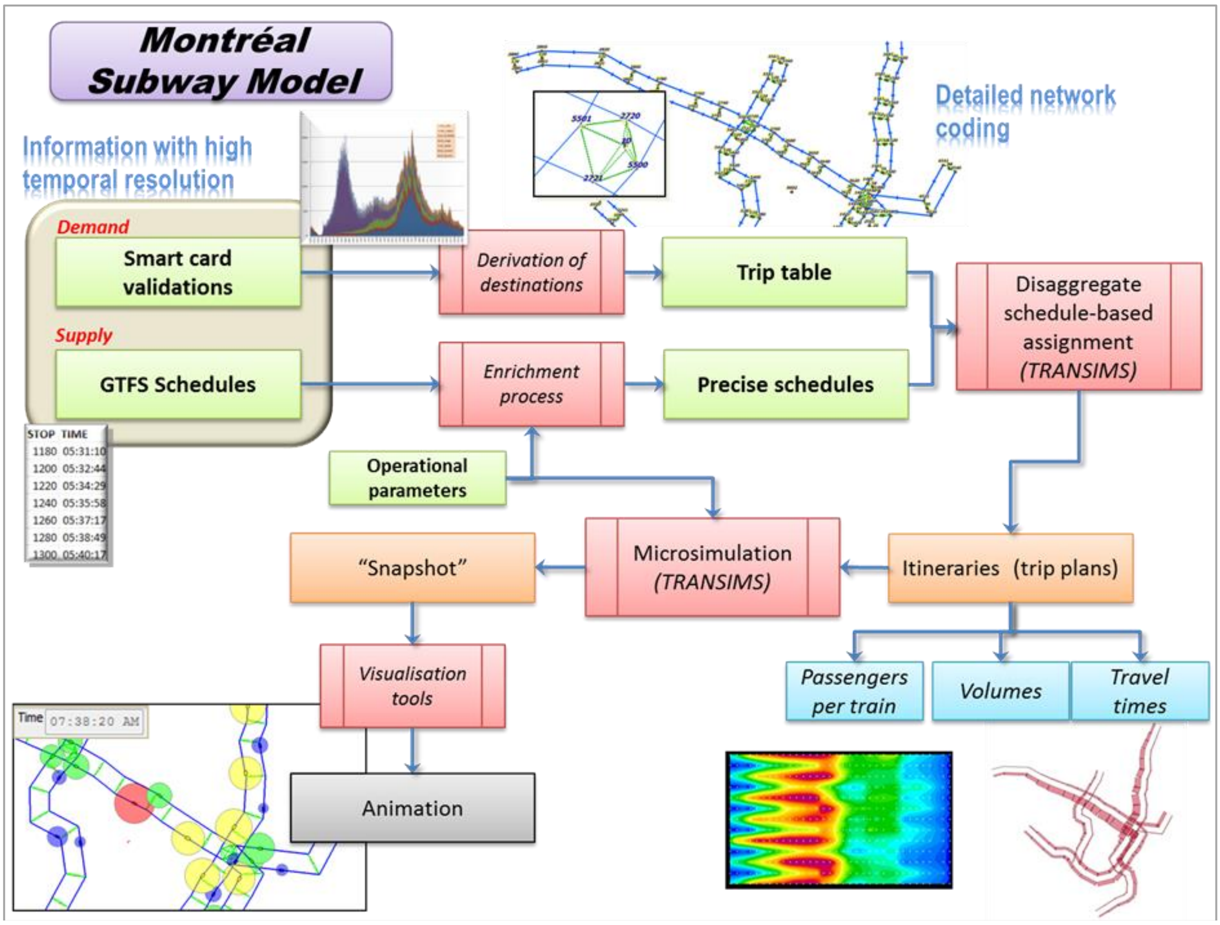


Figure 3 – The microsimulation and visualization process

The TRANSIMS microsimulator represents the movements of in-service transit vehicles as they travel along their planned routes. In this paper, each planned journey of a transit vehicle (a subway train) is referred to as a vehicle-trip. A vehicle-trip is characterized by its planned route (trip pattern) and its departure time from the origin terminus. The microsimulator generates a second-by-second snapshot of each vehicle-trip and stores vehicle-trip attributes in a snapshot file (example shown in Figure 4). Each record in the snapshot file represents a vehicle-trip at particular instant in time. The columns of the snapshot file contain the vehicle-trip attributes including x and y coordinates and the simulated passenger load.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	VEHICLE	TIME	LINK	DIR	LANE	OFFSET	SPEED	ACCEL	VEH_TYPE	DRIVER	PASSENGERS	X_COORD	Y_COORD	Z_COORD	BEARING	
2	109001	19270	4540	0	1	30	15	0	7	9	0	302784.9	5042951.7	0	208	
3	109001	19271	4540	0	1	45	15	0	7	9	0	302778.3	5042939.3	0	208	
4	109001	19272	4540	0	1	60	15	0	7	9	0	302771.6	5042926.9	0	208	
5	109001	19273	4540	0	1	75	15	0	7	9	0	302764.9	5042914.6	0	208	
6	109001	19274	4540	0	1	90	15	0	7	9	0	302758.2	5042902.2	0	208	
7	109001	19275	4540	0	1	105	15	0	7	9	0	302751.5	5042889.8	0	208	
8	109001	19276	4540	0	1	120	15	0	7	9	0	302744.9	5042877.4	0	208	
9	109001	19277	4540	0	1	135	15	0	7	9	0	302738.2	5042865.1	0	208	
10	109001	19278	4540	0	1	142.5	7.5	-7.5	7	9	0	302734.8	5042858.9	0	208	
11	109001	19279	4540	0	1	157.5	15	7.5	7	9	0	302728.2	5042846.5	0	208	
12	109001	19280	4540	0	1	172.5	15	0	7	9	0	302721.5	5042834.1	0	208	
