

# SIMULATION TOOLS TO SUPPORT PRACTICAL MULTIMODAL LOGISTICS NETWORKS MODELING AND DESIGN

## 1. Introduction

There is often a problem with selecting a proper simulation due to a wide selection of simulation tools that are contemporarily available. The author focuses their research mainly on the area of logistics, especially on problems related with logistic multimodal networks. Owing to the extensive literature on the subject (books and journals), the internet sources (websites devoted to simulation tools, access to open-source software), conference materials (e.g. Winter Simulation Conference – [www.wintersim.org](http://www.wintersim.org)) and wide market offer of software manufacturers, the choice of the right simulation tool is quite difficult. Yet, he has wide experience in using various simulation tools, such as spreadsheets, programming languages and programming libraries as well as simulation packages. Therefore, the author has made an attempt to survey the available simulation tools and techniques from the viewpoint of their practical modeling and designing multimodal logistic networks. This paper discusses the possible uses of process simulation software techniques and their applicability to “Multimodal networks” in logistics. The main questions are:

- What types of software can be used for developing simulation models?
- What specific packages are available?
- How can an appropriate package be selected?
- Which “Multimodal Logistics Networks” requirements are available?

A full overview of the features of all types of simulation is to be found in the work of Ricky G. Ingalls [2]. Looking for the clarification of the explanation, the following simulation approaches are introduced and explained:

- DES - Discrete Even Systems,
- ABS - Agent Based Systems,

The Research Highlights of performed works are:

- Selection of IT tool appropriate for multimodal networks simulation.
- Focus on complementary approaches based on Discrete Even Systems (DES) and Agent Based Systems (ABS).
- Presentation of reasons which driven the choice of the tool.

The major objective of the present paper is:

- to make an attempt to select such a tool and show its applications.

The paper structure is as follow. Section 2 presents characteristics of DES (Discrete-Event Simulation) and ABS (Agent Based Simulation) with special emphasis on possibilities of connecting these two approaches. Section 3 includes the description of the tool which was selected by the author (with selection reasons) and two examples of simulation models: a model of simulation made according to Milk Run algorithm and the model of multimodal network – logistics center. The final conclusions are stated in section 4.

## 2. DES and ABS approach

For over 40 years, DES (Discrete-Event Simulation) has been the mainstay for the process simulation of manufacturing and supply chain. DES is useful for problems that consist of queuing simulations or complex network of queues, in which the processes can be well defined and their emphasis is on representing uncertainty through stochastic distributions [6]. Many of these applications occur in manufacturing, supply chain and service industries as well as queuing situations.

DES models are characterized by [6] a process oriented approach (focus is on modeling the system in detail, not the entities). They are based on a top-down modeling approach and have one thread of control (centralized). They contain passive entities (i.e. something is done to the entities while they move through the system) and intelligence (e.g. decision making) is modeled as part of the system. In DES, queues are the crucial element; a flow of entities through a system is defined; macro behavior is modeled and input distributions are often based on collected/measured (objective) data. These attributes describe manufacturing and supply chain processes too.

ABS (Agent Based Simulation) help to better understand real-world systems in which the representation or modeling of many individuals is important and for which the individuals have autonomous behaviors. ABS offers something novel, interesting and potentially highly applicable to manufacturing and supply chain. However, there is relatively little evidence that ABS is much used in the Operational Research community. There are few publications relating to its use in OR and OR-related simulation journals. Much greater volume of ABS papers can be found in journals in disciplines such as Computer Science, Social Sciences and Economics.

To sum up, ABS models are characterized by the following features [6]:

- They are individual-based (bottom up modeling approach); the focus is on modeling the entities and interactions between them;
- Bottom up modeling approach;
- Each agent has its own thread of control (decentralized);
- Active entities, i.e. the entities themselves can take on the initiative to do something; intelligence is represented within each individual entity;
- No concept of queues;
- No concept of flows; macro behavior is not modeled, it emerges from the micro decisions of the individual agents;
- Input distributions are often based on theories or subjective data;

These attributes do not describe manufacturing and supply chain processes but provide descriptions of numerous aspects of management.

