DOI: 10.18372/2310-5461.57.17449

UDC 656.135:004.94

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OPTIMIZATION OF THE SIMULATION PROCESS OF PRODUCT SUPPLY FROM THE MANUFACTURER

Introduction and formulation of the problem

In many areas of transport logistics, cargo delivery can increase its value by an amount equivalent to the value of the goods themselves. Of particular relevance are studies that allow to accurately calculate the volume of cargo transportation, calculate the number of transport units required to ensure cargo flows, determine rational routes for the movement of vehicles with cargo, as well as optimize the total cost of transportation. Besides vehicle routing, real transport companies also need to solve the problem of vehicle loading [1].

Transportation management includes many different aspects, such as planning and organizing transportation and fleet maintenance, human resource management, and risk management. Information technology will benefit the organization only if it forms an integral part of the business planning, business process design and business process operation.

The use of simulation modeling allows you to determine the maximum load of vehicles, minimize transportation costs, and also calculate the probability of exceeding costs. Simulation modeling solves real-world problems safely and efficiently. It provides an important method of analysis which is easily verified, communicated, and understood. Across industries and disciplines, simulation modeling provides valuable solutions by giving clear insights into complex systems. Unlike physical modeling, such as making a scale copy of a building, simulation modeling is computer based and uses algorithms and equations. Simulation software provides a dynamic environment for the analysis of computer models while they are running, including the possibility to view them in 2D or 3D [2].

One of the most effective software platforms for creating a model and conducting simulation experiments today is the AnyLogic system. AnyLogic is the standard in multimethod modeling technology, delivering increased efficiency and less risk when tackling complex business challenges. The unmatched flexibility found in AnyLogic allows users to capture the complexity of virtually any system, at any level of detail, and gain a deeper insight into the interdependent processes inside and around an organization. These issues can be solved by software AnyLogic, and therefore the main task of transportation management can be solved.

In the case of a company that commercializes products with a high level of personalization, managing the supply chain and inventory levels can be a very difficult task. This paper examines an example of this kind with a company that produces spare parts for many different models of aircraft and performs their maintenance at Ukrainian airports.

Analysis of recent research and publications

Modeling of the cargo transportation process helps to depict all stages of cargo delivery from a place of production to the end consumer. One of the simulation tools is AnyLogic software, whose users have the opportunity to imitate this process and obtain quantitative indicators that will help in choosing a transportation organization. AnyLogic is the only simulation tool to offer a full range of cloud technologies, changing the way people run models. Users of which have the opportunity to simulate this process and get quantitative indicators that will help in choosing the organization of transportation. AnyLogic uses GIS maps and builds routes as close to real as possible. To use this software, it is enough to have basic training in the field of information technology, which is an undoubted advantage of AnyLogic [3].

It is a modern Java-based model development environment with a multilingual graphical interface and a well-designed contextual help system. This software product contains a large library of visual components [4-6]. The developer can also create and add their own components to the environment. Models are stored as Java applets.

Optimization of the AnyLogic model consists in successive execution of several model runs with different parameter values and finding the optimal parameter values for a given task.

For example, a significant range of literature is devoted to the problems of simulation modeling of economic systems [6, 7]. However, the development of this mathematical direction dictates new research to improve the means of formulating and implementing models and planning simulation experiments.

The author [8] has developed a simulation model in the AnyLogic environment for the execution of orders by the car fleet, which takes into account the coefficient of car utilization, which will be defined as the ratio of "car operating time to total working time".

Studies [9-13] use AnyLogic to solve a wide range of problems related to cargo and passenger transportation. The analysis of literature sources shows many simulation models in the AnyLogic environment, which are developed on the basis of local tasks and each of them is unique. Therefore, the solution of the task of transportation of spare parts by the manufacturer is actual.

Formulation of article goals

The main goal of the research is to build a simulation model of the process of supplying spare parts from the manufacturer and to conduct an optimization experiment to determine the required number of trucks, provided that they are loaded at no more than 85%. Describe the logic of application processing by the enterprise, where it is necessary to take into account: receipt of an application, time for loading a truck, sending it to a client, unloading a truck, notification of delivery and returning a truck to the enterprise.