13	109001	19281	4540	0	1	187.5	15	0	7	9	0	302714.8	5042821.8	0	208	
14	109001	19282	4540	0	1	202.5	15	0	7	9	0	302708.1	5042809.4	0	208	

Figure 4 - An example TRANSIMS snapshot file

The number of times a given vehicle-trip will appear in the snapshot file is equal to the number of time intervals during which the vehicle-trip is active in the simulation. Since the animation time interval is a user-specified parameter, the snapshot file can be compressed or expanded according to the required temporal resolution. Also, the simulation period for each vehicle can be adjusted according to the story the analyst wishes to tell. For example, the standard application of a travel-demand model of transit is concerned only with in-service vehicles since out-of-service vehicles do not carry passengers. From an operator's perspective, however, the "behaviour" of out-of-service vehicles is essential for the calculation and optimisation of the costs of providing transit service. In such a case, a method can be developed to simulate transit vehicles during deadhead and interline trips.

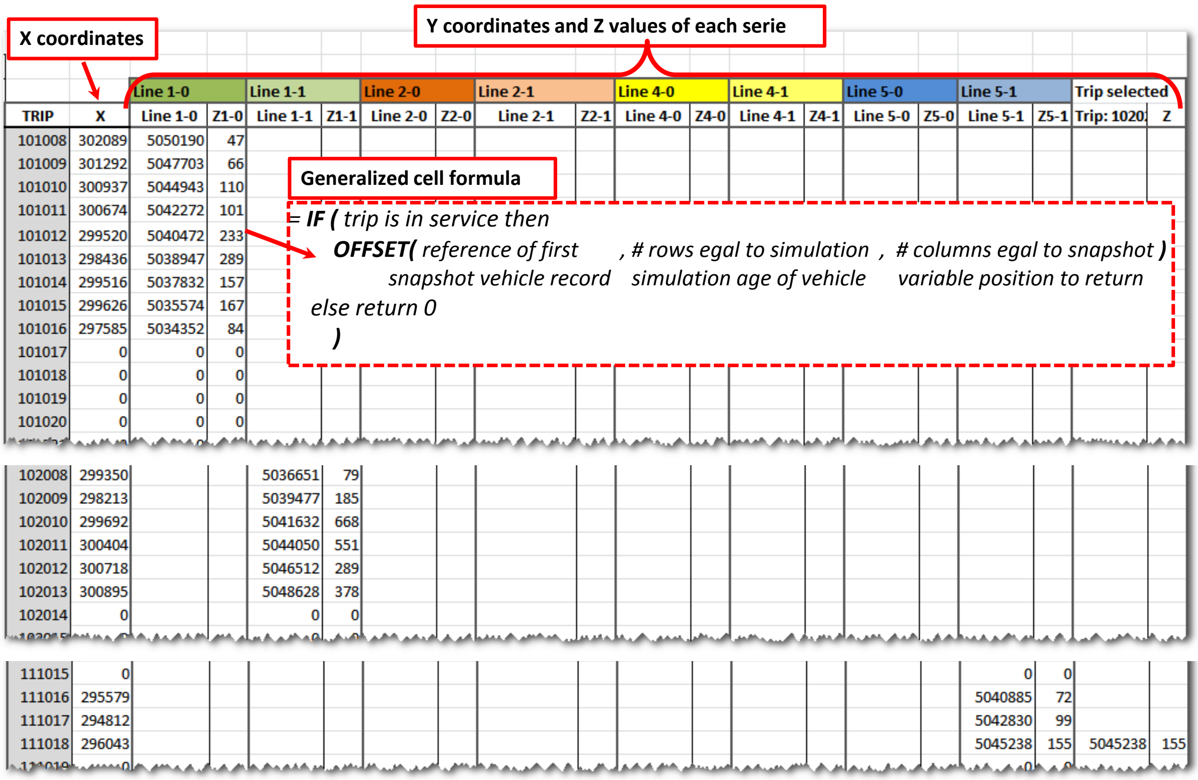
In addition, while the snapshot file portrays the evolution of the system over time, it also contains all the information necessary to construct timelines of various system objects. Here it is possible to make a distinction between cross-sectional and longitudinal analyses. The snapshot is by definition cross-sectional, but a sequence of snapshots can be used, in conjunction with the principles of integration over time, to describe cumulative phenomena such as the number of vehicles or passengers in the system, the number of vehicle-km travelled or the total delay relative to the planned schedule.

