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VIT

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REPORT ON BETA VERSION OF THE SIMULATION SOFTWARE

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About the Document

This document reports technical details of beta version of simulation software, the content of the developed software modules and the documentation about how to use it. Also it refers to the activity of *Tasks 6.2 Classification of events coming from the vision system*, *Task 6.3 Logic layer* and *Task 6.4 Reliability modelling and prediction* from months 4 to month 12 inside the Workpackage *WP6: System security and data management* .

The document has been produced by the collaboration of the workpackage WP6, the participants of the workpackage have all duly contributed to the activity of the workpackage and the production of this document and they endorse the final version as the conclusion of the workpackage.

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INTRODUCTION

The main objective of this work package is to evaluate and analyse the risk connected with the information coming from the vision systems.

In a project context, risk is the chance of something happening that will have an impact upon objectives or imply variation from a desired or planned outcome; a systematic identification, analysis and assessment of risk contribute significantly to the success of a project.

A very important objective is the development of Control Loops to assure terminal reliability.

With the terms “*Channel*” or “*Control Loop*” we refer to the match of the input hardware devices (vision systems), which permit the events recognition from the field, with the recovery actions (control actions), which permit to assure plant safety when these events occur (plant blocks, human intervention, etc).

Simulation is a process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system both in standard and anomalous conditions and/or evaluating various strategies.

Through the use of the simulation model of the terminal it is possible to understand if the vision systems and the defined high level logic permit to manage the plant in safe conditions and guarantee a correct operability.

In detail, the final outputs of this WP are:

- a report which contains a classification of all the events/informations/failures coming from the vision systems and a definition of the recovery actions for these events
- a simulation model of the terminal which simulates both the material handling processes and the vision system events
- the numeric deliverables of the simulation analysis which permit to compare different scenarios

Structure of the report

The present report is structured as follows:

1. **Classification of the events originated by the vision system:** this section reports the state of advancement of the work related to task T6.2 (Analysis and classification of the events originated by the vision system in relation to the system structure)
2. **Designing of the logic layers:** this section reports the state of advancement of the work related to task T6.3 (design and prototyping of the logic layer and procedures that permit to define the actions consequently to the events coming from the vision system)
3. **The Simulation Model:** this section reports the state of advancement of the work related to task T6.4 (a stochastic simulator will permit to estimate the reliability level resulting from the defined architecture and procedures). It contains a description of all the features of the simulation model of the terminal (Beta Version). It includes the description of the terminal logics, the input data file and the Access Database which stores information about trains
4. **Technical Specifications:** this section contains technical specifications about the features of the simulation tool (Rockwell Arena Professional Edition 12.0).
5. **System Requirements:** this sections lists all the simulation software beta release files and all the software and hardware requirements.
6. **Beta release simulation software User’s Guide:** this section contains a short user’s guide of the simulation software.

AUDIENCE

The present deliverable is filed as Confidential, as it contains critical information for the VIT project and also for the Metrocargo system.

Therefore the audience of the document is restricted the project participants --- the SME's who will find the technical details following their user requirements and the RTD performers who will use the present report as a guideline of their research and development activity.

1. Classification of the events originated by the vision system

In order to implement the vision system logics in the simulation model of the terminal, a detailed analysis of all the events originated by the vision devices has been necessary.

First of all, it's important to distinguish two different type of events:

- Standard events, which deal with the correct functionality of the vision system. The recognized standard events are:
 - The vision system for the automatic positioning for load / unload correctly determine the position of the wagon's pin or the position of the twist lock (this event has no consequences on the plant logic)
 - The vision system for the reconstruction of the train profile correctly recognize it (this event has no consequences on the plant logic)
 - The vision system for people security correctly interprets the dynamic of the scene detecting human presence in the dangerous area (this event "triggers" an action which will be, on the final system, a plant block) while ignoring mechanical devices in motion
- Failure events, which deal with the not correct functionality of the vision system (ex: the ownership code of a container is not recognized by the cameras)

A failure is defined as "the termination of the ability of an item to perform a required function", it is the non-fulfillment of a functional requirement.

To identify all the potential "failure modes" of an item, it is necessary to identify all the functions of that item, and all the associated functional requirements.

To collect data about the failure events of the vision system, meetings with the leaders of the other RTD WPs have been organized and a form has been designed and compiled (in excel template). It contains the following attributes for each failure:

- A "**WP**" field; it defines the WP to which the failure event refers
- A "**Devices**" field; it contains a small description of the vision devices involved
- A "**Failure Description**" field; it contains a small description of the failure event
- A "**Frequency**" field; it contains a classification of the events based on the number of observations (estimate):
 - A failure is classified as "rare" if its frequency is less than one per year
 - A failure is classified as "remarkable" if its frequency is less than one per month, but more than one per year
 - A failure is classified as "frequent" if its frequency is one per month at least
 - A failure is classified as "daily" if its frequency is almost one per day
- A "**Failure Type**" field; it is null for "rare" events and it classifies the failure events in three different types:
 - A failure is classified as "time" if it is a time-based failure; these are stochastic failures which occur according to a given frequency distribution
 - A failure is classified as "count" if it is a count-based failure; such failure occurs after the resource has been released the number of time specified (number or probability distribution)
 - A failure is classified as "percentage" if it is a percentage-base failure; it is a particular "count" failure (ex. False positive and false negative)
- A "**Count**" field; it defines the number of resource releases for count-based failures and it is not null if the "Failure Type" is "count"

- A “**Percentage**” field; it defines the failure percentage for percentage-based failures and it is not null if the “Failure Type” is “percentage”
- A “**Up Time**” field; it defines the time between failures for time-based failures and it is not null if the “Failure Type” is “time”
- A “**Up Time Units**” field; it defines the time unit for the time between failures for time-based failures

NOTE: In the next section failures will be also classified according to their effects on the plant safety and on the terminal correct operability

Figure 1 shows the complete template table which collects and classifies all the possible failure events analysed with the help of the developers of the WP3, WP4 and WP5. All the data are referred to standard weather and operability conditions.

Failure percentages for the cameras for people security in the loading area are the result of the matched failure probabilities of the terminal and the loading area cameras (a human presence can be detected both by terminal area and loading area cameras).

Upon completion of the field tests, the values in the “Frequency” columns will be changed and the template table will be completed with data about different weather and operability conditions (fog, rain, etc.).