The emergence of ABS as a technique in Operational Research is timely. Globalized business is a highly complex management process, and making decisions in this environment is not well supported by the current set of tools, including DES [4].

### 2.1. Available agent systems

Table 1 presents a list of selected agent systems. The list includes systems which really originate from the agent-based approach.

Apart from the presented list, numerous systems based on Java, such as iGen, ICARO-T, JABM, JAMEL, JANUS, JAS, JASA, JCA-Sim, Madkit, Mason, Moduleco, Sugar-scape, VSEit, are also available. There is a number of excellent academically developed tools; the commercially available software is limited to AnyLogic (but AnyLogic originates from DES so we classified it as DES system which included ABS approach). All of these products require knowledge of object oriented programming techniques and the modeler needs to be comfortable with Java. It is difficult to find an agent system which makes it possible to combine agent based and DES approach.

### 2.2. Available DES Systems

Table 2 presents a list of selected DES systems. This list includes systems which really originate from discrete events approach.

There are a few systems which offer a possibility to combine DES with ABS. One system of this kind is AnyLogic. It supports agents in a continuous or discrete environment and also supports sophisticated animation capabilities to visualize agent behaviors. It contains a graphical modeling language and also allows the user to extend simulation models with Java code. The Java nature of AnyLogic allows model extensions via Java coding as well as the creation of Java applets which can be opened with any standard browser. Another system is Simio. The Simio framework is a graphical object-oriented modeling framework, useful for simulation modeling, as opposed to a simple set of classes in an object-oriented programming language. The graphical modeling framework of Simio fully supports the core principles of object oriented modeling without requiring programming skills to add new objects to the system. Simio framework is domain neutral, and allows objects to be built in such a manner that many different application areas are supported. The Simio framework supports multiple modeling paradigms. The framework supports the modeling of both discrete and continuous systems, as well as an event, process, object, and agent modeling view. The next system is Flexsim. The Flexsim Simulation Software is a new generation of simulation software. The from, the scratch, the own developed simulation kernel, the seamless integration of Microsoft C++ and the use of the newest OpenGL technology for unrivalled 3D animation in combination with the just as compact as practice-oriented library are the highlights of Flexsim. The software is offered in the following versions: GP (General Purpose Simulation), CT (Container

Name	Description	www
Altreva Adaptive Modeler	Software application for creating market simulation models for price forecasting of real-world stocks and other securities.	www.altreva.com
AgentBuilder	An integrated software toolkit for quick development of intelligent software agents and agent-based applications	www.agentbuilder.com
AOR Simulation	AB discrete event simulation; special extensions for modeling cognitive agents (with beliefs and speech-act-based information exchange communication).	oxygen.informatik.tu-cottbus.de/aor/
Ascape	General-purpose agent-based models.	ascape.sourceforge.net
Brahms	Multi-agent environment for simulation organizational processes	www.agentisolutions.com
Construct	Multi-agent model of a group and organizational behavior.	www.casos.cs.cmu.edu/projects/construct/index.php
FAMOJA	Resource flow management, theoretical systems science, applied systems, environmental analysis	www.usf.uos.de/projects/famoja/
JADE	Distributed applications composed of autonomous entities	jade.tilab.com/
NetLogo	Social and natural sciences; they help beginning users get started with authoring models	ccl.northwestern.edu/netlogo/

Tab. 1. List of selected available agent systems [5]