ANIMATION IN AN EXCEL SPREADSHEET

The previous section of this paper described how the TRANSIMS microsimulator generates a snapshot file. The current section describes a methodology for using the snapshot file in Excel to produce an animated dashboard that displays dynamic indicators of the state of the system. The goal is to design a visualization tool that, in addition to generating an animated sequence, would provide supplementary visual and numerical information useful for an operator or a strategic planner performing an exploratory analysis of the simulation results. A series of experiments conducted by experts in other fields demonstrated the utility of MS Excel for the presentation of certain spatiotemporal phenomena of which the evolution of the Walmart chain is a notable example (Ferry, 2010). The resulting visualization tools include animation as well as numerical indicators describing the state of the system at each time step. This approach informs the method described below.

Excel generates graphs by plotting data contained in a range of spreadsheet cells. The graph can be made dynamic in one of two ways: enlarging the range (for cumulative effects) or moving the range (for cross-sectional effects). In the present paper, where the intent is to animate the movement of subway trains, the second option is used. Time-varying indicators of the state of the system can be constructed by calculating statistics over the active data range. The heart of the animation tool is an integer variable within a loop structure (written in VBA). The value of the integer increases by 1 with each pass of the loop. The integer value is associated with a time increment which controls the temporal resolution of the animation sequence. Beginning from a defined start time (07:00:00 for example), the current simulation time is computed using the incremental value. At each value of current time, attributes from the corresponding records of the snapshot file are read into a three-column range containing the x-coordinate, the y- coordinate and the passenger load. For a simulation of the Montreal subway from 7 a.m. to 9 a.m., the snapshot file with a resolution of 1 second contains 403,392 records and for a particular second there may be up to 65 active vehicle-trips. With these dimensions, a scan of the snapshot file to retrieve vehicle information would result in a very slow image refresh rate during animation. Consequently, the animation input data must be structured in such a way as to obviate the need for a scan of the snapshot file.

An excerpt of the table containing the input data is illustrated in Figure 5. The table is composed of nine data series – one for each line-direction in the four-line Montreal subway network and an additional series for a vehicle trip selected by the user. Each cell of the table points to a specific record in the snapshot file according to the vehicle number and the current simulation time. A generalized version of the cell formula used to access the snapshot file is included in the figure. The “IF” function will return 0 if vehicle *j* is not service at time *t*. Otherwise, the “OFFSET” function is used to find the snapshot file record corresponding to vehicle *j* at time *t* using three input parameters: the reference cell, the number of rows to offset and the number of columns to offset. No scan of the snapshot data is required since each of the first two parameters is accessed from a pre-constructed index.



