

SERVER-CLIENT APPLICATIONS AIDED BY GENERIC SIMULATIONS REGARDING EARTHMOVING OPERATIONS IN CIVIL ENGINEERING PROJECTS

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ABSTRACT

Simulation is a powerful tool whose potential has not been fully explored and applied within the Civil Engineering context. Despite Discrete Event Simulation benefits and capabilities, its complex and time consuming elaboration makes it an unpractical choice along this field. This article shows an example regarding earthmoving operations in Civil Engineer projects reflecting how simulation models can be easily and quickly deployed fitting customer needs and requirements. By Transforming simulation models into specific purpose applications remotely simulated barriers such as knowledge, experience, time and software restrictions are fulfilled delivering simulation benefits remotely. The goal of this work was to create a Web based application to support the decision making process in the construction management field. This work was achieved by integrating the Arena software as the remote simulation engine with Visual Basic as a programming platform used to build up the infrastructure needed to manage a Server-Client Based Simulation system.

1 INTRODUCTION

The use of simulation in construction operations, such as earthmoving systems, has not been generally used by construction companies due to the lack of confidence, experience and knowledge on its application (Schramm, Silveira et al. 2008). Civil engineering is probably one of the fields in which simulation application is being poorly and lately applied (Halpin, Jen et al. 2003) with just a few approaches in a nonacademic context (AbouRizk and Hague 2009). Therefore, some other methods such as spreadsheets, queuing theory (Alkass, et al. 2003), CPM - PERT methodology and some mathematical approaches (Smith 1999) are still being used in order to analyze the productivity and efficiency in earthmoving operations through the estimating of costs and times among other variables disregarding simulation advantages.

This article suggests a solution to this problem by setting up computer applications for a specific purposes regarding Earthmoving operations aided by generic remote simulations through a Server-Client platform. Through this system, simulation models can be easily replicated in most similar situations in a personalized way by a wide variety of users. Deep knowledge, experience and specialized software around simulation use are not totally required through the use of this platform. The Discrete Event Simulation is remotely and automatically done by a server. Under this method, users can obtain all the advantages, possibilities and capabilities that simulation can offer without interacting directly with it.

Through this approach, Discrete Event Simulation (DES) can become a more attractive and suitable alternative among civil engineering project management; considering earthmoving projects as a first attempt. In addition, cost and time analysis, risk management and evaluating the “*What if?*” can be the most valuable contributions to this field among other benefits. Furthermore, using DES as a tool to support the planning phase on a project can lead into a more accurate and productive execution, obtaining considerable savings in time, efforts and money.

Since internet was developed in early 1990's, the simulation community was forced and encouraged to incorporate their work, experience and knowledge into this global platform attracted by the numerous benefits and technologic potentials offered by the World Wide Web (Bencomo 2004). Even though, Web Based Simulation is still on a research stage (Byrne, et al. 2010), with just a few number of real and efficient applications considering real customers needs and requirements (Wiederman 2001). As said by Byrne in 2010, the Web Based Simulation holds a great promise as a web service-oriented infrastructure and so far it is an emerging area within the simulation field, leading into a huge concept to develop.

Web Based Simulation (WBS) concerns a system in which internet plays an important and active role during the simulation process. Byrne (2010) divides WBS into seven categories or paradigms. In this paper, the term Server-Client Based Simulation makes reference to the *Remote simulation and visualization* paradigm established by him. In this approach, the internet plays a mediating role by transporting information between the user and a remote computer. A server works mainly as a simulation engine administrating and managing a simulated projects library for specific purposes. *Common Gateway interfaces* or *socks* are also important tools to manage the communication protocols among clients and servers platforms (Bencomo 2004).

In this case, setting up the platform implies also the design of desktop applications that users may need in order to interact with the whole system. This interaction concerns the model input building, the remote connection controllers and the results interpretation module. Under this scheme, these applications must be custom-designed in concordance with the respective simulations on the server.