WP	Devices	Failure Description	Frequency	Failure Type	Count	Percentage	Up Time	Up Time Units
WP3	Cameras For Automatic Positioning for Load / Unload	Cameras breaking off.	Rare					
	Cameras For Automatic Positioning for Load / Unload	Failure during the container loading	Daily	Percentage		0.5		
	Cameras For Automatic Positioning for Load / Unload	Failure during the container unloading	Daily	Percentage		0.5		
WP4	Cameras For Reconstruction of the train profile	Cameras breaking off.	Rare					
	Cameras For Reconstruction of the train profile	Wrong Train	Rare					
	Cameras For Reconstruction of the train profile	Wrong List	Frequent	Time			TRIA(25,30,35)	Days
	Cameras For Reconstruction of the train profile	Ownership code not recognized on train arriving	Remarkable	Percentage		0.001		
	Cameras For Reconstruction of the train profile	Ownership code not recognized on train leaving	Remarkable	Percentage		0.001		
	Cameras For Reconstruction of the train profile	Wrong recognition of the empty spaces	Daily	Percentage		2		
WP5	Cameras For People Security	Cameras breaking off.	Rare					
	Cameras For People Security (Terminal Area)	Cameras don't recognize a human operator who is passing	Daily	Percentage		3		
	Cameras For People Security (Terminal Area)	Cameras recognize a human operator who is not passing	Daily	Percentage		8		
	Cameras For People Security (Loading Area)	Cameras don't recognize a human operator who is passing	Remarkable	Percentage		0.03		
	Cameras For People Security (Loading Area)	Cameras recognize a human operator who is not passing	Remarkable	Percentage		0.4		

Figure 1 – Vision system failures in standard conditions

2. Designing of the logic layers

With the terms “logic layers” we refer to the definition of the recovery actions consequently to the events coming from the vision system.

A recovery action can be defined as a process which starts as the result of a defined event during job execution; usually recovery is used in case of job failure. The conventional way to trigger a recovery action is to define an event which activates it; recovery is started only if the event occurs or if any check is not ok.

It is necessary to define actions both for standard and failure events. In particular, the failure occurrences could produce a strong impact on plant safety and performances.

In this section events are also classified according to their effects on the plant:

- An event is a “**Minor**” event if it causes a not remarkable degradation of the system performances with a negligible damage to the system
- An event is a “**Significant**” event if it causes a remarkable degradation of the system performances with an appreciable damage to the system
- An event is a “**Critical**” event if it could potentially cause loss of primary system functions resulting in significant damage to the system or a dangerous situation for the human operators

When the field tests will be finished and the different scenarios will be tested by using the simulation model, this classification could be changed.

As outlined in the previous section, detection of human presence in a dangerous area is the only standard event for which a definition of a control logic is needed. (Standard event coming from the vision systems are listed in the previous paragraph). It is a “critical” event and it generates a warning sound alarm and, if the situation persists, it finally generates a plant stop. Its frequency is less than one per year according to the SME’s opinion (“rare” event).

With the help of the SME’s and the developers of the WP3, WP4 and WP5 the effects of the failures have been quantified in the following template file, which contains:

- A “**WP**” field; it defines the WP which has described the failure event
- A “**Devices**” field; it contains a small description of the vision devices
- A “**Failure Description**” field; it contains a small description of the failure event
- An “**Importance**” field; it classifies a failure according to its effects on the plant (Minor/Significant/Critical)
- A “**Down Time**” field; it defines the duration of the failure or the delay caused by the failure (ex: for a failure of a camera for the automatic positioning for the unloading a human intervention is needed; this operation required about 4 minutes NORM(4,1))
- A “**Down Time Units**” field; it defines the time unit for the duration of the failure or for the delay

WP	Devices	Failure Description	Importance	Down Time	Down Time Units
WP3	Cameras For Automatic Positioning for Load / Unload	Cameras breaking off.	Significant	NORM(20,5)	Minutes
	Cameras For Automatic Positioning for Load / Unload	Failure during the container loading	Minor	NORM(1,0.2)	Minutes
	Cameras For Automatic Positioning for Load / Unload	Failure during the container unloading	Minor	NORM(1,0.2)	Minutes
WP4	Cameras For Reconstruction of the train profile	Cameras breaking off.	Significant	NORM(15,3)	Minutes
	Cameras For Reconstruction of the train profile	Wrong Train	Significant	NORM(10,3)	Minutes
	Cameras For Reconstruction of the train profile	Wrong List	Significant	TRIA(4,5,6)	Minutes
	Cameras For Reconstruction of the train profile	Ownership code not recognized on train arriving	Minor	DISC(0.2,0.5,1.0,5)	Minutes
	Cameras For Reconstruction of the train profile	Ownership code not recognized on train leaving	Significant		
	Cameras For Reconstruction of the train profile	Wrong recognition of the empty spaces	Minor	TRIA(1.5,2,2.5)	Minutes
WP5	Cameras For People Security	Cameras breaking off.	Significant	NORM(10,3)	Minutes
	Cameras For People Security (Terminal Area)	Cameras don't recognize a human operator who is passing	Significant		
	Cameras For People Security (Terminal Area)	Cameras recognize a human operator who is not passing	Minor		
	Cameras For People Security (Loading Area)	Cameras don't recognize a human operator who is passing	Critical		
	Cameras For People Security (Loading Area)	Cameras recognize a human operator who is not passing	Significant	NORM(15,3)	Minutes

Figure 2 – Failure effects in standard conditions

Finally, for each failure, recovery actions have been defined and collected (with the help of the SME's) in a template file which has:

- A “**WP**” field; it defines the WP which has described the failure event
- A “**Devices**” field; it contains a small description of the vision devices
- A “**Failure Description**” field; it contains a small description of the failure event
- A “**Recovery Actions Description**” field; it contains a small description of the actions that are needed when the failure event occurs (ex: if the ownership code is not recognized by the cameras, an alert is sent and a human intervention is needed; a human operator can

recognizes the code viewing the camera's image (about 20% probability) or if it is not possible the human operator recognizes the code viewing the container directly)

- A “**Notes**” field; it contains some notes about the failure event (a bigger description of the failure)

Figure 3 shows the complete template table which collects and describes all the possible recovery actions analysed with the help of SME's and developers of the WP3, WP4 and WP5.

WP	Devices	Failure Description	Recovery Actions Description	Notes
WP3	Cameras For Automatic Positioning for Load / Unload	Cameras breaking off.	Camera replacement with human operator intervention	Two cameras on the same side must be failed simultaneously to not perform loading/unloading operations. This is a really rare event. The failed camera can be replaced when there are no trains in the terminal
	Cameras For Automatic Positioning for Load / Unload	Failure during the container loading	Alert and human operator intervention	The position of the wagon's pin is determined by using two sonars, placed on opposite turrets.
	Cameras For Automatic Positioning for Load / Unload	Failure during the container unloading	Alert and human operator intervention	Sensors give alerts if the container's twist locks are not centered
WP4	Cameras For Reconstruction of the train profile	Cameras breaking off.	Camera replacement with human operator intervention	
	Cameras For Reconstruction of the train profile	Wrong Train	Alert	A wrong train arrives into the MC terminal. This is a really exceptional case
	Cameras For Reconstruction of the train profile	Wrong List	Alert and human operator intervention for the right list searching	The list doesn't match with the arriving train's profile. (A train arrives before or after its schedule time)
	Cameras For Reconstruction of the train profile	Ownership code not recognized on train arriving	20% Alert and a human operator recognizes the code viewing the camera's image 80% Alert and a human operator recognizes the code viewing the container directly	
	Cameras For Reconstruction of the train profile	Ownership code not recognized on train leaving	Notification to the general control System	A human intervention is not possible because the recognition occurs when the train is leaving and it can't be stopped.
	Cameras For Reconstruction of the train profile	Wrong recognition of the empty spaces		This event causes a delay in the loading/unloading operations because the automated devices (shuttle and turrets) can't find the right position
WP5	Cameras For People Security	Cameras breaking off.	Camera replacement with human operator intervention	
	Cameras For People Security (Terminal Area)	Cameras don't recognize a human operator who is passing		This is a not given alert (False Negative). It is not a critical event because these type of cameras are monitoring the terminal area where human presence is normal
	Cameras For People Security (Terminal Area)	Cameras recognize a human operator who is not passing	An alert is sent to the camera for loading area's security (about 2 seconds)	This is a false alert (False Positive)
	Cameras For People Security (Loading Area)	Cameras don't recognize a human operator who is passing		This is a critical event (False Negative)
	Cameras For People Security (Loading Area)	Cameras recognize a human operator who is not passing	Warning sound alarm and terminal block	This is a critical event (False Positive)