		Line 1-0		Line 1-1		Line 2-0		Line 2-1		Line 4-0		Line 4-1		Line 5-0		Line 5-1		Trip selected	
TRIP	X	Line 1-0	Z1-0	Line 1-1	Z1-1	Line 2-0	Z2-0	Line 2-1	Z2-1	Line 4-0	Z4-0	Line 4-1	Z4-1	Line 5-0	Z5-0	Line 5-1	Z5-1	Trip: 1020	Z
101008	302089	5050190	47																
101009	301292	5047703	66																
101010	300937	5044943	110																
101011	300674	5042272	101																
101012	299520	5040472	233																
101013	298436	5038947	289																
101014	299516	5037832	157																
101015	299626	5035574	167																
101016	297585	5034352	84																
101017	0	0	0																
101018	0	0	0																
101019	0	0	0																
101020	0	0	0																
102008	299350			5036651	79														
102009	298213			5039477	185														
102010	299692			5041632	668														
102011	300404			5044050	551														
102012	300718			5046512	289														
102013	300895			5048628	378														
102014	0			0	0														
111015	0															0	0		
111016	295579															5040885	72		
111017	294812															5042830	99		
111018	296043															5045238	155	5045238	155

Figure 5 - Data table used to generate bubble graph and general formula for obtaining vehicle data at a specific instant in time

The steps of the animation algorithm are summarized in Figure 6 and are described in more detail below.

Step 0: Initialization

The snapshot file is sorted by vehicle and then by time and the two indexes are constructed.

Step 1: Compute current time

If the incremental integer variable is defined as *c* and the time increment for each animation frame has a value of *d*, then the current time *t* in terms of number of time increments is computed as $t = cd$.

Step 2: For each vehicle j, determine its simulation age

The simulation age of vehicle *j* is the amount of time the vehicle has been active in the simulation given the current time *t* and is calculated as:

$$\sum_{k=1}^{t} n_{kj}$$

where n_{kj} is the number of times vehicle *j* appears in the snapshot file during time interval *k*. Each n_{kj} is computed before the animation is launched and the values are stored in two-dimensional index (index 1).

Step 3: For each vehicle j, determine the current row r_{tj} of the snapshot file

Since the snapshot file has been sorted (see Step 0), the current snapshot file row (r_{tj}) for vehicle *j* at time *t* is:

$$r_{tj} = f_j + \sum_{k=1}^{t} n_{kj}$$

where f_j is the row number of the first occurrence of vehicle *j* in the snapshot file. The f_j's are also computed in advance and stored in index 2.

Step 4: Retrieve snapshot information

The range of spreadsheet cells that serve as input to the visualizer point to the current snapshot row and retrieve the x and y coordinates of the vehicle-trip, as well as its passenger load. Separate ranges can be constructed for each line or line-direction to create distinct series. In addition to providing information to an x-y graph, the range of cells pointing to current rows of the snapshot file can be used to calculate dynamic characteristics of the system using standard functions (SUM, COUNT etc.).