2 ROCKWELL-ARENA AND VISUAL BASIC CAPABILITIES

Combining the Arena Simulation Software with any programming platform such as Visual Basic in an independent, remote and asynchronous way is probably one of the most important facts that determine whether or not a simulated model is capable of being reused or used by a final, unknown and external user for a particular job under this concept. This integration not only allows to create a control panel from which every single aspect in a simulation is capable of being controlled, defined, manipulated or created by the user in a custom way, it also brings to simulation the opportunity to interact with databases, files, graphical interfaces, port connection abilities and so many other unrestricted possibilities found in programming platforms.

Arena and Visual Basic are very compatible tools that allow almost any kind of information exchange. When used properly, the combination of these tools could lead into a wide range of potentials and abilities. It is just matter of an extensive and careful programming work, comprising the structured, the event and the object-oriented programming paradigms in a creative way.

During this work, the need for relaying on Visual Basic capabilities was very important in every single step. Visual Basic was not only used to design the entire platform, it was also important as it was the intermediary between the user and the simulations, telling them how to behave and build their programming structure to fit the user needs and requirements.

Before getting deep in this work, it is important to highlight the main idea behind this work: Simulation models can be built, modified and controlled from an external panel, source or platform in order to behave and think in a custom and generic way. This is important considering the need for fitting the simulation models with the user needs inside a predefined context or environment.

3 EARTHMOVING OPERATIONS

Estimation and analysis around Earthmoving operations is a problem that has intrigued many researchers around the world for years (Smith 1999). So far, many simulation attempts were done in order to estimate earthmoving productivity obtaining significant results, but finding limitations on real projects applications; relegating the idea mainly on academic institutions for research purposes (Hajjar and Abourizk 1999). In those attempts, some ways for executing Earthmoving Operations are taken into account considering their importance, relevance and frequently use in mining and Civil Engineering projects (Shi and AbouRizk 1994; Singh 1997).

The earthmoving process involves the excavating, transport and dumping phases, stages that are repeatedly done during the whole process. This job can be accomplished by a Scraper being pushed by a Bulldozer and a Truck being loaded by an Excavator or a Loader (Figure 1), followed by a transport phase comprising a custom-designed road configuration. The productivity and performance of this simple but intricate process concerns many variables such as equipment capabilities, soils, terrains, distances, slopes and traffic among others.

To begin with, it is important to establish the variables that influence the performance and development of this process. These variables belong mainly to the transport and excavation phases. During the transport phase, the moving velocity is known as one of the most important undetermined variables to estimate due to the numerous aspects that define it. Many efforts were done in order to understand this issue. For example (Perdomo 2001) took a deep analysis on the several physical and technical aspects concerning engines and machines construction, getting an accurate and complex approach. (Alkass, et al. 2003) proposed an interesting formula extracted from a linear regression technique which is valid from his perspective, studies and objectives, concerning only the variables within their approach. Somehow, the lack of a general mathematical formula that explains its behavior in relation to other aspects is still a fact; complicating its understanding and possible forecasting. The analysis done in this work comprises variables such as road conditions, equipment features and load aspects, restating previous approaches.



Figure 1: Earthmoving Types

Nowadays, civil engineers rely on tables (Figure 2) included in the machine specifications manuals comprising aspects such as machine gross weight, power and road rolling resistance plus grade resistance, in order to study the behavior of the travel speed. Using these tables to calculate the speed can be a very tedious and extensive process considering the complexity level of the possible road configuration to analyze. Furthermore, the numerous measures that have to be taken extend the time required to do this job. To improve this process, a linear regression is also done by taking the necessary data from some of these tables, elaborating a linear regression analysis. This process leads into a mathematical formula that comprises the aspects mentioned above. Then, this formula is included into the simulation models whose inputs and constraints are defined further by the user, getting finally an automatic and generic sequential procedure considering any kind of road configuration and its attributes.