Figure 3 – Logic layers

3. The Simulation Model

Nowadays, the growth of freight transport shows a rapidly increasing trend which cannot be met by the current infrastructures and management tools. To remain competitive intermodal terminals must meet increasing demand for storage and processing capacities, while at the same time reduce operating costs and maintain the highest levels of safety.

The management of an intermodal terminal is a complex task, which involves a great number of decisions to be taken at different levels, from strategic development down to the single move of a container or ITU (Intermodal Transport Unit). Almost as often, the sheer amount of the information makes nearly impossible for the human operators to see the whole terminal in its complexity, considering the multiple interactions of the various concurrent processes, such as yard planning, resource allocation (berths, container handling equipment, and manpower), ship/train/trucks loading and unloading.

It is clear that Simulation Techniques could bring the advantage of making a better use of the available information and, consequently, to increase the overall performance. Terminal operators would prefer to explore if, new handling devices, new vision systems and new management methodologies can improve the terminal performance before investing in new equipments. Simulation can provide the decision makers with the help they need in creating the strategies for development. Simulation is an effective tool to make the best use of all relevant data, including many variable parameters and terminal resource limitations. Simulation allows for precise evaluation of complex given situations and exact modelling of different future scenarios, including expansions and improvements.

The models describing the terminal processes and the solution techniques must be studied and designed with great care, often with a conflicting objective in mind: models should include all the significant characteristics but, at the same time, they should be simple enough to be computationally solvable.

The main processes which must be implemented in a simulation model of an intermodal terminal are:

- Loading/unloading of ITUs onto/from the train
- Storage of ITUs on the yard
- Arrivals and departures of ITUs by truck

Simulation is well known in the container terminal industry and it is most commonly used to model throughput, layout and equipment scenarios at new and existing terminals.

The simulation of the intermodal terminal can be approached with different schemes. It can be modelled either as a continuous system, describing the ITUs (Intermodal Transport Units) moves as a flow, or a discrete system, where the single ITUs are modelled. The second approach has been preferred in order to study the behaviour of the ITUs in the terminal with their handling and storage processes.

The simulation model is an efficient tool to test and improve container handling reliability and all terminal operations. In particular, simulation will be used to model all the vision systems implemented in the other WPs. The vision systems in the model can be affected by “disturbs” or failures, based on stochastic events (where the parameters permit, for example, to simulate different weather conditions).

In case of anomalous conditions the control logic will alert operators or even block the plant. Alerts and blocks require operators procedures.

Through the use of the simulation model is possible to run different scenarios, analyze the simulation outputs and evaluate the risks connected with errors coming from the vision systems.

The simulation model we are studying represents the different processes that permit the containers to be unloaded and loaded from trucks and trains.

Container arrived via train and waiting for a truck or arrived via truck and waiting for a train are temporarily stored on the plant facility.

So far the terminal logics have been studied and analyzed, the flow of entities has been defined and a beta version of the simulation model of the terminal has been built.

Simulation module first release

The model so far implemented includes:

- **Stochastic Containers Arrival Patterns (from trucks):** a create module generates containers arriving at the terminal by trucks with a specified rail destination. For each containers the terminal logics must (see Figure 4):
 - accept the incoming ITUs;
 - search in the DB the first free position on a scheduled train through a VBA routine;
 - assign a resource (crane) and a buffer area to each ITUs according to its destination and its train position;
 - move the ITUs into the correct storage areas;
 - release the crane;