Presenting main material

The task for modeling the transportation process consists of the following order. There are seven airports (Boryspil International Airport, Lviv International Airport, Zaporizhzhia International Airport, Odesa International Airport, Sumy Airport, Kharkiv International Airport, Chernivtsi International Airport), which require spare parts for aircraft maintenance and repair twice a week.

There is an enterprise in Kiev – the Antonov Serial Plant, which manufactures and delivers the necessary components for aircraft. Notification from airports comes to the enterprise in the form of an order. After that, it takes two to three hours to load the truck. The same amount of time is required for unloading a truck at the airport. After receiving the spare parts, the airport notifies the company about this by the message «Delivered! ».

Then the truck is sent back to the Plant. It is required to simulate the process of delivering spare parts to estimate the optimal number of vehicles, given that the company has a total of seven trucks.

The coordinates of the airports and the company that manufactures and supplies spare parts for aircraft, as well as the route between them, which is used for delivery, are set using the GIS Map component. In the properties of the GIS map the source of routes was selected – OSM server (Open Street Map server). After than go to the map editing mode to select a specific display area (Ukraine) and find all airports, enterprise. Select Convert To GIS Points/Regions, the label of the selected object will appear on the map.

For the convenience of placing Agents in the marked points, combine them into a collection. To do this, select all the airport labels, right-click on any of the labels and select Create Collection. In the properties of the collection, set the name airport Location. As the name implies, the coordinates of airports will be stored in this collection. Airports must be placed in these coordinates. To do this, create a Population of agents that will be models of airports.

Now it is necessary to associate the created population of the Airport agent with the coordinates of airports and with the number of airports, that is, associate with the airport Location collection. To do this, let's go to the properties of the population, click the Contains a given number of agent of airports on the object main. Enter the following expression in the Initial number of agents column: (*airport Location. size)*. This function returns the number of elements in the airport Location collection (7 in this case).

To associate airports with their coordinates, in the Initial location section, select Place agent: in the node and in the graph Node enter an expression: *airport Location .get (index)*. This function returns the addresses (indexes) of elements in the airport Location collection (the same marks on the map).

At first step, the single agent for the factory «Manufacturing», the population of the agent «Airport», which contains a collection of airports with their coordinates (airport Location), the population of agents «Truck» and the agent type «Order» are created.

Create A single agent named Manufacturing to host the Kyiv plant. Now we need to associate the manufacturing agent with the label on the map.

Create a new population of agents named Truck to add them into the model, that notice delivery is carried out by trucks. For further optimization, take out the number of trucks as a separate parameter of Track.

It is clear that all trucks belong to the production (manufacturing agent), it is necessary to specify the initial location in the properties of the trucks agent population, as the Antonov Serial Plant.

Airports must form an order to receive spare parts, so agent is created by Instead of Agent Population, select Agent type only named Order.

Need to show that trucks are a production resource. To do this, from the Projects tab (or from the main object), open the Manufacturing agent type and transfer the Resource Pool block from the Process Modeling Library palette to it, which specifies the set of available resources, in this case trucks (Fig.1).

Number of resources value corresponds to the value of the previously created number Trucks parameter, and it should also be noted that this block adds the trucks population to the new resources (Population of agents: main. trucks). This completes the initial data entry.

The initial data is described: airports (their coordinates), production (coordinates), trucks (as a production resource), an application for ordering spare parts is created (as an Order agent type). Now let's move on to the logic of airports and production.