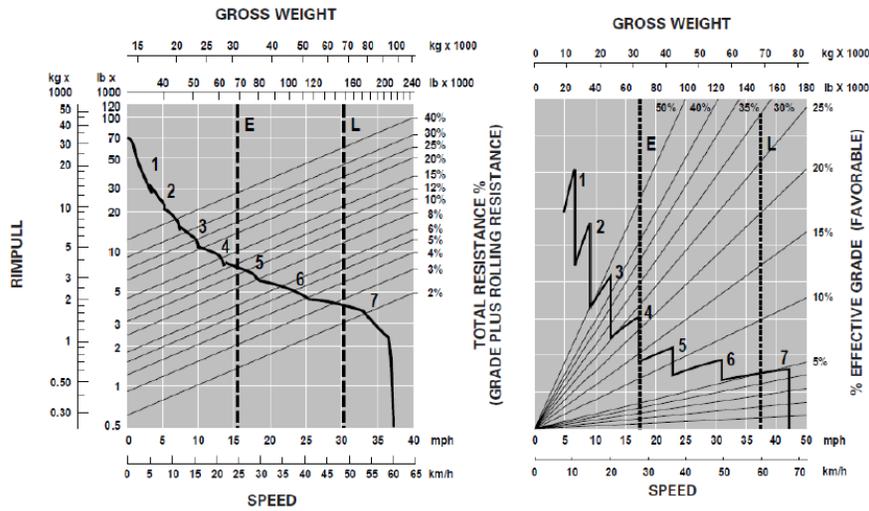


Figure 2: Caterpillar Performance Tables (Caterpillar 1997).

At this point, it is important to work on the features that feed this analysis. First, the need for having a generic way to implement a set of distance segments configuration with the attributes associated with each one such as length, slope, and terrain are very important. The remaining unknown in this analysis is the gross weight associated with the moving entity on the road configuration system. This feature is defined at the previous stage on the earthmoving process; the excavation phase, where the type of soil, density and machine load capacities are defined. From a general perspective, the excavation is the process that determines the gross weight of the transfer entity; being this a truck or a scraper. Here, the need of establishing the information associated with the machine specifications such as load capacity, weight, and soil attributes such loose/Bank densities will help the simulation model to compile those aspects into the model and finally estimate the most appropriate travel speed under those variables or conditions. This article will show how these and other important aspects such as costs, times and other variables are managed through a series of desktop applications designed exclusively to create, organize and set the main data that the simulation model will need to run further on a server platform.

4 SETTING UP THE INTERNET PLATFORM

Using internet as a platform to launch computational tools in a world-wide range for specific purposes, being thought or analyzed by simulation models, can be a very productive practice as long as it represents a considerable cost-time saving alternative (Byrne, et al. 2010). Relying on Discrete Event Simulation when building complex and accurate software can be a very less time consuming and accurate activity as simulation can be used mainly to do the tough part of any application in an easier and faster way when used properly.

It is important to define the main agents, functionalities and relations along the system. As shown in Figure 3, internet is used as a global interconnector between servers and users. These connections are done using defined IP addresses and PORTS in order to share information between servers and users considering multiple possibilities. Once this structure is defined, some roles for each member are required to be set. In addition, some questions need to be answered before continuing. Who will build up the information? How is this information going to be built? Which aspects are contained in that information? How and where is that information going to be sent? What will be done with that information? What kind of response is expected? These questions are very useful as they help to identify the main actors, interactions and actions along the system.