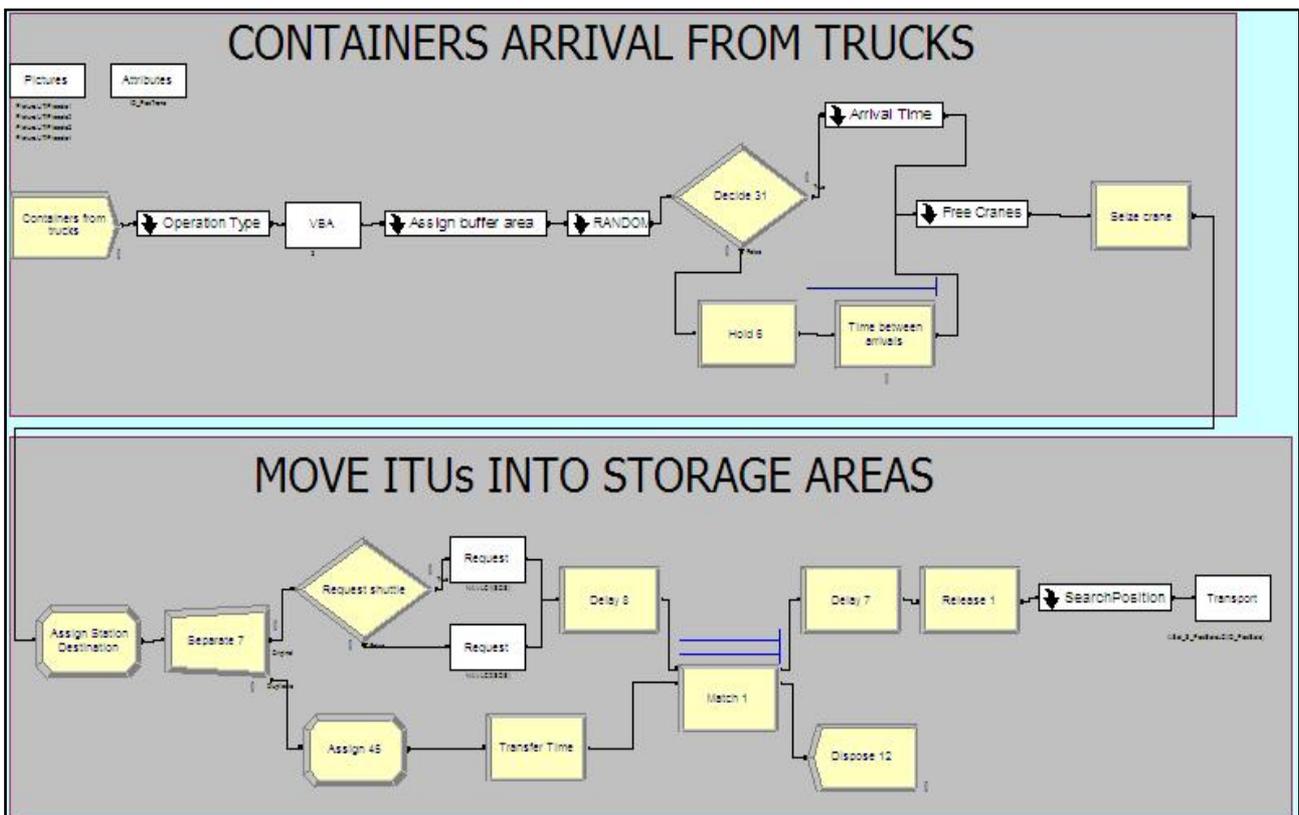


Figure 4 – Containers Arrival Logic

- **Trains Arrival Patterns:** a create module generates trains arriving at the terminal to be loaded/unloaded and an Access DB table is automatically created (with a record for each position on the train). The configuration of the wagons is stochastic (wagons on a train are created according to a discrete “wagontype” distribution); each train has a different number of containers to be unloaded.

For each train the terminal logics must (see Figure 5):

- accept the incoming train;
- recognize the ITUs that must be unloaded;

- determine the areas where ITUs must be stored;
- allocate resources (shuttles and turrets) for the loading/unloading operations;
- perform the loading/unloading operations;
- tell the train to depart the terminal when it has been unloaded;

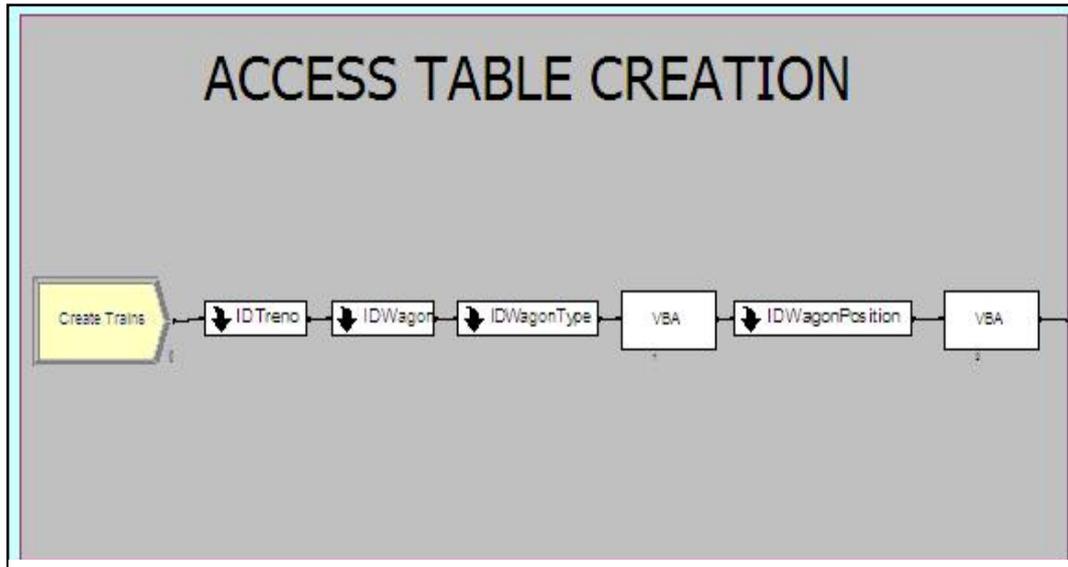


Figure 5 – Trains Table Creation

- **Containers Handling Logic (for loading/unloading operations):** the simulation model includes all the transfer devices; the train loading/unloading operations occur via the robots supported by the vision systems. Each position in the buffer area is assigned to a specific couple of shuttles. The train loading/unloading process starts as soon as possible, that is, when the train is on the platform. The possible operations are (see Figure 6):
 - searching an ITU on the train;
 - unloading an ITU from a wagon of an entering train on a specific buffer area, according to its destination;
 - searching an ITU in the buffer areas;
 - loading an ITU on a wagon of a departing train from the buffer area;

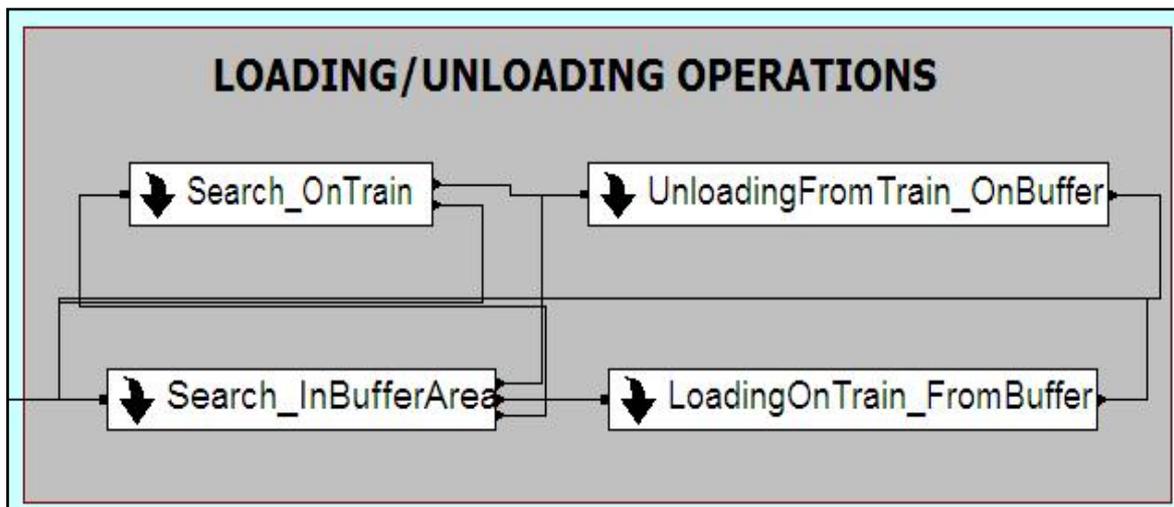


Figure 6 – Containers Handling Logic

- **Failure logic for vision system and recovery actions:** some modules have been introduced to simulate vision system and their failure conditions (according to the templates described in the previous sections);

Figure 7 shows the logics implemented for failures which occur during the containers unloading operations (twist lock not centred) and for a wrong recognition of the empty spaces on the train:

- two “decide” modules contain the failure stochastic percentages (as they have been defined in the template tables);
- two “process” modules simulate the delays caused by the failure events (delays for supervisor intervention) and allocate a human operator for the recovery operations;
- two “record” modules collect statistic about the number of the failures (and alerts) which are really observed in the simulation period (percentages are stochastic and not deterministic elements)