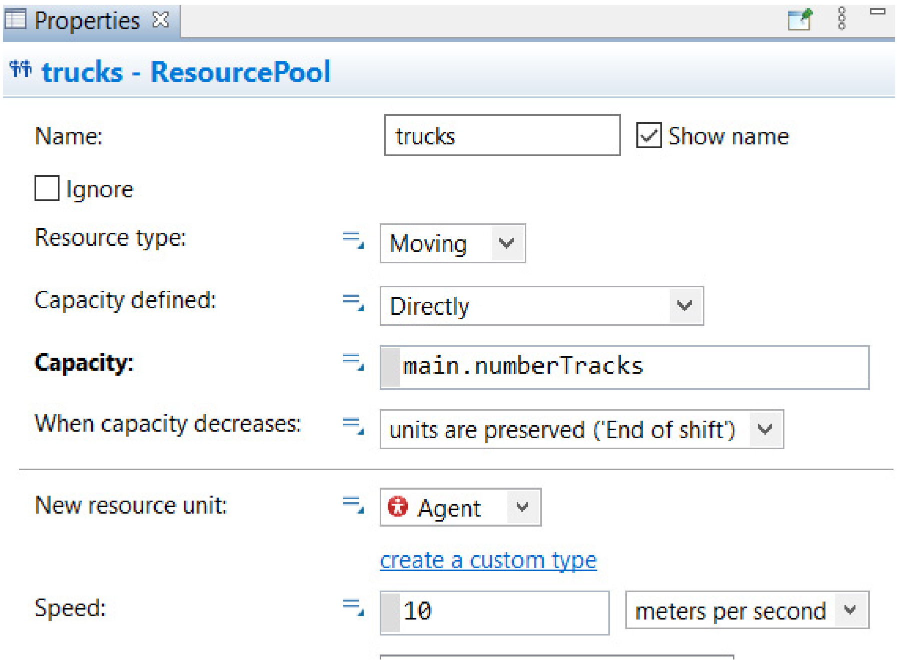

Fig. 1. Properties of the Resource Pool block

The process of placing an order for new spare parts is described, taking into account that each airport sends an application in the same form. The logic of this process includes the normal operation state (time period when no spare parts are needed), the spare parts waiting state (time period when the order is sent to the factory) and back (transition to normal operation, which is done when the «Delivered!» message is sent). The structure and properties of the transition to normal operation of Airport are shown in Fig. 2.

Parts are required by airports 2 times a week - this means that the transition from the state of normal operation to the state of waiting for spare parts occurs at a given intensity:

With a given intensity / Rate; 2 times a week / per week.

As soon as the airport enters the state of waiting for spare parts, an order must be formed and sent to the enterprise. To reflect this in the state diagram, let's return to the properties of the waiting Details element. In the Entry action column, write the following expression:

Order order = new Order(this);
Send (order, main.manufacturing).

In the first line, a new order is formed with this parameter, which indicates the airport from which the order is received. The second line of code is needed for sending – the send function, which has two arguments: what to send (the order created above) and to whom to send (to production – to the manufacturing agent). Now the airport can send orders for spare parts.

The next step is to construct an order processing process on the plant, which takes into account: receipt of the application, time to load the truck, send it to the customer, unload the truck, notify about the delivery and return the truck to the company.