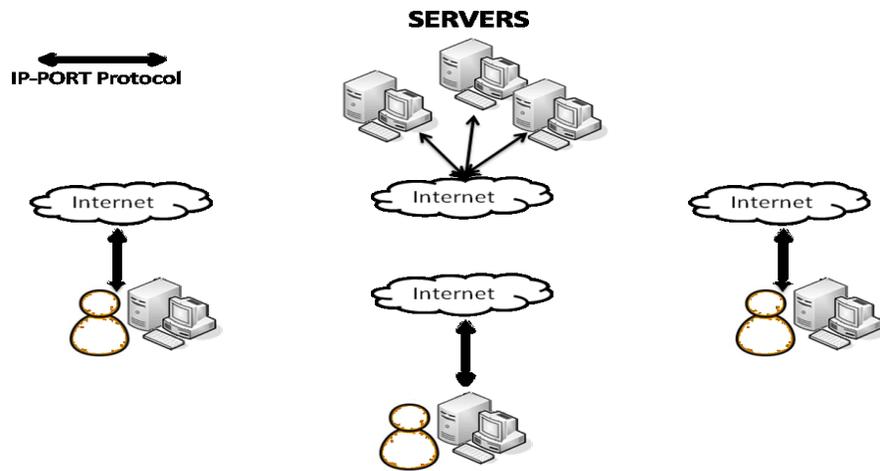


Figure 3: System Infrastructure

4.1 Server Platform

This is one of the most breakable, sensible and essential member in the whole chain as it is in charge of doing the tough tasks along the system. Its functions not only concern the storage and deployment of the simulation models, it is also in charge of managing all the incoming connections as well as satisfying the users requests by filtering the reports originated by the simulations (Figure 4). In this element, there is something called *resident program or application* which remain at a background stage allowing the server to listen every single incoming connection at all time (Figure 5). The connection with the user is achieved by a fixed IP address and a fixed PORT both embedded and predefined in the user and server application. After the user hooks into the server and drops the necessary information to run the simulation, the user is held until the information is incorporated and processed into the respective simulation, finally obtaining the reports or results. These reports are automatically modified into a friendly report that can be saved or stored anywhere in the computer belonging to the user. Only at this point, the user is unhooked from the server, resetting the server for the next user or information package arrival.

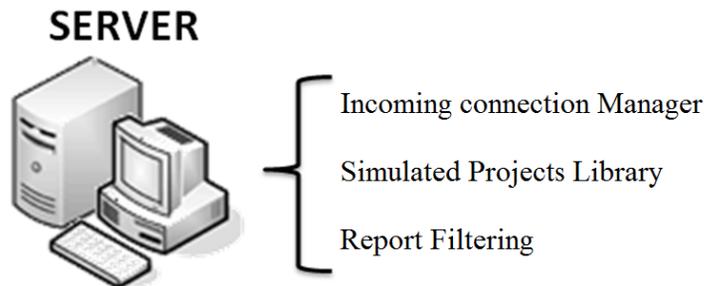


Figure 4: Server Platform

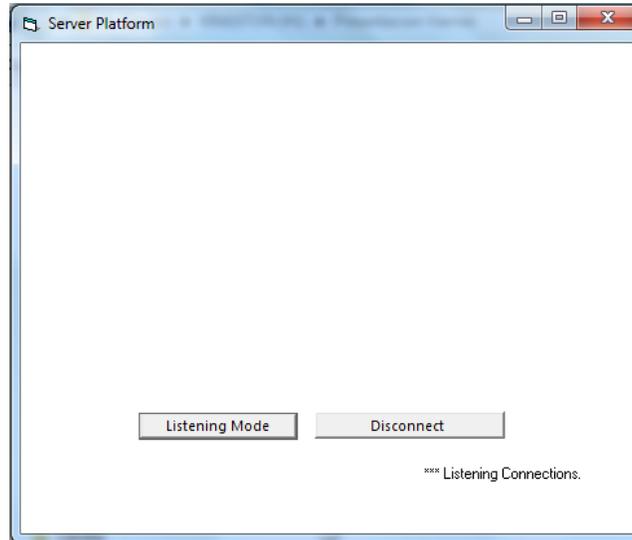


Figure 5: Server Platform.exe

4.2 Client Platform

Having established the main actor on the chain and therefore the IP addresses and PORTS need along the system, the *Client Platform* is the key needed to enter the different places on the system. As shown on figure 6, this is the place where all the information is created (*Data Base Manager*), managed and organized (*Control Panel*), sent and received (*Remote Connection Manager*) and Interpreted (*Report Manager*). In content and shape, these aspects vary depending on the simulations or projects stored at the server, but essentially they are basically required in future projects.