Name	Description	O/C	www
PowerDEVS	an integrated tool for hybrid systems of modeling and simulation based on the DEVS formalism;	O	<a href="http://www.fceia.unr.edu.ar/lsd/powerdevs/index.html">www.fceia.unr.edu.ar/lsd/powerdevs/index.html</a>
SimPy	an open source process-oriented discrete event simulation package implemented in Python;	O	<a href="http://simpy.sourceforge.net/">simpy.sourceforge.net/</a>
Tortuga	an open source software framework for discrete-event simulation in Java;	O	<a href="http://www.ohloh.net/p/tortugades">www.ohloh.net/p/tortugades</a>
Facsimile	discrete-event simulation/emulation library;	O	<a href="http://www.facsim.org/">www.facsim.org/</a>
Galatea	the product of two lines of research: simulation languages based on Zeigler's theory of simulation and logic-based agents;	O	<a href="http://galatea.sourceforge.net">galatea.sourceforge.net</a>
MASON	fast discrete-event multi-agent simulation library core in Java;	O	<a href="http://cs.gmu.edu/~eclab/projects/mason/">cs.gmu.edu/~eclab/projects/mason/</a>
AnyLogic	graphical general purpose simulation tool which supports discrete event (process-centric), system dynamics and agent-based modeling approaches;	C	<a href="http://www.xjtek.com/">www.xjtek.com/</a>
Arena	simulation and automation software developed by Rockwell Automation; it uses the SIMAN processor and simulation language;	C	<a href="http://www.arenasimulation.com">www.arenasimulation.com</a>
Enterprise Dynamics	simulation platform developed by INCONTROL Simulation Software; features include drag-and-drop modeling and instant 2D and 3D Animation;	C	<a href="http://www.incontrolsim.com">www.incontrolsim.com</a>
ExtendSim	general purpose simulation software package;	C	<a href="http://www.extendsim.com">www.extendsim.com</a>
Flexsim	discrete event simulation software which includes the basic and three product lines: distributed simulation system (DS), container terminal library (CT) and Healthcare Simulation ( HC);	C	<a href="http://www.flexsim.com">www.flexsim.com</a>
Witness	a discrete event simulation environment, with graphical 2D & 3D and scripting interfaces, for modeling processes and experimentation;	C	<a href="http://www.lanner.com">www.lanner.com</a>
Plant Simulation	developed by Siemens PLM Software; it enables the simulation and optimization of production systems and processes;	C	<a href="http://www.plm.automation.siemens.com">www.plm.automation.siemens.com</a>
ProModel	discrete event simulation tools;	C	<a href="http://www.promodel.com">www.promodel.com</a>
Simio	tool for rapid modeling of discrete-event systems to provide rapidly an accurate 3D animated model;	C	<a href="http://www.simio.com">www.simio.com</a>

Tab. 2. List of selected DES systems available on market (O – Open Source, C – Commercial) [5]

Terminal Simulation), and HC (Healthcare Simulation). Flexsim is an object oriented simulation tool. Therefore, it is naturally well suited to ABS. It also possesses special features for modeling large volume systems, either through its built-in modeling constructs, or C++ for especially demanding agent based models.

### 3. Examples of multimodal logistics network simulation

Based on performed research works author has decided to choose Flexsim as their main simulation tool. There are two major reasons for this decision.

The first one is that in Flexsim the ability to combine any number of models together provides unlimited scalability so that, in principle, any size of agent model can be constructed [1]. This can be especially important when agent based models have the possibility to become computatio-

nally intensive. Flexsim is able to represent agents with objects and can describe the state models of each agent object in its own modeling language or c++. The 3D virtual reality environment of Flexsim allows the agents to operate in a detailed high fidelity world where geometry, shapes and motion exist. Rapid development of agent models is facilitated through the built-in flexscript language engine which does not require compilation steps, and if more simulation execution power is required, the same code can be promoted seamlessly to c++ for optimal performance.

The other reason is that Flexsim offers possibilities to work through the three levels of users: occasional, intermediate and advanced. According to these levels, Flexsim offers a possibility to work with (see figure 1):

- the pick list,
- the code template (user friendly),
- logic builder,
- the code edit (access to Flexscript/C++).