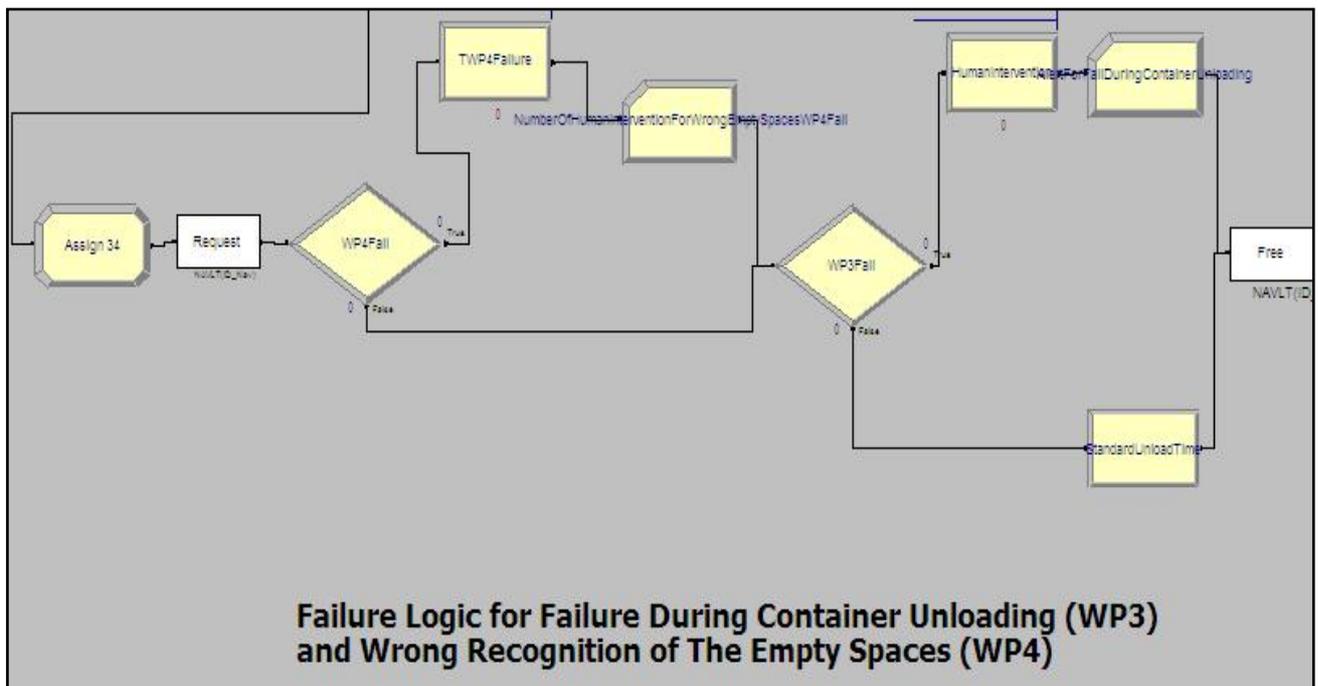


Figure 7 – An example of the failure logics related to WP3 and WP4

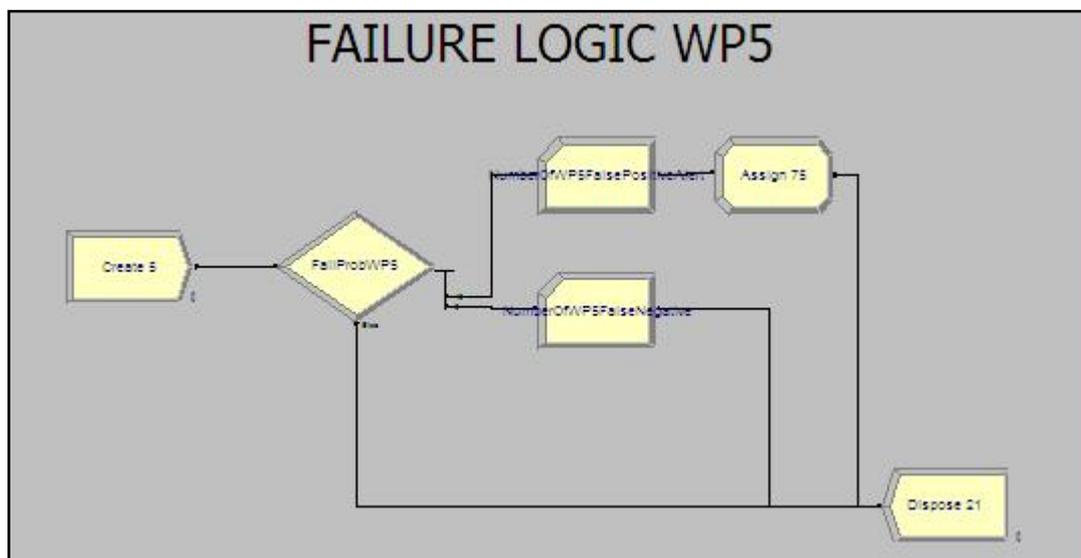


Figure 8 – An example of the failure logics related to WP5 (false positives and false negatives)

- **Model Outputs (Terminal KPIs):** two different types of outputs are defined in the simulation model (KPIs concerning the functionality of the terminal and KPIs about the plant safety and the people security). Outputs for “rare” failure events have not been defined; if the final field tests will give different results for these events, specific outputs will be defined.

The most important outputs of the simulator are:

- **“TimeInTerminal”** output; it reports the average time in terminal per train (time for the train scanning and the loading/unloading operations). It must be compared with the temporal constraint of 40 – 45 minutes
 - **“LoadedContainer”** output; it collects the total number of the loaded containers during the simulation time
 - **“UnloadedContainer”** output; it collects the total number of the unloaded containers during the simulation time
 - **“MovedFromTruckToBufferPerHour”** output; it reports the cranes’ hourly productivity
 - **“LoadedContainerPerHour”** output; it reports the average number of loaded containers per hour
 - **“UnloadedContainerPerHour”** output; it reports the average number of loaded containers per hour
 - **“TerminalUtilization”** output; it is determined from taking the utilization at each instant and the calculating a time-weighted average.
 - **“NumberOfWP5FalseNegative”** output; it collects the total number of the false negatives for WP5 cameras during the simulation time;
 - **“NumberOfWP5FalsePositiveAlerts”** output; it collects the total number of the false positives and alerts sent by the WP5 cameras during the simulation time;
 - **“AlertForFailDuringContainerUnloading”** output; it collects the total number of the alerts sent by the vision system for errors during containers’ unloading operations
 - **“AlertForFailDuringContainerLoading”** output; it collects the total number of the alerts sent by the vision system for errors during the containers’ loading operations
 - **“HumanInterventionForWrongEmptySpaces”** output; it collects the total number of the human interventions caused by a failure in the reconstruction of train profile
- **The infrastructures** modelled in the terminal simulator are:
 - Automated buffer areas for the storage of the ITUs;
 - Cranes for the handling of the ITUs from the storage area to trucks and from trucks to the storage area;
 - All the transfer devices, which include shuttles and turrets.