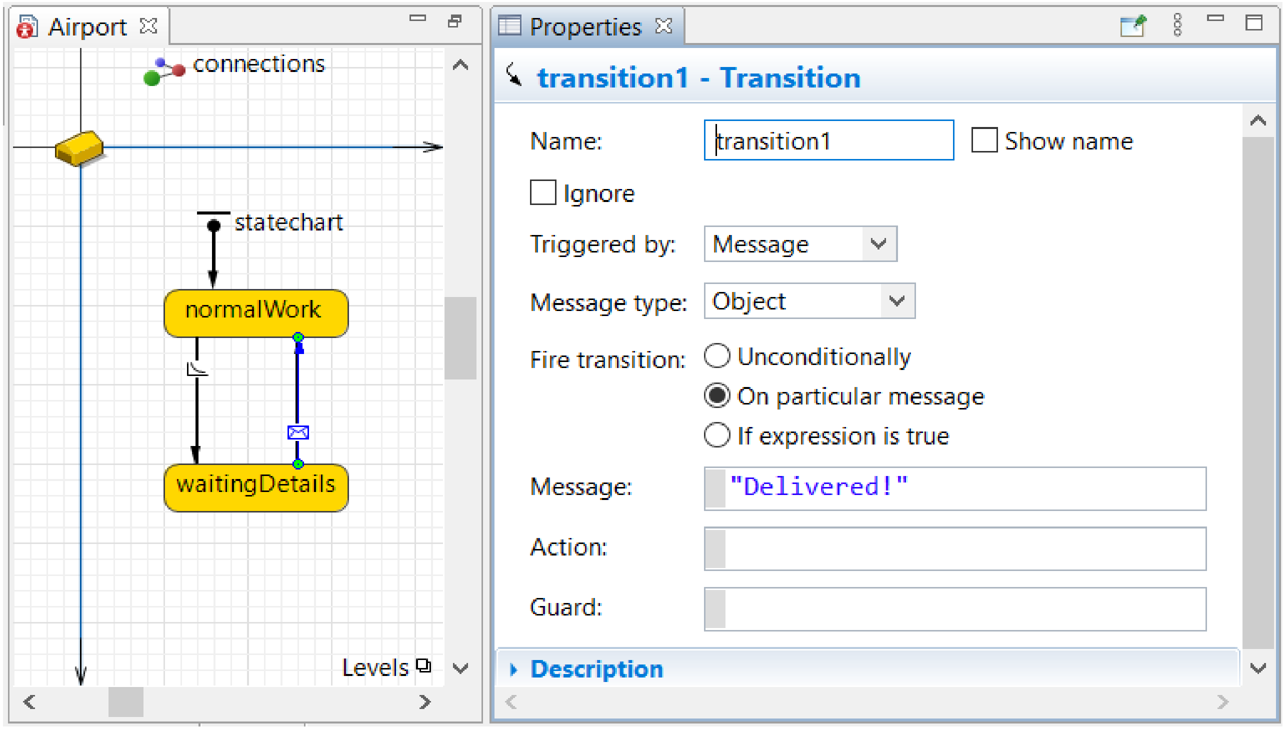

Fig. 2. Structure and properties of the transition to normal operation

After receiving an order, a resource (truck) is allocated in plant for the execution of this order. It is loaded with ordered spare parts, which takes two to three hours, and sent to the airport. There, the truck is unloaded (within two to three hours), after which a delivery notification is sent, and the truck returns to plant, becoming a free resource. Below, in Fig. 3, a model of this process is shown.

The process is entered through the Enter block, which receives orders. Next, the received order enters the queue for waiting for resources, to do this, drag the Seize block, which is responsible for capturing resources, and connect it to the Enter block. Open the properties of the Seize block and in the Resource sets item click on the «+» image - from the pop-up list select trucks (trucks).

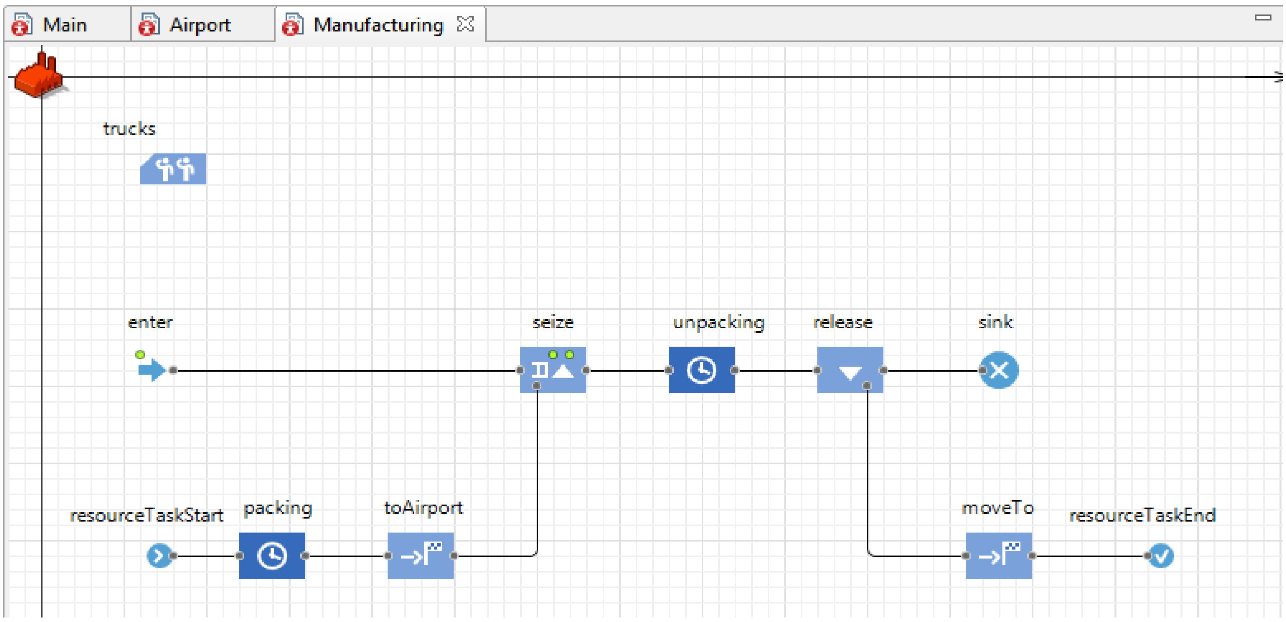

Fig. 3. Processing and execution of the order in the plant

Before a resource can be grabbed, it must be prepared, which in our case means booting the machine. Resources are prepared and sent in a special sub-process for resources, which begins with the Resource Task Start block.