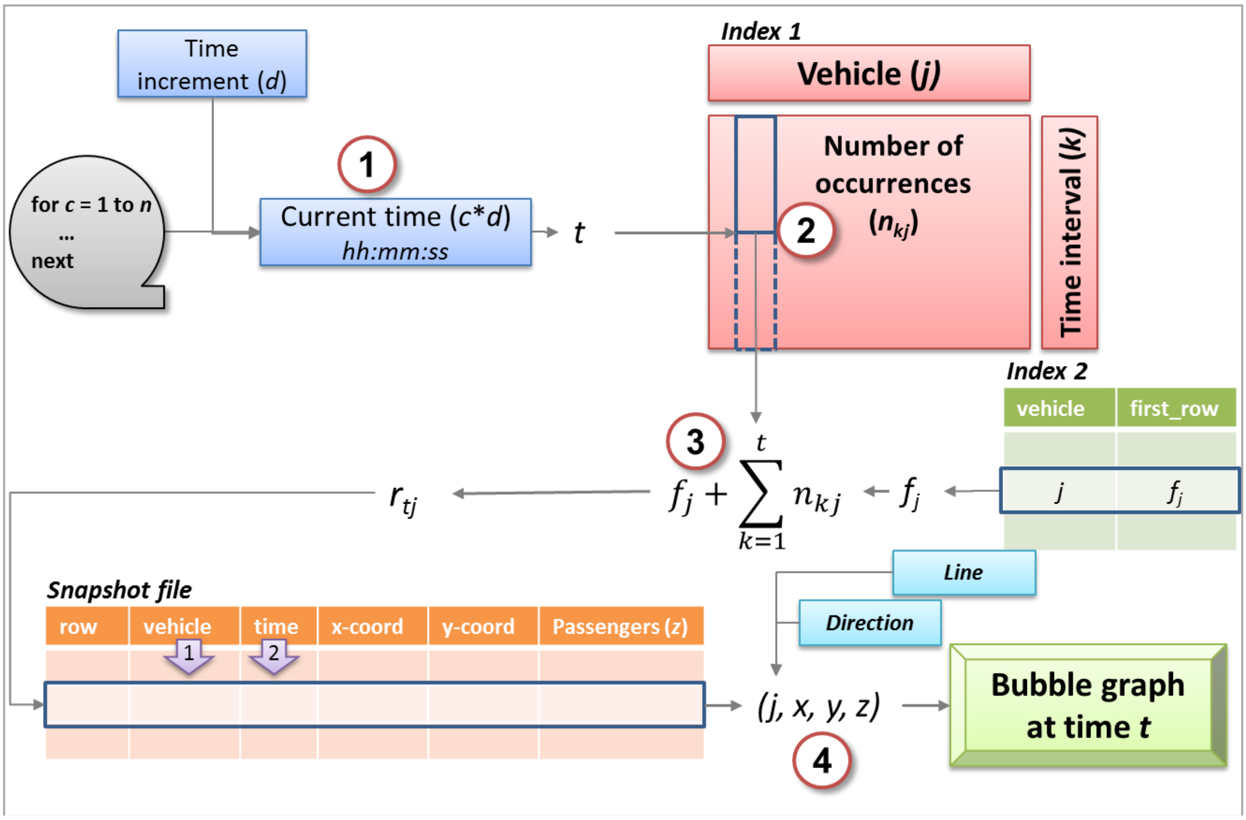


Figure 6 – Animation of a microsimulation snapshot file using Excel

RESULTS

The final result is an animated dashboard (Figure 7) describing multiple aspects of the Montreal subway system at each simulated moment in time. The example presented below is based on snapshot file records for the time interval beginning at 7:00 a.m. and ending at 8:59 am with a temporal resolution of 10 seconds. Therefore, the animation consists of 720 different images or frames. A total of 296 individual vehicle runs carrying 157,665 passengers are represented. The dashboard displays three major instruments simultaneously: an x-y graph animation on the left, animated indicators of the state of the system at the top right and individual trip statistics at the bottom right. Optionally, the animated x-y graph can be replaced by with fourth instrument: a static x-y graph showing the tracks of specific vehicle-trips selected by the user. Each instrument warrants a brief discussion.

XY Graph Animation

This instrument is composed of a GIS-type environment that shows the movement of vehicles as well as the variation of passenger load over the course of the simulation. It is constructed using an Excel bubble graph that requires three input columns (x, y, z). Each bubble represents a vehicle-trip whose position is indicated by the x-y coordinates and the passenger load (the z-coordinate) is represented by the diameter of the bubble.

To enrich the spatial information represented by the bubble graph, a georeferenced image is used as a background. This image is constructed beforehand by superimposing multiple geographic layers in a GIS software. The subway platforms layer is geocoded using x-y coordinates and the layer of subway lines is composed of edges traced between sequential platforms. A polygon layer representing the service territory is included as well. The maximum and minimum limits of bubble graph’s horizontal and vertical axes are fixed to match the spatial extent of the georeferenced image.

Animated indicators

This instrument is composed of a graph and a table, both of which are dynamic. The graph shows the evolution of the number of in-service vehicles as well as the number of passengers in the system over the course of the two-hour period. A vertical line indicates the current simulation time. The table displays current numerical information by line and direction. Moving from left to right, the third column shows the number of in-service vehicles, the fourth column shows the total number of passengers and the fifth column indicates the average number of passengers per train.

Individual trip statistics

The third instrument displays information on each vehicle trip. In addition to being dynamic, this feature is also interactive in that the user can scroll down the list of vehicle trips. Nine vehicle trips are displayed simultaneously. By clicking on a specific vehicle-trip in the table, the vehicle will be highlighted in the animated x-y graph.

For each vehicle-trip, the trip pattern is indicated as well as its start time and the end time. The load profile is displayed with the maximum load points clearly identified. The magnitude of the maximum load is indicated numerically in the second column from the right and the last column on the right represents the maximum load graphically. This element evaluates the maximum load relative to a threshold represented by a vertical red line. In the present example case this threshold, which could be used to evaluate passenger comfort or the probability of finding a seat, is arbitrarily set at 750 passengers per train.

