

*Architecture for the Modeling and Analysis
of Rapid Transit*

A-MART

Minor Appendix K
Model Comparisons

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Introduction

In order to understand the performance of stations, we needed to simulate the behavior of passengers on the real layout of stations to determine cause and effect. There are various simulation tools available and we researched transportation specific tools, diverse modeling and simulation tools as well as software that would allow us to develop our own model. We found seven candidates which are TranSims, Arena, CPN tools, C#, Excel, MATLAB and Pajek. Detailed information are given as follows:

TranSims

One of the first open-source packages the team found, TranSims is very domain specific towards the transportation realm, as given away by its name, but not specific to the domain of rapid transit. We found that the simulation, while network based, was not at all focused on enabling the analysis of crowding along platforms or in a train or other part of a system, and therefore this software was at a significant disadvantage.

"Transportation Analysis Simulation System (TranSims) is an agent-based transportation forecast model developed by Los Alamos National Laboratory. It is an integrated set of tools developed to conduct regional transportation system analyses. With the goal of establishing, TranSims is an ongoing public resource available to the transportation community.

The TranSims software simulates real-time movements of individual vehicles on a regional transportation network and estimates the air pollution emissions generated by these movements. It shows how a synthetic population moves throughout a metropolitan area via auto, transit, and non-motorized modes as part of a daily routine. It simulates the activities and time use of every modeled traveler during the course of the day, or days, including their vehicles. TranSims provides a high level of detail and accuracy not previously available."

- More information could be found at <http://transims-opensource.org/>

Arena

The second simulation tool we considered, Arena, is discrete-event based simulation software designed for business analysis. It is widely used in dealing with queuing problem. We found that Arena is very suitable for modeling passenger flow in rapid transit system with analysis report. However, it is hard to simulate the performance of trains. In addition, Arena can not be used to simulate abstract station so that it could only be applied to station level in our case and therefore this software was disadvantage with extension

"Arena Basic is simulation modeling software designed for business consultants and business analysts. It can also be widely deployed as a desktop tool and serve as a natural extension to those who use various flowcharting packages such as VISIO to document business processes.

Arena Basic simulation software is most effective when modeling and analyzing business, service, or (non material handling intensive) manufacturing processes or flows.

Arena Professional is targeted toward industrial or manufacturing systems engineers, business analysts, consulting firms providing services to a specific industry/application, or corporations with a dedicated simulation team. Arena Professional simulation software is most effective when analyzing complex, medium to large-scale projects involving highly sensitive changes related to supply chain, manufacturing, processes, logistics, distribution, warehousing, and service systems. "

- More information could be found at <http://www.arenasimulation.com/default.asp>

CPN tools

CPN tools was introduced to the team by advisor. It is a tool for editing, simulating and analyzing Colored Petri Nets and Colored Petri Nets is a formal modeling language that is well suited for modeling and analyzing large and complex systems. CPN tools is very powerful and low level language. In terms of

that, it would take sometime to learn it. In addition, we will not get a good visualization if we use CPN tools to model a rapid transit system.

"CPN Tools is a tool for editing, simulating and analyzing Coloured Petri Nets. The GUI is based on advanced interaction techniques, such as tool glasses, marking menus, and bi-manual interaction. Feedback facilities provide contextual error messages and indicate dependency relationships between net elements. The tool features incremental syntax checking and code generation which take place while a net is being constructed. A fast simulator efficiently handles both untimed and timed nets. Full and partial state spaces can be generated and analyzed, and a standard state space report contains information such as boundedness properties and liveness properties. The functionality of the simulation engine and state space facilities are similar to the corresponding components in Design/CPN, which is a widespread tool for Coloured Petri Nets."

- More information could be found at <http://wiki.daimi.au.dk/cpntools/cpntools.wiki>

C#

C# is a multi-paradigm programming language that encompasses functional, imperative, generic, object-oriented and component-oriented programming disciplines. It is suitable to create any element in rapid transit system and simulate the performance both passengers and trains. In terms of its object-oriented characteristic, it is extendable for our simulation from a lower level.

"C# (pronounced C Sharp) is a multi-paradigm programming language that encompasses functional, imperative, generic, object-oriented (class-based), and component-oriented programming disciplines. It was developed by Microsoft as part of the .NET initiative and later approved as a standard by Ecma (ECMA-334) and ISO (ISO/IEC 23270). C# is one of the programming languages designed for the Common Language Infrastructure."

- More Information could be found at <http://msdn.microsoft.com/en-us/vcsharp/default.aspx>

Excel

Microsoft Office Excel is widely used for calculation and data analyzing. Ideally, we would like to know the performance of the passenger in a rapid transit system every second. In this case, a lot of data needs to be generated in a certain format. We think Excel would be a good choice to process the data and plot graphs.

"Microsoft Excel (full name Microsoft Office Excel) is a spreadsheet-application written and distributed by Microsoft for Microsoft Windows and Mac OS X. It features calculation, graphing tools, pivot tables and a macro programming language called VBA (Visual Basic for Applications). It has been the most widely used spreadsheet application available for these platforms since version 5 in 1993. Excel is part of Microsoft Office."