To begin with, the very basic data such as machines, soils and other important information must be created. For the specific operations or simulations mentioned on this article, some root features are important to be considered as the main input for the system. Earthmoving operations relay on important fixed data such as soils, terrains and machinery characteristics. Within the soil and terrain data, aspects such as type of soil as well as Loose and Bank densities among others characteristics affect directly the behavior of the system. On the other hand, the machine type and its characteristics such as technical specifications and failure historic information are also important features that may need to be established at the Data Base Manager. These aspects will determine the whole costs and time needed to accomplish the earthmoving process under an input project data.

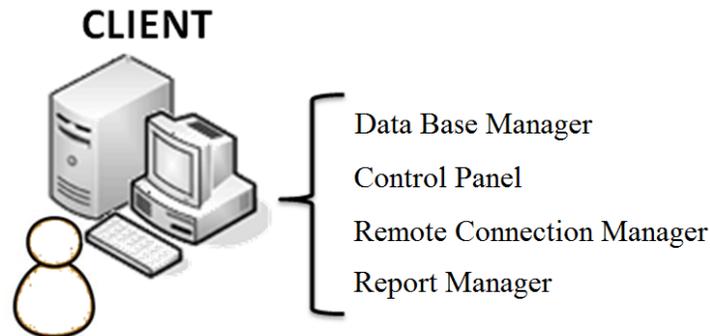


Figure 6: Client Platform

4.2.1 Data Base Manager

The idea behind the *Data Base Manager* (Figures 7-10) is to let the user create his own data with soils, terrains and equipment, information that will be used subsequently to set the files or information packages that will be sent to the respective simulation on the server. Those files contain information such as variables, resources and times among other aspects that the simulation will use to program its logic and build itself, behaving according to the user needs in a generic and flexible way. This module is used only to create the very basic information that supports any kind of simulation. After the data base is created, the following module is used to organize a consolidate all the project information in one single file or package referring to the information already created on the *Data Base Manager*.