It takes time to load the resource, that describe this process use bloc Delay. For the delay time, a uniform distribution between two and three hours is specified: *uniform (2, 3*). After the resource is loaded, it is sent to the airport by Move To.

The resource (truck) is sent to the Seize block, now information inside the order must be passed to this resource so that it knows exactly where the cargo should be delivered. To do this, go to the properties of the Seize object and in the Actions section in the column On seize unit write the following expression:

((Truck) unit). client = agent. Customer.

In this expression, the value of the client parameter, which is stored inside the Truck resource, is set to the value of the customer parameter of the Order agent.

As soon as the truck has arrived at the airport, it must be unloaded. This process is modeled similarly to the machine loading process, namely by the Delay block, which in this case will be called unpacking.

After the order is completed, the resource becomes free (Release block), and the agent (Order) is sent to the Sink block, where it will be deleted. Since the resource (truck) has been released, it must be sent to production, to do this, use the Move To block again, in which specify the destination of the manufacturing agent, which is located on the main agent.

The subprocess for a resource must end with a Resource Task End block. In order for the resource to return to the shared Resource Pool and be available for a new order. The last stage of order processing is to route all incoming orders to the order processing block Enter.

The result of the constructed simulation model of order fulfillment at the factory is shown in Fig. 4.

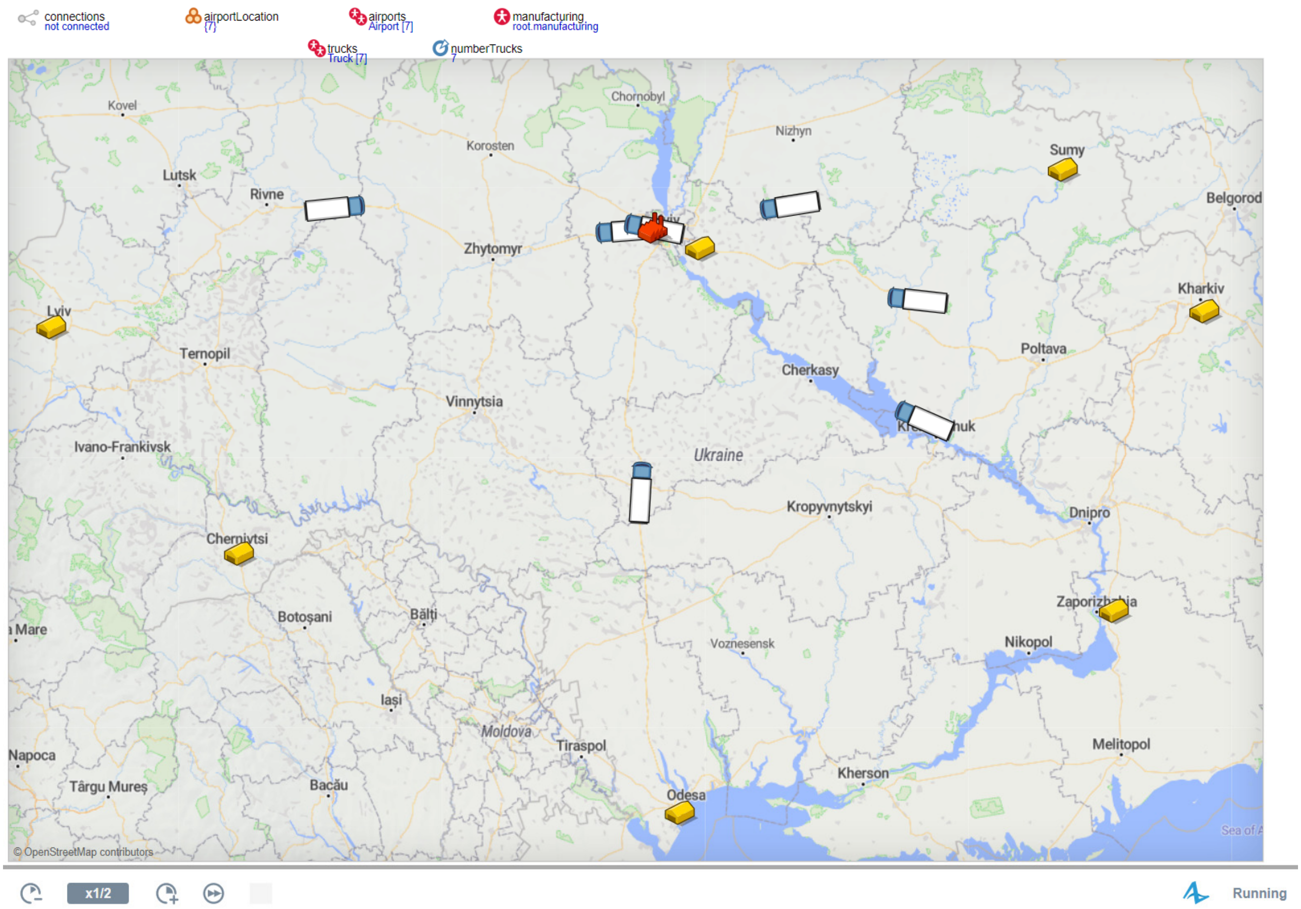

Fig. 4. Simulation model for delivering spare parts to airports

Pay attention to the truck block by opening the manufacturing agent. During order processing, the number of seized resources is fixed, by which it is possible to assess the rationality of resource use. When using seven trucks, the average resource utilization is approximately 24 percent (Fig. 5).

Under the terms of the task, the loading of resources during the transportation of spare parts should be no more than 85%, so some of the resources are idle and cause damage to the plant. It is necessary to create an experiment to optimize the number of trucks to deliver the order to all airports.

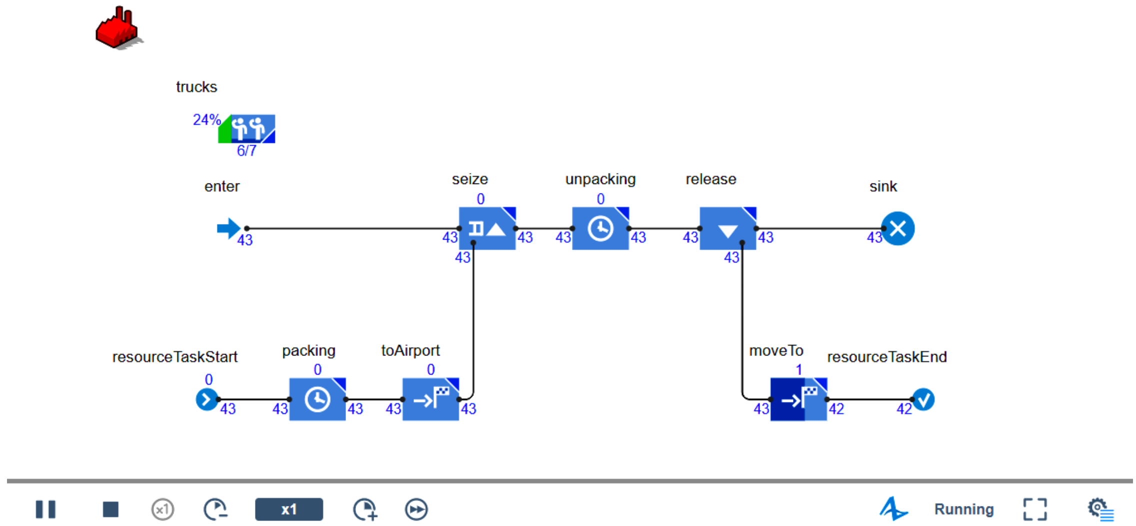

Fig. 5. Resource usage for parts delivery

In the optimization properties, the parameters and requirements were specified according to Fig. 6.