An input data file (.xls) allows to feed the simulation module with a possible configuration. Acting on this input data file the user can modify the terminal definition. In particular, the user can modify structural parameters, such as:

- Train parameters: number of trains per day, number of wagons per train and wagons’ configuration (in the sheet called “*Trains*”);
- Truck parameters: time between arrivals, direction probability for ITUs (called “*Trucks*”);
- Timestamps: transfer, translation and handling time for all the terminal equipments (called “*Times*”);

An Access database is used to store information on trains. When a train arrives at the terminal, a table called trainsettings is created. It contains a record for each train position and it includes the fields below:

- TRAINSETTINGS_IDTrain: a progressive number which identifies trains in the simulation model
- TRAINSETTINGS_IDDirection: a number (from 1 to 4) which identifies the right destination for each train
- TRAINSETTINGS_IDWagon: a number which identifies the wagon on the train (from 1 to the maximum number of wagons for each train)
- TRAINSETTINGS_IDPosOnWagon: a number which identifies the containers' position on the wagon (1 or 2)
- TRAINSETTINGS_IDPosition: a number which identifies the containers' position on the wagon (from 1 to 2*Maximum Number Of Wagons)
- TRAINSETTINGS_IDContainer: a progressive number which identifies containers in the simulation model
- TRAINSETTINGS_IDContainerType: a number which identifies the type of each container (1 or 2)
- TRAINSETTINGS_IDUnloading: a number which identifies the type of operation:
 - 1. The container must be unloaded or the position is empty
 - 2. The container remains on the train
- TRAINSETTINGS_Assigned: It is a Boolean value:
 - 0. The position is not assigned
 - 1. The position is assigned

Run of standard scenarios

Note: this paragraph refers to field test performed between month 12 and month 15

The outputs coming from critical scenarios must be analysed in order to understand the real influence of perturbations on system security and terminal productivity and they must be compared with the outputs coming from the standard scenario and with the desired service level.

The simulation model of the terminal has been fed by the SME's experts through the use of the input data excel file with a suitable configuration.

The following scenarios have been run:

- A “**Standard Scenario**” with no failure events coming from the vision system
- A “**Standard Failure Scenario**” with standard vision system failures added. Only events with “daily” frequency are modelled.
- A “**Critical Weather Conditions Scenario**” in which critical weather conditions are simulated; the frequency of the failure events is changed according to the test fields. When the complete results of all the field tests will be available, the frequency of the events will be re-defined and other scenarios will be run.

For each scenario 7 days are simulated (replication length) and 10 simulation runs are executed (number of replications).

Figure 9 shows an example of the Arena's outputs in Crystal Report. Taking in account a SME's experts requirement, all the simulation results have been collected in a "VIT_Terminal Simulation-Results" Excel file (so results are more intelligible and it is easier to compare different scenarios).

Time Persistent				
Time Persistent	Average	Half Width	Minimum Average	Maximum Average
LoadedContainerPerHour	15.6856	0.18	15.2561	16.1500
MovedFromTruckToBufferPerHour	16.5070	0.20	16.0185	17.0371
UnloadedContainerPerHour	16.0270	0.24	15.5318	16.7407

Figure 9 – An example of Crystal Report's outputs

For each scenario, results are collected in a table which contains a row for each output and four different columns (Figure 10, Figure11, Figure 12):

- An **“Average”** field; it reports the average of the replication averages;
- An **“Half Width”** field; this statistic is included to determine the reliability of the simulation results. This value may be interpreted by saying "in 95% of repeated trials, the sample mean would be reported as within the interval sample mean \pm half width". The half width can be reduced by running the simulation for a longer period of time.
- A **“Minimum Average”** field; it contains the smallest average across all replications
- A **“Maximum Average”** field; it contains the largest average across all replications

Standard Scenario	Average	Half Width	Minimum Average	Maximum Average
TimeInTerminal	42.2 Minutes	0.37 Minutes	41.49 Minutes	43.31 Minutes
LoadedContainers per week	2727	18.11	2690	2763
UnloadedContainers per week	2790	25.45	2752	2859
Moved From Trucks To Buffer Per Hour	16.44	0.14	16.16	16.72
Loaded Containers Per Hour	15.63	0.13	15.37	15.91
Unloaded Containers Per Hour	16.03	0.25	15.42	16.68
Terminal Utilization	34.75%	1.00%	34.16%	35.66%
Human Operator Utilization	0%	0%	0%	0%
Number Of WP5 False Negative (Terminal Area) per week	0	0	0	0
Number Of WP5 False Positive Alerts (Terminal Area) per week	0	0	0	0
Alerts For Fail During Container Unloading per week	0	0	0	0
Alerts For Fail During Container Loading per week	0	0	0	0
Human Intervention For Wrong Empty Spaces per week	0	0	0	0

Figure 10 – Outputs of the Standard Scenario

Standard Failure Scenario	Average	Half Width	Minimum Average	Maximum Average
Time In Terminal	43.05 Minutes	0.61 Minutes	41.98 Minutes	44.75 Minutes
Loaded Containers per week	2740	16.01	2717	2784
Unloaded Containers per week	2791	35.75	2712	2871
Moved From Trucks To Buffer Per Hour	16.65	0.18	16.27	17.04
Loaded Containers Per Hour	15.83	0.16	15.48	16.17
Unloaded Containers Per Hour	16.03	0.25	15.61	16.75
Terminal Utilization	35.45%	1.20%	34.57%	36.85%
Human Operator Utilization	2.73%	0.06%	2.45%	3.07%
Number Of WP5 False Negative (Terminal Area) per week	15.3	2.08	11	20
Number Of WP5 False Positive Alerts (Terminal Area) per week	39.7	4.84	31	50
Alerts For Fail During Container Unloading per week	14.2	2.78	9	19
Alerts For Fail During Container Loading per week	13.8	2.47	7	19
Human Intervention For Wrong Empty Spaces per week	52.2	5.62	39	63

Figure 11 – Outputs of the Standard Failure Scenario

Critical Weather Conditions Scenario	Average	Half Width	Minimum Average	Maximum Average
TimeInTerminal	43.38 Minutes	0.49 Minutes	42.28 Minutes	44.56 Minutes
LoadedContainers per week	2754	23.37	2685	2790
UnloadedContainers per week	2794	30.48	2724	2867
Moved From Trucks To Buffer Per Hour	16.71	0.22	16.08	17.12
Loaded Containers Per Hour	15.89	0.2	15.32	16.24
Unloaded Containers Per Hour	16.01	0.26	15.55	16.69
Terminal Utilization	35.72%	1.20%	34.82%	36.70%
Human Operator Utilization	5.50%	0.06%	5.03%	6.27%
Number Of WP5 False Negative (Terminal Area) per week	27.9	3.7	21	37
Number Of WP5 False Positive Alerts (Terminal Area) per week	54.7	5.99	43	69
Alerts For Fail During Container Unloading per week	26.8	2.92	20	33
Alerts For Fail During Container Loading per week	28.2	4.92	19	41
Human Intervention For Wrong Empty Spaces per week	112	6.09	96	125

Figure 12 – Outputs of the Critical Weather Conditions Scenario

The most frequent events are:

- A wrong recognition of the empty spaces on the train;
- A false positive alert coming from cameras monitoring the terminal area;

These events are not critical; they have no risks for people security, and they have not an important influence on system productivity.