- More information could be found at <http://office.microsoft.com/en-us/default.aspx>

MATLAB

MATLAB was a clear candidate due to its wide acceptance in the community, relative high familiarity rate, and power to work complex problems. Largely, however, we were restricted on licensing issues and the majority of the team did not have the training to develop or even use a simulation developed in MATLAB.

"MATLAB is a numerical computing environment and programming language. Maintained by The MathWorks, MATLAB allows easy matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. Although it is numeric only, an optional toolbox uses the MuPAD symbolic engine, allowing access to computer algebra capabilities. An additional package, Simulink, adds graphical multidomain simulation and Model-Based Design for dynamic and embedded systems."

-More information could be found at <http://www.mathworks.com/>

Pajek

Pajek is very suitable and widely used for analyzing and simulating large networks. Even though we could take the whole rapid transit system as a network, the analysis of crowding was not covered and therefore this software was at a significant disadvantage.

"Pajek (Slovene word for Spider) is a program, for Windows, for analysis and visualization of large networks. It is freely available, for noncommercial use."
-More information could be found at <http://vlado.fmf.uni-lj.si/pub/networks/pajek/>

Evaluation Criteria

We then had to determine which option was best suited for our project. To do this we first defined the requirements of the tool in which we could evaluate each option's ability to deliver by scoring each option. The following requirements were defined for our tool:

Learning Curve

Since we had to develop a model which could be widely used in different areas within the time constraints of the course we had to find a tool that would not require too extensive of a learning curve. Of the candidates Transim is developed for large intermodal regional transportation systems and is very complex and requires training sessions. Similarly, Pajek was developed in Slovenia for large network analysis and did not appear to be easily learned. C# is easy to learn and designed for rapid prototyping. Anyone who knows Java or other objected oriented language can learn to use it quickly.

Data collection

Data and the ability for a model to assimilate input data and provide output data in a usable form is essential to a project like this.

Licensing

Some tools are not free for public use such as Arena and CPN tool or have limited versions available for student use. Both Transim and Pajek are free for non-commercial use. C# is totally free to download on the internet and to use for development purposes.

Integrity

Arena is widely used for discreet event simulation. CPN tools is extensively used for rapid prototyping but depends very heavily on the accuracy of the decisions made in forming the nets. Excel is widely used for industry data analysis.

Extensibility

In the project, we introduce the zooming level concept in which critical levels are the station, neighborhood and track. The model should be able to extend to a higher or lower level. C# is an object oriented language which makes it easy to build on and extend. Pajek, Matlab and Excel are limited for extension. Other tools are domain-specific to the rapid transit or transportation in general domain.

Visualization

Transim has various visualization methods available. Arena has decent architectural view of process, but not as configurable or intuitive as others. CPN tool is not good at visualization as it is highly specific to the abstract domain of colored petri nets. C# has the ability for the user to define the visualization and is extremely extensible.

Conclusion

Based on the criteria we defined, weights are given to each simulation tool from one to five. The below matrix represent the scoring of each option against the requirements. According to the composite scores, as you Can see, C# was the highest score. Before moving forward with C# we decided to attempt modeling of stations in both CPN tools and Arena which can be viewed in Appendices U and V. Finally, we decided to use C# as our modeling language and use Excel and MATLAB to assist processing data.

		Transim	Arena	CPN Tools	C#	Excel
Criteria:	Learning Curve	Developed for large intermodal regional transportation systems-very complex. Requires Training sessions.	Relatively simple with built in guides and tutorials	4- Easy to model, simulate and analysis	Easy to learn and perform rapid prototyping.	Commonly used
		2	2	1	4	5
	Data Collection	3- Data collection capability, unknown if access station platform information ia available.	easy to import and anlyze data - stochastic based	5-Easy to import and export in various forms	Easy to import and export data in various forms	Easy to save data that is readable by Excel
		5	3	4	5	5
	Liscensing	free for non commercial use	2- Student version is free, but severly limited, full version only avail in labs	3-License is required.	Free for use from Microsoft	We all have licenses
		5	2	3	5	5
	Integrity	Sponsored by DOT	widely used for Discreet Event Sim	5- widely used in modeling and simulating	Extensively used for rapid prototyping bu corporations.	Extensively used in industry for data analysis
		5	5	3	4	4
	Extensibility	Complex, designed for intermodal transportation analysis. Requires extensive work to add capabilities for platform analysis	3- Arena is discreet event simulation only, specially models resources, with trains as resources, it is not easy to expand to the system	3-Generic, but Easy to add additional analysis and extend	The object oriented nature makes it easy to build on.	Easy to add additional analysis
		2	3	3	5	4
	Visualization	Various visualization methods available.	decent architectural view of process, but not as tailorable as others	Horrible, ugly interface	Comes with extensive visualization functions for real-time and post mortem analysis	Excellent graphing tools
		4	2	1	5	5
Composite Score:	3.8	2.8	2.5	4.7	4.7	
Selection:	No	Possible for model validation	No	Yes, for modeling of the system	Yes, for data visualization	

Figure 1. Quantitative Evaluation of Simulation Framework Options