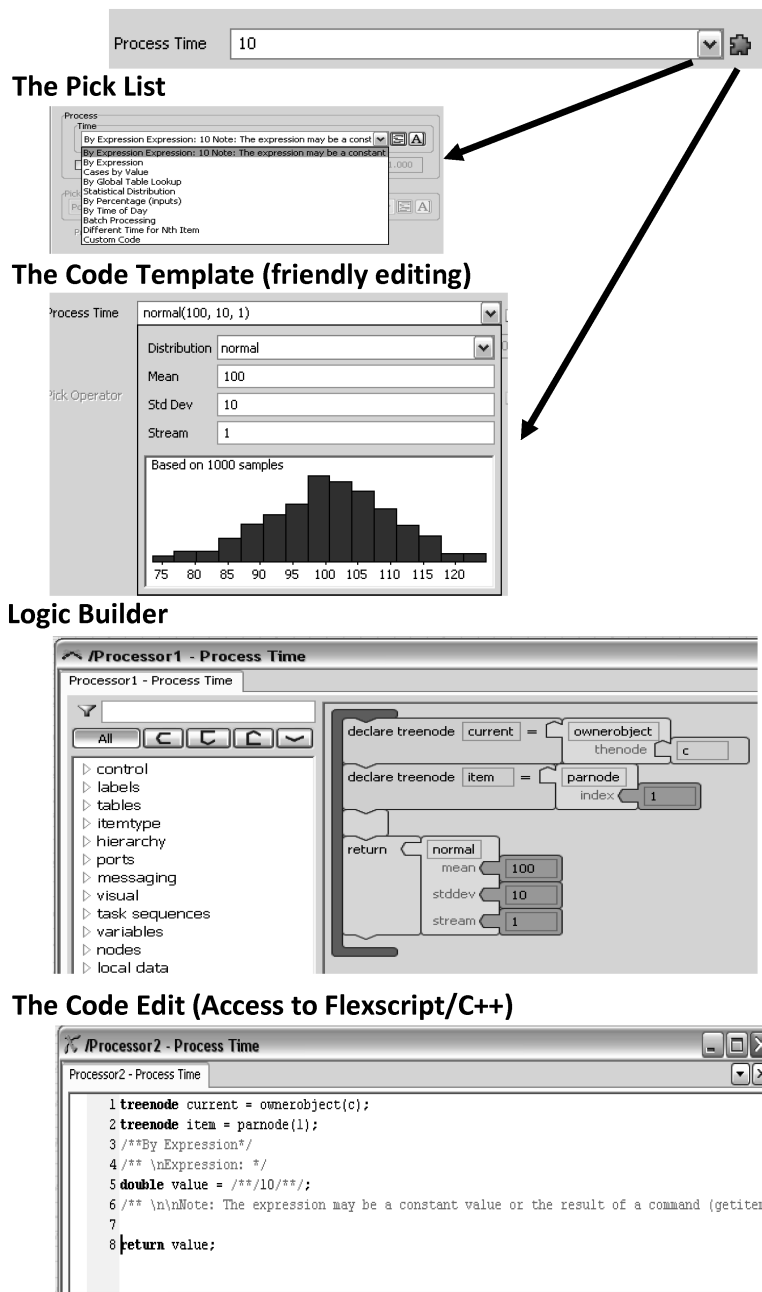


Fig. 1. Different levels of user possibilities in Flexsim, source: [SOCILAPP]

Moreover, Flexsim allows for mixing process driven functionality (characteristic for DES) with task-driven functionality (characteristic for ABS). A task-driven approach ensures that jobs can be undertaken in a realistic manner. For example, an operator has the job of performing a set of inspections of idle equipment when not otherwise engaged in the process work. The task-based approach allows for the creation of activities for the operator which are totally independent of any processing activities and it allows him to become engaged in a set of tasks which may require him to travel, acquire tools and remain “busy” for a period of time. Furthermore, using a task driven approach, resources can incorporate their own ‘intelligence’ to decide what jobs to do and when – it is a paradigm of ABS approach. The task-driven approach results in the task executor methodology.

According to this methodology the user has possibilities to create an ordered “Job list” of tasks which can be carried out in a specific sequence (Figure 2). The Task Executors can also work in partnership with other resources so that an operator can be given a job and part of the job may require the use of a Forklift Truck. The operator can then be tasked with becoming the driver of the fork truck in order to carry out part of the operation and thus coordinating the travelling and transferring of parts between multiple task executors. Task Executor functionality includes the ability to model Robots, Overhead Gantry Cranes, Fork Lift Trucks, AGV’s and Operators.

According to ABS paradigms, the communication between “agents”, i.e. simulation objects, is necessary. Flexsim offers the use of message passing which allows one operation to send a message to another operation (this can be time delayed if the modeler wishes). Furthermore, on receipt of the message the receiving process can choose to act on, ignore or further delay the message until a more appropriate time. This functionality is commonly used as it is a more natural way to model control logic but it also makes the model more understandable for someone reviewing the model code, and therefore improves the maintainability of the model. An important factor of message passing is that the receiving object can act on the message irrespective of its state, i.e. it can close a connection to another element at the time the message arrived even if the process is currently idle.