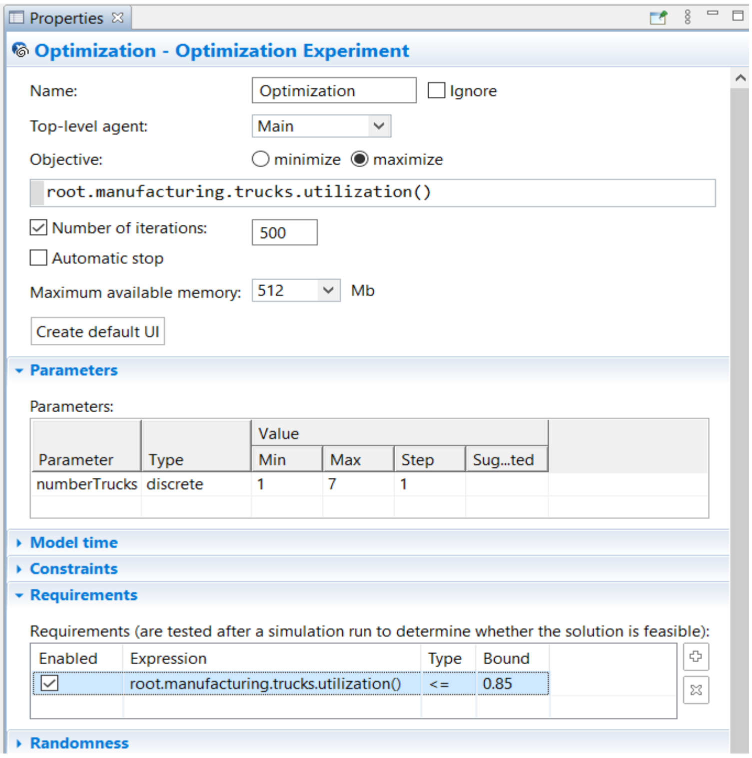

Fig. 6. Properties of the optimization experiment

Number Trucks (the number of trucks) is selected as a variable parameter, which varies discretely from 1 to 7. The objective function is the average load of all trucks, which is maximized with a constraint (no more than 85 %). The *root.manufacturing.trucks. utilization* line of code allows you to access the utilization average load parameter of the trucks resource of the manufacturing agent located on the root agent (in this case, main). An example of the run of the experiment shows Fig. 7.

As can be seen from Fig. 6, the best feasible value of resource utilization is 64 % when using 2 trucks. According to the results of the conducted research, the average value of resource use at the enterprise will fluctuate within 60–85 %.

Conclusions

In this paper, a simulation model of the process of transportation of spare parts to airports manufactured at the Antonov Serial plant is developed. The process of placing an order for new spare parts is described, taking into account that each airport sends an application in the same form. The logic of order processing by the plant is

described, which takes into account: receiving an application, time for loading the truck, sending it to the customer, unloading the truck, notification of delivery and returning the truck to the company.

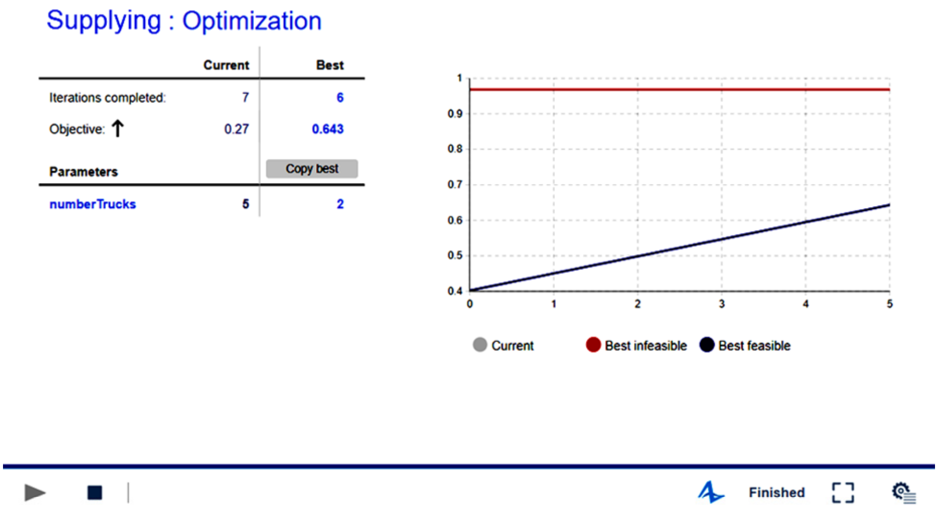

Fig. 7. Optimization of the spare parts delivery process

The logic of order processing by the plant is described, which takes into account: receiving an application, time for loading the truck, sending it to the customer, unloading the truck, notification of delivery and returning the truck to the company.