In fact, analysing the results, it is possible to note that also in critical weather conditions the very strict temporal constraints of 40 – 45 minute for trains' loading/unloading is met.

The terminal utilization varies between 35% and 36% , that corresponds to 8-9 operating hours per day (with 12 arriving trains per day).

The outputs coming from the analysed scenarios have been discussed by the SME's experts and they have been validated. When the field tests will be finished, other scenarios will be tested by using the simulation model.

4. Technical Specifications

The simulation model of the terminal has been implemented by using Rockwell Arena Professional Edition 12.0¹. Rockwell Arena is the preeminent solution for better business decisions with simulation. Arena is an easy-to-use, powerful tool that allows you to create and run experiments on models of your systems. By testing out ideas on this computer "laboratory," one can predict the future with confidence and without disrupting current environment.

Arena is used to model any business environment, from customer service to manufacturing to health care to logistic systems. Arena integrates very well to Microsoft technologies. It includes Visual Basic for Applications so models can be further automated if specific algorithms are needed. It also supports importing Microsoft Visio flowcharts, as well as reading from or outputting to Excel spreadsheets and Access databases.

In the present work the simulation modules have been integrated with Microsoft Office for input/output functionalities: a specific input data file (.xls Microsoft Office 2003) has been performed to introduce and change different project parameters easily, by using VBA routines. A specific DB Access has been created to store information on the elements produced by the simulation.

In addition to the Arena Professional Edition, Rockwell Automation offers a full suite of products to provide enterprise-wide simulation, optimization, 2D and 3D model animation. Default Animation Symbols accompany most of the Arena Packaging Template modules; the model animation has been built by modifying these symbols.

Rectangles of different colours have been introduced to represent containers with different destinations and queues have been animated to represent the buffer areas.

All the transfer devices (cranes, shuttles, etc.) have been modelled and animated by using the "transporter" module; each transporter in the simulation model has been associated to a network (a system map that guided transporters follow). A network consists of individual links, groups of links, or combinations of individual and groups of links. Finally, each link has been defined by specifying a beginning intersection and an ending intersection.

There are two ways to show entities moving through the system; Connector Animation provides a mechanism for viewing the entity flow along connectors, the lines that connect modules together graphically.

For the simulation model of the terminal Facility-based Animation has been used. It is another method of animating entity flow through the system. Facility-based animation uses stations to represent physical locations where specific processes or events occur, and involves animating the physical relationships as they exist in the real system. This method involves non-zero entity travel times and permits constrained movement using a material handling device (animated by using intersections, links and transporters animation).

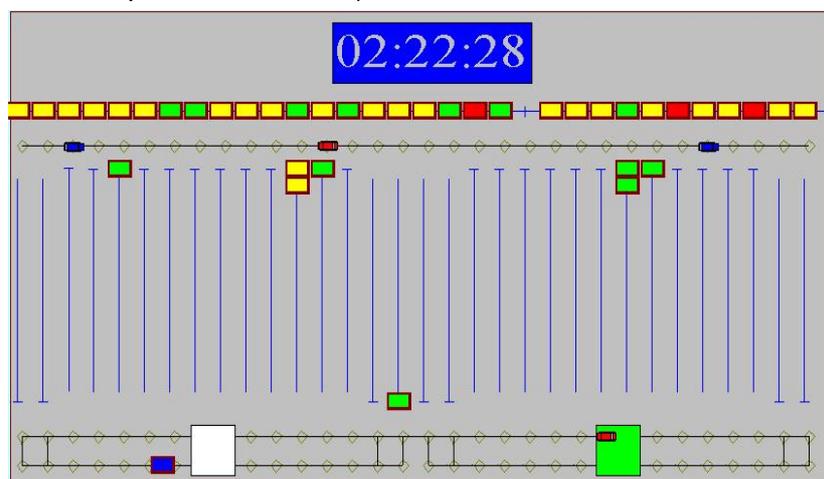


Figure 13 – An example of 2D Terminal Animation

¹ <http://www.arenasimulation.com/>

5. System Requirements

Simulation software Beta release

The simulation software beta release includes the files below:

- Terminal_Model_BetaVersion.doe; it's the Arena Professional Edition 12.0 file (the simulation model of the terminal).
- DB_Terminal_v_06.mdb; it's the Access DB which is connected with the simulation model through vba routines.
- XL_Input_Terminal_v_06_sc17.xls; it's the input data file which allows the user to easily modify the project parameters.

Software Requirements

To run the model, the system must meet the following software requirements:

- Rockwell Arena 12.0 runtime mode; Arena's runtime mode feature allows Arena models built using a commercial license to be opened and run in unlicensed software. This allows model developers to freely distribute models to other parties who will be using the models to perform simulation analysis.
When a model is placed under runtime restrictions, Arena's functionality is oriented towards allowing analysts to change model parameters, perform simulation runs, and analyze the results of these runs, while prohibiting any enhancements to the model logic or animation. When opening a model, Arena automatically places a model under runtime restrictions if the model uses an unlicensed feature and the demonstration limits are exceeded. A model must have been saved using a valid commercial Arena license to be opened in runtime mode.
- Windows XP Professional (SP2 or later), Windows XP Home (SP2 or later), Windows 2000 Professional (SP4 or later), Windows 2000 Server (SP4 or later), Windows Server 2003 (SP1 or later).
- Microsoft Internet Explorer 6.0 (Service Pack 1) or later.
- Adobe Acrobat Reader 7.0 or later to view documentation.
- Microsoft Office 2003 to view and use the Input Data File and the Access DB

Note: Arena was tested using the latest anti-virus software.

Hardware Requirements

To use Arena, the system must meet the following hardware requirements:

- Hard drive with 75-250MB free disk space (depending on operating system and options installed);
- 64MB RAM (recommended 128MB RAM or higher, depending on operating system)
- Minimum Pentium® processor 300Mhz or higher. The Arena software can be run on single processor, dual processor, and dual-core processor computers; however, only one instance of Arena can be run at a time.

Note: The running and animation of Arena and some large simulation models can be calculation-intensive, so a faster processor with additional memory may result in significantly improved performance. In addition, a larger monitor and a screen resolution of at least 1024 x 768 is recommended for improved animation viewing.