The ability to tie parts and resources together to simulate the movement between processes is present in many tools, however limitations are common. Flexsim allows for the pickup, move (with acceleration and deceleration) and drop off of parts either using a direct straight line connection or via a complex network using a variety of resource types (Flexsim refers to these as Task Executors). The flexibility of these Task Executors allows the user to easily model scenarios.

Within typical simulation tools, different groups of operators may be defined. However, within a group it is often not possible to easily limit operators to areas of a facility so that they may experience idle time and not be pulled to another area of the facility where work currently exists. Using the allocation methodology for teams, this can be easily achieved to allow a far most realistic modeling of resource utilization.

Below, there are two examples of implementing the logistic multimodal network. The first one refers to solving a transportation problem with use of the Milk Run algorithm. The other shows the multimodal network of a logistics center.

### 3.1. Example 1 – Milk Run system

Apart from the direct supply, the so-called milk run system is practically used for most modes of transport, especially in the area of close logistics. This solution is characterized by multiple collection and delivery of goods by means of using

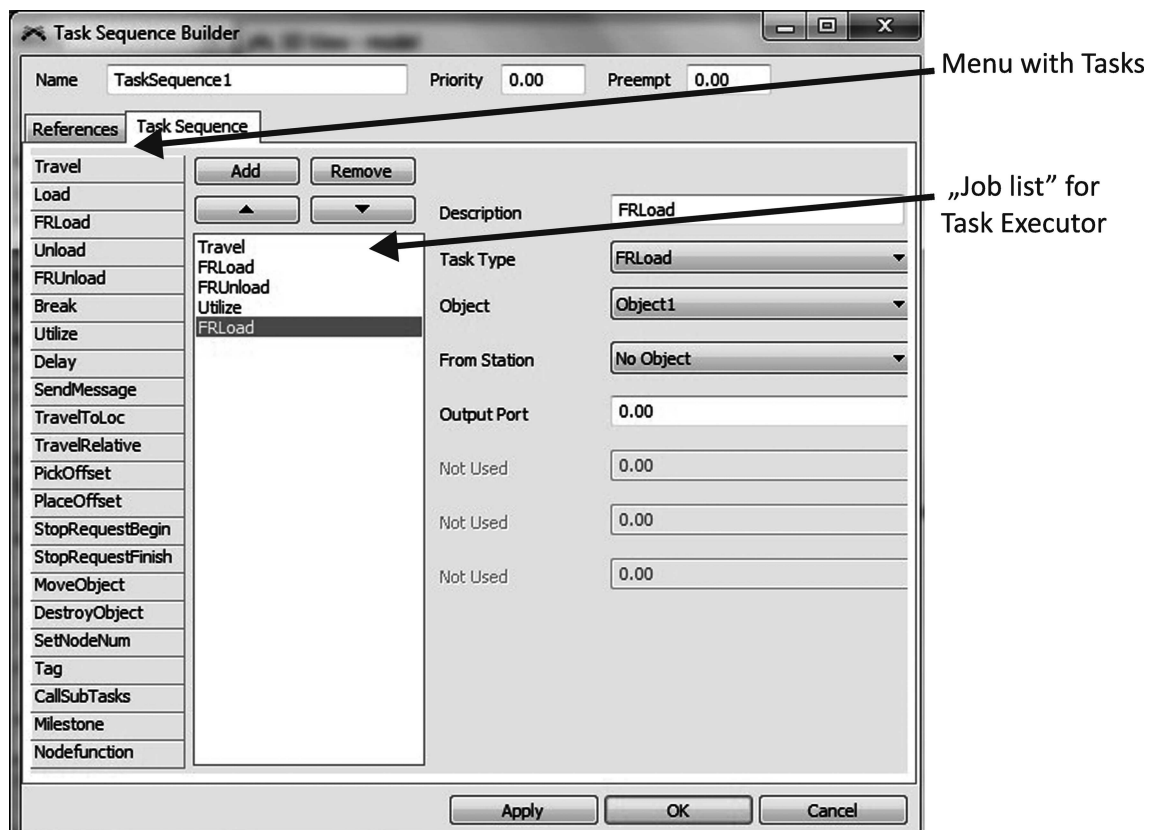


Fig. 2. Window "Task Sequence Builder" for task driven modeling in Flexsim, source: [SOCILAPP]