An optimization experiment was created and conducted to minimize the number of cargo vehicles for the supply of spare parts to Ukrainian airports. The results of the experiment showed that the best allowable value for the use of resources is about 64 % when using 2 trucks, the average value of resource use at the enterprise will fluctuate within 60–85 %.

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Мєдвєдєва Н. А. Багрій М. М.
ОПТИМІЗАЦІЯ ПРОЦЕСУ МОДЕЛЮВАННЯ ПОСТАЧАННЯ ПРОДУКЦІЇ ВІД ВИРОБНИКА

У роботі розроблено імітаційну модель процесу перевезень запчастин від виробника до аеропортів методом агентного моделювання в середовище AnyLogic. При побудові моделі використовувано ГІС-карту ресурсу OpenStreetMap, яка дозволяє додавати координати об'єктів та будувати маршрути транспортування максимально наближені до реальних.

Імітаційна модель побудована для серійного заводу «Антонов» та семи аеропортів України, яким двічі на тиждень потрібні запасні частини для технічного обслуговування та ремонту літаків. Замовлення приходить від аеропорту до заводу через повідомлення. Після чого відбувається завантаження фури, максимальна кількість машин складає сім одиниць. Оптимальний час для завантаження та розвантаження вантажних фур складає від двох до трьох годин. Після отримання запчастин аеропорт оповіщає про це завод через повідомлення «Доставлено!». Далі фура відправляється назад на підприємство-замовник запчастин.

При розробленні імітаційної моделі створені одиничний агент для заводу (Manufacturing), популяцію агентів (Airport), яка містить колекцію аеропортів з їх координатами, популяцію агентів (Truck) та тип агенту (Order). Описано процес оформлення замовлення нових запчастин, враховуючи, що кожен аеропорт надсилає запит однакової форми.

Описано логіку обробки замовлення підприємством, де враховані: отримання заявки, час на завантаження фури, відправлення до клієнта, розвантаження фури, оповіщення про доставку и повернення фури на підприємство.

Створено та проведено оптимізаційний експеримент для мінімізації кількості вантажних транспортних засобів для постачання запчастин до аеропортів України від виробника чи постачальника, завантаження яких складає не більше 85 %. Результати експерименту показали що оптимальне допустиме значення для використання ресурсів становить близько 64 % при використанні 2 вантажівок. За результатами проведеного дослідження середнє значення коефіцієнта використання ресурсів на підприємстві коливатиметься в межах 60–85 %.

Ключові слова: імітаційне моделювання, перевезення, середовище AnyLogic, оптимізаційний експеримент.

Miedviedieva N., Bahrii M.
OPTIMIZATION OF THE SIMULATION PROCESS OF PRODUCT SUPPLY FROM THE MANUFACTURER

A simulation model of the process of transportation of spare parts from the manufacturer to airports was developed using the method of agent modeling in the AnyLogic environment. During the construction of the model, a GIS map of the OpenStreetMap resource was used, which allows you to add coordinates of objects and build routes as close as possible to real ones.

The imitation model was built for the Antonov Serial Plant and seven Ukrainian airports, which need spare parts for aircraft maintenance and repair twice a week. The order comes from the airport to the factory via notification. After that, the truck is loaded, the maximum number of cars for transportation is seven. The time for loading and unloading is two to three hours. After receiving the spare parts, the airport notifies this enterprise by the message «Delivered!». Then the truck is sent back to the enterprise.

During the development of the simulation model, the single agent for the factory «Manufacturing», the population of the agent «Airport», which contains a collection of airports with their coordinates, the population of agents «Truck» and the agent type «Order» are created.

The process of placing an order for new spare parts is described, given that each airport sends a request of the same form. The logic of order processing by the plant is described, which takes into account: receiving an application, time for loading the truck, sending it to the customer, unloading the truck, notification of delivery and returning the truck to the company.

An optimization experiment was created and conducted to minimize the number of cargo vehicles for the supply of spare parts to Ukrainian airports, the loading of which is no more than 85%. The results of the experiment showed that the best allowable value for the use of resources is about 64% when using 2 trucks. According to the results of the conducted research the average value of the resource utilization rate at the enterprise will range from 60–85 %.

Keywords: simulation modeling, transportation, AnyLogic environment, optimization experiment.

Стаття надійшла до редакції 26.02.2023 р.
Прийнято до друку 12.04.2023 р.