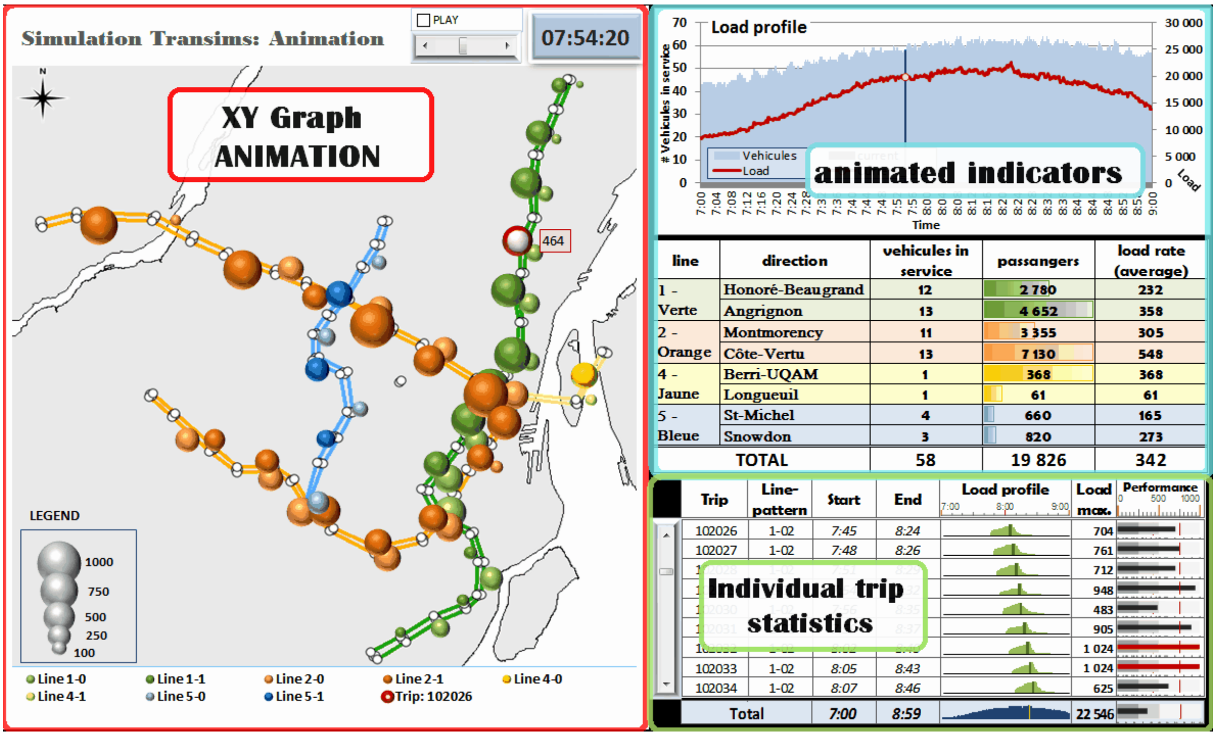


Figure 7 – Animation of the Montreal subway system using Excel

Vehicle tracks

The fourth and final instrument (shown in Figure 8) displays the track or spatiotemporal history of specific vehicle-trips selected by the user. As such, the graphic is not dynamic but it is interactive. The figure represents the number of passengers in the vehicle at each station as circles of varying diameter, as in the animated bubble graph. The number of passengers at each station is displayed numerically using data point labels.