single round trips and synchronizing transport in regard to specified demand for load in multi-stand collection points. In the milk run system, goods are collected from one supplier and then delivered to several destinations, or goods are collected from several suppliers and delivered to one destination. The scheduling of deliveries in this system is much more complex than in case of direct deliveries. It includes the amount of particular goods, frequency of deliveries, decisions concerning routes and delivery and collection sequence in specific loading points [3]. Figure 3 presents an example of applying milk run transport system in the simulation model built with use of Flexsim software.

### 3.2. Example 2 – The multimodal network of logistics center

Designing the network of multimodal transport is the basis for functioning and organization of logistics centers. They use various modes of transport and goods/raw materials change their position in various unit loads in the whole center area due to fact that logistic functions, such as sorting, completion, storing, packing are implemented in the network. Owing to the analytical and optimizing qualities of the simulation and the functionality of Flexsim software, it is possible to reliably represent the real state (transport multimodality) and optimization of flow according to the accepted modified variables and object function. Figure 4 shows a general plan of the multimodal network of the logistics center and Figure 5 presents examples of particular areas with changeable unit loads.

Figure 5 presents various areas of the logistics centre that use various unit loads as well as modes of transport. Part A

shows loading pallets transporting goods in containers with use of forklifts. In part B simulation was run in the sorting plant area with a pallet unit load containing collective packaging. The used mode of transport here is a gantry crane. Part C presents the area of rack storage where automatic cargo lifts are used. Part D illustrates the area of unpacking and completion with use of conveyor and operator system. The described-above simulation model allows for integration of schedules in the whole internal supply chain. It also makes it possible to optimize flow in the whole modelling area, from delivering goods until eventually dispatching them with use of various unit loads and modes of transport.

### 4. Conclusions

Researches identify two main barriers for combining DES and ABS implementation in the area of multimodal logistics networks. These barriers are at different levels:

- Features of manufacturing and supply chain processes – queuing simulations or a complex network of queues, in which the processes can be well defined and their emphasis is on representing uncertainty through stochastic distributions.
- All of ABS products expect knowledge of object oriented programming techniques and the modeller needs to be comfortable with Java. These are not skills that an average manager has developed during his career. For this reason, ABS remains the domain of relatively few skilled experts and academic researchers.

Presented paper focuses on the choice of IT tool for multimodal networks simulation. Main findings are reasons