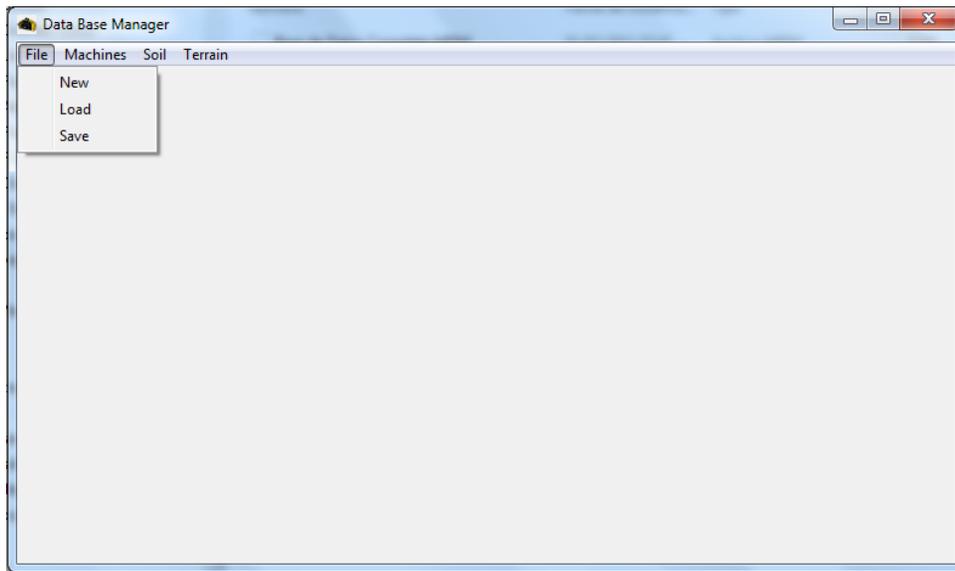


Figure 7: Data Base Manager

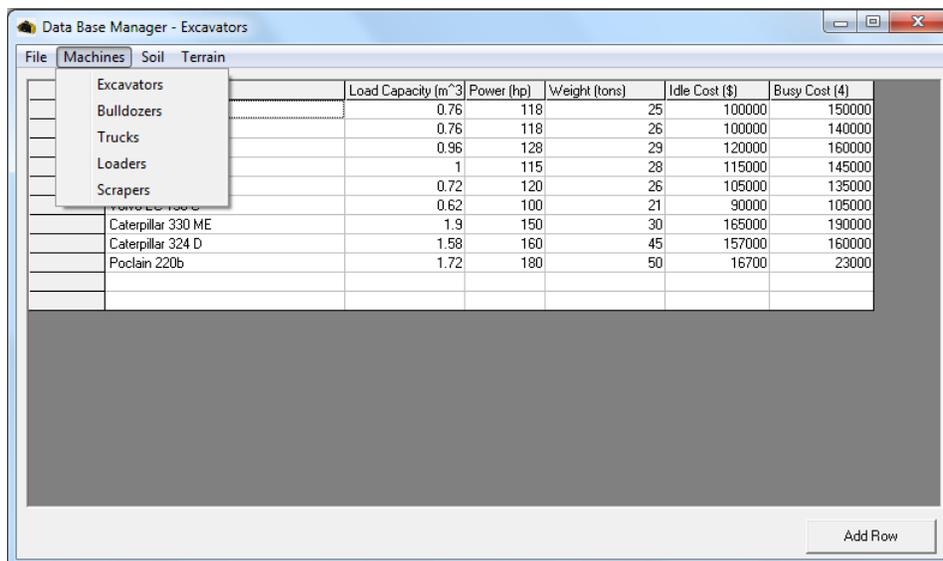


Figure 8: Data Base Manager – Resource Data

The screenshot shows a window titled "Data Base Manager - Soil". It has a menu bar with "File", "Machines", "Soil", and "Terrain". Below the menu bar is a table with the following data:

Soil Name	Bank Density (Kg/m ³)	Loose Density (Kg/m ³)
Basalto	1960	2970
Bauxita	1420	1900
Caliche	1250	2260
Carnotita	1630	2200
Ceniza	560	860
Arcilla Lecho Natural	1660	2020
Arcilla Seca	1480	1840
Archilla Mojada	1660	2080
Arcilla y Grava Seca	1420	1660
Arcilla y Grava Mojada	1540	1840
Antracita en Bruto	1190	1600
Antracita lavada	1100	1100
Ceniza Carbon Bituminoso	600	700
Bituminoso en bruto	950	1280
Bituminoso Lavado	830	900
Tierra apisonada y suelta	1510	1900
tierra Excavada y Mojada	1600	2020
Tierra Marga	1250	1540
Granito Fragmentado	1660	2730
Grava de cantera	1930	2170
Grava Seca	1510	1690

An "Add Row" button is located at the bottom right of the window.

Figure 9: Data Base Manager – Soil Data

The screenshot shows a window titled "Data Base Manager - Terrain". It has a menu bar with "File", "Machines", "Soil", and "Terrain". Below the menu bar is a table with the following data:

Terrain Type	Rolling Factor (Kg/Ton)
Paved Terrain	20
Strong Dirt Terrain	32.5
Loose Dirt Terrain	50
Sand Terrain	75
Mud Terrain	100

An "Add Row" button is located at the bottom right of the window.

Figure 10: Data Base Manager – Terrain Data

4.2.2 Control Panel Module

The *Control Panel* (Figure 11-13) is then used to build up the item that contains all the essential information mentioned above required to build up the simulation model. Aspects concerning the type of excavation, resource deployment, distance segments configurations, excavation variables, times among other variables can be set in any generic and customized way according to the project and users requirements.

The idea behind this element is to create a file or files containing the whole necessary information related to the type of earthmoving operation, automatically being named with an appropriate extension con-

cerning the type of excavation. So with this module the user can create his own database of projects, situations, or sceneries for a further communication with the server.

This module is designed according to the simulations stored at the server. In this case, it is created exclusively for earthmoving projects. For other purposes concerning other kind of information and projects, the *Database Manager* and the *Control Panel* module must be custom-built regarding the whole idea behind this work; Using Discrete Event Simulation through a Server-Client platform to aid specific purpose applications oriented specific contexts and projects.