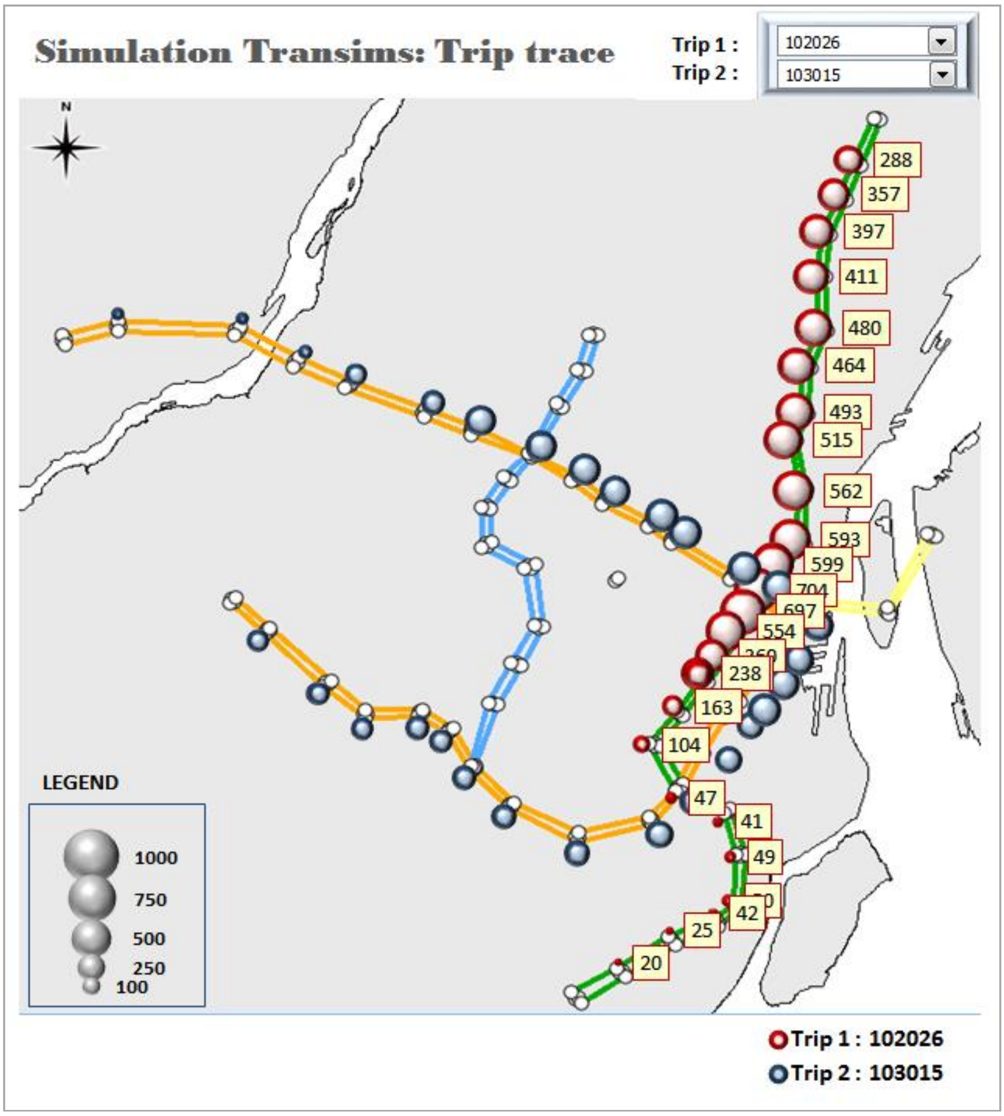


Figure 8 – The tracks of specific vehicle trips selected by the user

CONCLUSIONS

Transportation-related data and models are becoming progressively more voluminous and complex. GTFS, smart card transactions, activity-based models and microsimulation all represent a few instances, among many others, where visual synthesis mechanisms are necessary if the represented phenomena are to be effectively explored, analysed and communicated. This paper has presented the development in MS Excel of a dynamic, interactive visualization tool for synthesizing the results of a microsimulation of a subway network performed in TRANSIMS using smart card transaction data and GTFS schedule information. The interface presents the results in graphical and numerical form and captures the variability of travel demand and transit system behaviour at a high spatiotemporal resolution. In addition, the adopted methodology is based on a totally disaggregate approach to data modelling that conserves all the spatiotemporal variation contained within the data throughout the analysis. Finally, the methodology presented in this paper may contribute to bridging the gap between "big data" and decision-making in transportation system operations and strategic planning. For example, the visualization tool described above has potential applications in the evaluation of transit capacity, the study of congestion in public transit systems, the optimization of transfers between public transit vehicles, and crowd safety and control. The approach is generally applicable to any context where high-resolution spatiotemporal data representing transportation supply and demand are available.

An important extension of the methodology would be the inclusion of bus service. Currently in Montreal, detailed and precise information on the location of city buses is unavailable since most buses are not yet equipped with a GPS receiver. Animated dashboard-type visualization tools analogous to the ones presented in this paper can be constructed when and where such data exist.

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NOTE

The opinions, facts and comments in this paper are the sole responsibility of the authors and do not necessarily represent the views of the collaborating institutions. Numerical results are presented solely for the purpose of demonstrating the methodology.

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