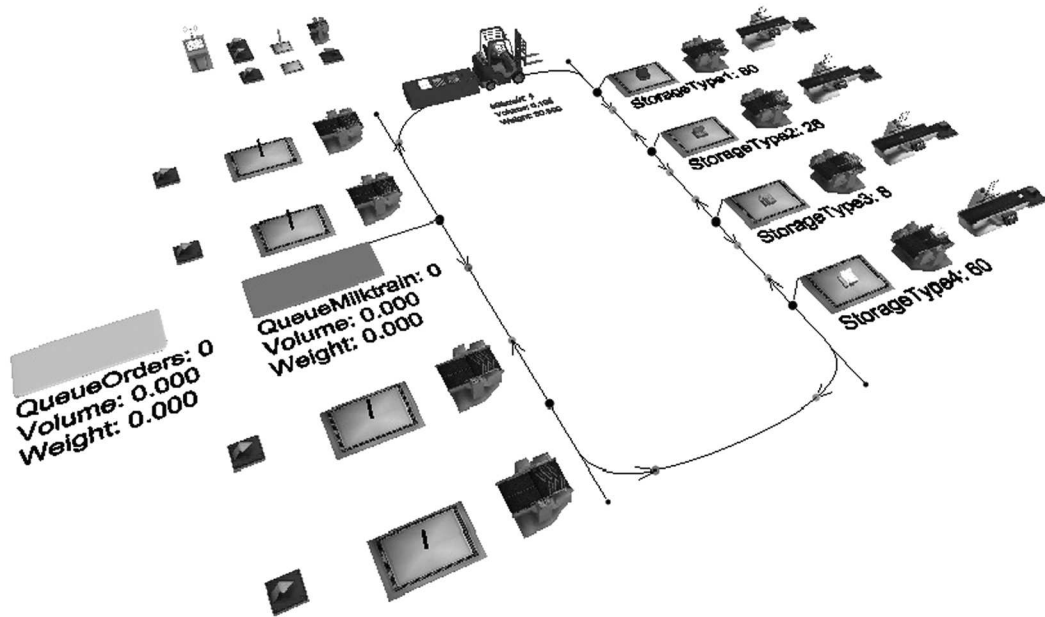


Fig. 3. Milk Run model in Flexsim, source: [SOCILAPP]

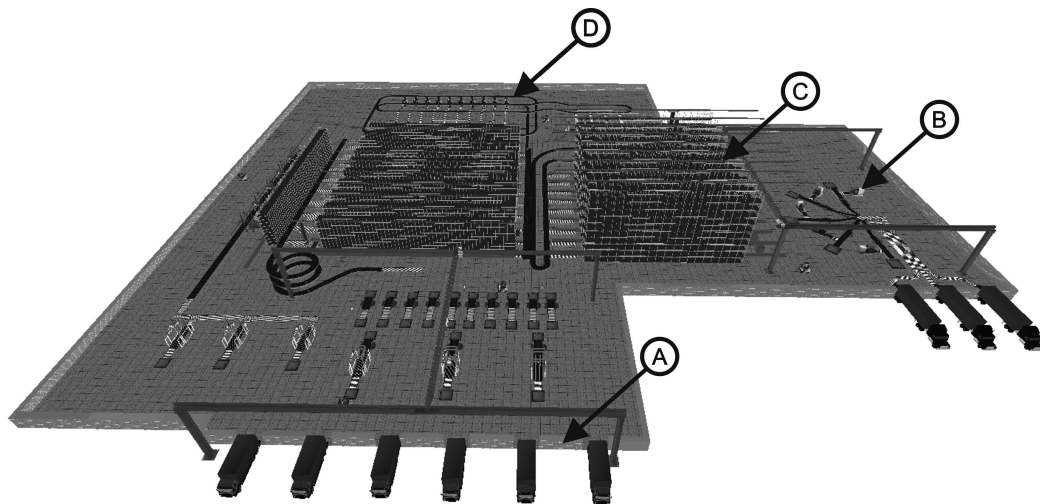
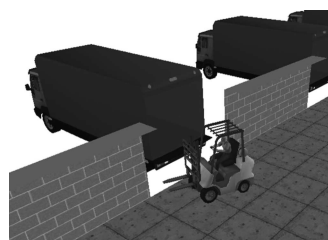
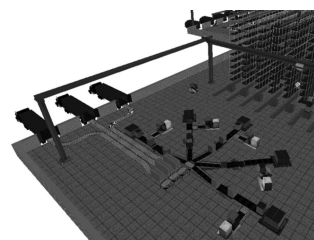


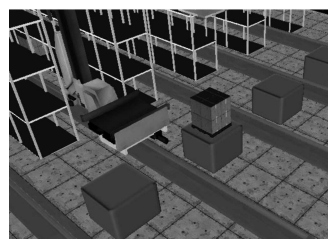
Fig. 4. Multimodal network – logistics centre model in Flexsim, source: [SOCILAPP]



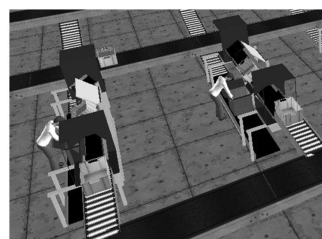
A. Loading pallets



B. Sorting plant area



C. Rack storage with automatic cargo lift



D. Unpacking and completion area

Fig. 5. Particular area of multimodal network in the logistics centre, source: [SOCILAPP]

which are presented and decided about selection of FlexSim software tool. Especially that the presentation of two practical examples are included. It seems that chosen tool is able to overcome these two barriers defined by researches.