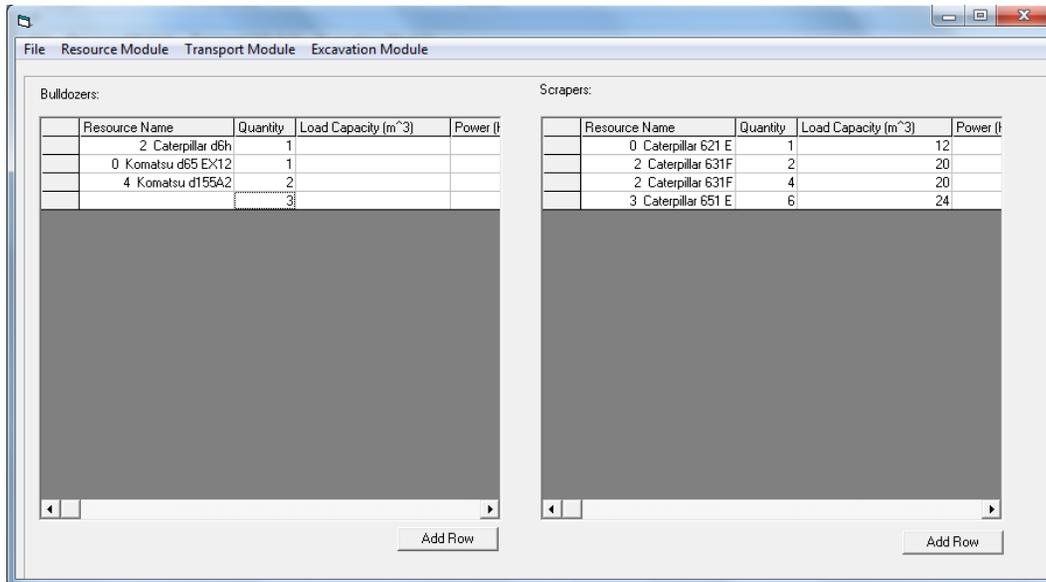


Figure 11: Control Panel: Resource Deployment

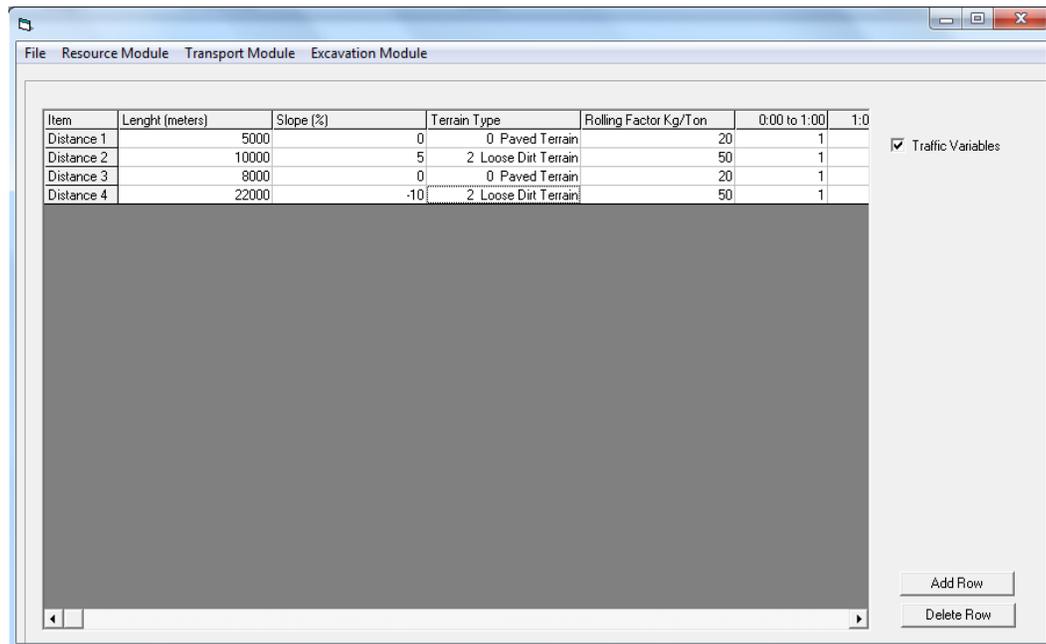


Figure 12: Control Panel – Distance Segments configuration

		Loose State	Bank State
Quantity to move m3	500000		
Type of soil	Piedra Caliza Fragmentada	1540	2610
Loading Factor	0.7		
Soil Loose State %		6%	94%
Pushing Time (min)	TRIA(2* 6* 10)		
Returning Time (min)	UNIF(2*5)		
Terrain Prep. Time (min)	NORM(5* 0.3)		
Reseting Time (min)	TRIA(2* 3* 5)		
Unloading Time (min)	UNIF(2* 4)		

Figure 13: Control Panel – Excavation: General Aspects

4.2.3 Connection Manager

Once the user has created one or more configurations or files with specific extensions for a particular operation or simulation, the *Connection Manager* (Figure 14) becomes very important. This module is in charge of sending those files into a known server or servers. First, using this application the user hooks into one of those servers with a IP address and PORT previously defined. Then, this application shows the user the different types of simulations that are currently stored at the server(s). Depending on his selection, a *window open dialog* appears; from which the user selects the file from his computer he wants to run on the server simulation, with the restriction of selecting only the files with the appropriate extension for that type of simulation. Finally the user is prompt to wait while the file is sent to the server, incorporated and run into the simulation in order to be finally transformed into a friendly result report. Once the report is sent back to the user and stored on an specific location in his computer, the application goes into an idle state for future sends.

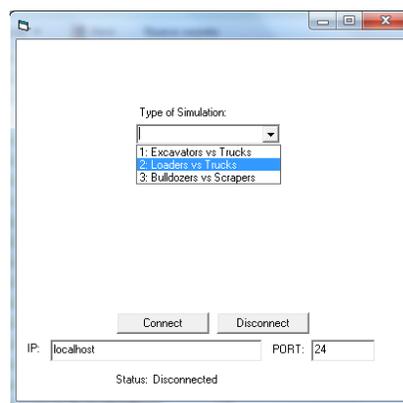


Figure 14: Connection Manager

4.2.4 Report Manager

Managing the information originated at the server is the final step in the whole remote simulation process. Considering no matter how friendly the reports obtained from the server are, the need for organizing and watching several reports graphically at the same time is essential. The *Report Manager* module is then used by the user in order to make comparisons between alternatives to find the best configuration for the system. Every