6. Beta release simulation software User's Guide

As a first action, the user must extract all the files from the folder in order to use the simulation model. To open the simulation model user can double-click on Terminal_Model_BetaVersion.doe icon, then following the steps below:

Step 1 To run the model, click on the “Go” button or the “Fast-Forward” button (for a faster simulation) on the “Standard Toolbar”

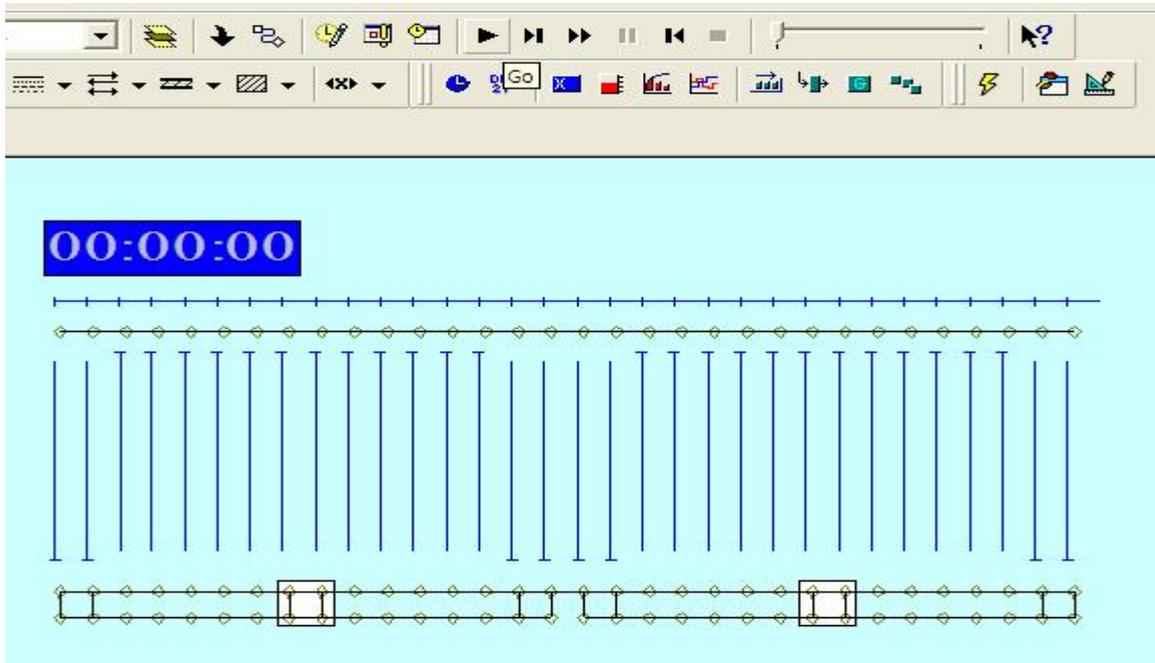


Figure 14 – The “Go” and the “Fast-Forward” button

Step 2 To view the model outputs after the simulation click on the “Yes” button.

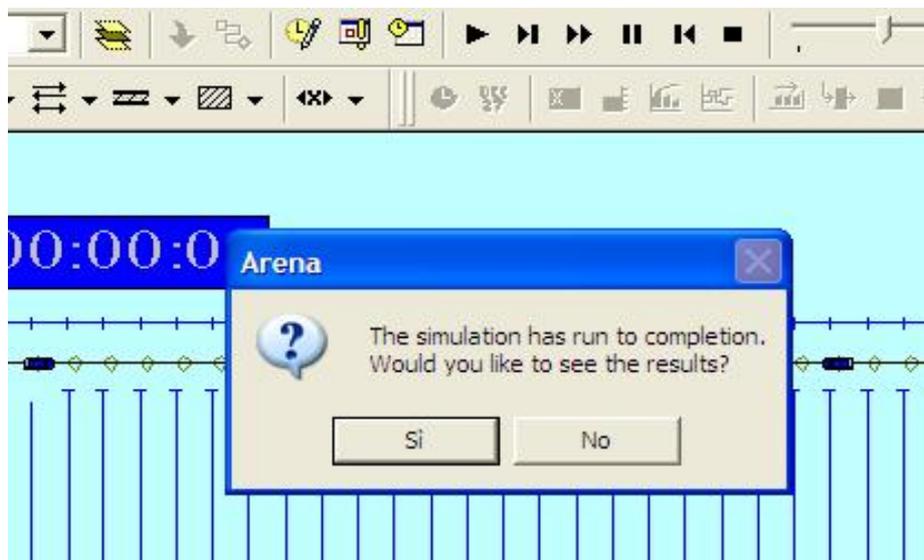


Figure 15 – Click “yes” to see the simulation results

Step 3 To update the input parameters of the terminal model:

- ✓ Modify the parameters on the .xls file
- ✓ Save the changes
- ✓ Open the model
- ✓ Run the specific VBA routines in the simulation model.

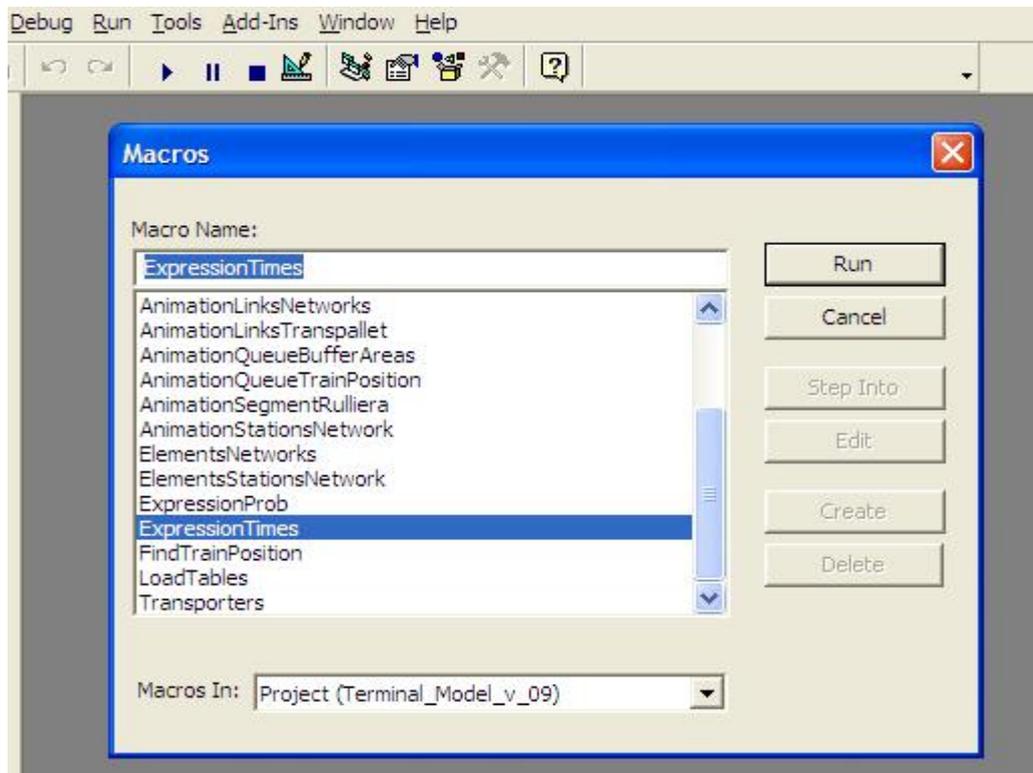


Figure 16 – The VBA Routine

The routines that must be run are:

- ✓ “ExpressionProb”
- ✓ “ExpressionTimes”
- ✓ “ExpressionParameters”