#### References:

- [1] Beaverstock M., Greenwood A., Lavery E., Nordgren W.: *Applied Simulation. Modeling and Analysis using Flexsim*. Flexsim Software Products, Inc., Canyon Park Technology Center, Orem USA 2011
- [2] Ingalls, R.G.: *Introduction to simulation*. [In:] *Proceedings of the 2008 Winter Simulation Conference*, ed. S. J. Mason, R. R. Hill, L. Monch, O. Rose, T. Jefferson and J. W. Fowler. Institute of Electrical and Electronics Engineers, Inc., 2008.
- [3] Lashine S.H., Fattouh M., Issa A.: *Location/Allocation and routing decision in supply chain network design*. *Journal of Modeling in Management*, vol 1, Issue 2, 2006, pp.173-182.
- [4] North M.J., Macal C.M.: *Managing business complexity: Discovering strategic solutions with agent-based modeling and simulation*. Oxford University Press, New York 2007.
- [5] Pawlewski P., Golińska P., Dossou P.E.: *Application potential of Agent Based Simulation and Discrete Event Simulation in enterprise integration modeling concepts*. [In:] Corchado J.M., Omatu S., *Advances in Distributed Computing and Artificial Intelligence Journal*, Special Issue 2012, pp. 23-32.
- [6] Siebers P.O., Macal C.M., Garnett J., Buxton D. and Pidd M.: *Discrete-Event Simulation is Dead, Long Live Agent-Based Simulation!* *Journal of Simulation*, 4(3), 2010, pp. 204-210.

#### Key words:

simulation, modeling, multimodal networks.

#### Abstract:

The author focuses his research mainly on the area of logistics multimodal networks modeling and design. Yet, he has wide experience in using various simulation tools, such as spreadsheets, programming languages and programming libraries as well as simulation packages. Therefore, the author has made an attempt to survey the available simulation tools and techniques from the viewpoint of their practical modeling and designing multimodal logistic networks. The Research Highlights of performed works are: selection of IT tool appropriate for multimodal networks simulation, focus on complementary approaches based on Discrete Event Systems (DES) and Agent Based Systems (ABS), presentation of reasons which driven the choice of the tool. One of the main paper's finding is analysis of existing simulation tools regarding defined requirements. Main findings are also reasons which are presented and decided about selection of FlexSim software tool. Especially that the presentation of two practical examples are included.

#### NARZĘDZIA SYMULACYJNE WSPOMAGAJĄCE MODELOWANIE I PROJEKTOWANIE LOGISTYCZNYCH SIECI MULTIMODALNYCH W PRAKTYCE

**Słowa kluczowe:** symulacja, modelowanie, sieci multimodalne.

#### Streszczenie:

Autor w swoich badaniach skupia się na modelowaniu i projektowaniu logistycznych sieci multimodalnych. Bazując na swoim doświadczeniu w używaniu różnych narzędzi symulacyjnych takich jak: arkusze kalkulacyjne, specjalizowane języki programowania, biblioteki programowe jak również pakiety symulacyjne – autor dokonuje w pracy przeglądu dostępnych technik i narzędzi symulacyjnych z punktu widzenia praktycznego ich wykorzystania w modelowaniu i projektowaniu logistycznych sieci multimodalnych. Najważniejsze punkty zrealizowanych badań to: właściwa dla symulacji sieci multimodalnych selekcja narzędzi IT, skupienie się na dopełniających się podejściach bazujących na systemach zdarzeń dyskretnych (DES – Discrete Event Systems) i systemach agentowych (ABS – Agent Based Systems), przedstawienie racji które kierowały wyborem określonego narzędzia. Jednym z najważniejszych efektów prezentowanych w pracy jest analiza dostępnych pakietów symulacyjnych oparta na zdefiniowanych wymaganiach oraz przedstawienie racji, które zadecydowały o wyborze pakietu symulacyjnego FlexSim, najlepiej spełniającego zdefiniowane wymagania. W pracy przedstawiono również dwa praktyczne przykłady modeli symulacyjnych sieci multimodalnych zrealizowanych z wykorzystaniem wybranego narzędzia.

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