single report downloaded from the server is custom-stored in the user's machine using different predefined file extensions in order to distinguish the origin or related simulation used to create it. Once this discrimination is done, with the use of the *Report Manager*, the user selects which files with same extensions are going to be graphically shown and compared in order to make a deeper analysis, finally opting for the best system configuration relaying on costs, times and other valuable information.

5 CONCLUSIONS

This example shows how an specific purpose application when aided by simulation models can be built in less time with less effort, comprising simulation advantages and capabilities. Furthermore the use of programming languages brings to simulation the opportunity to interact with databases, files, graphical interfaces, port connection abilities and so many other unrestricted possibilities found in programming platforms. Using internet as a main framework to launch computational tools in a world-wide range scope for specific purposes being thought or analyzed by simulation models can be a very productive practice. It represents a considerable cost-time saving alternative. Relaying on Discrete Event Simulation when building complex and accurate software can be a very less time consuming and a more accurate activity as simulation can be used mainly to do the hard and tough work of an application, letting the input/output data interfaces to specialized desktop applications. The main goal of this work was to create a Web based application whose brain relays on a generic simulation model stored at a server. Under this method, simulation can be delivered to any kind of user around the world as specific-purpose tools fitting any kind of need or requirements concerning real-world costumers, projects and problems. Discrete Event Simulation can become a more attractive and suitable alternative among civil engineering project management. Cost/time analysis, risk management and evaluating the "What if?" can be the most valuable contributions to this field among other benefits encouraging Civil Engineering to use modern computational tools.

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