

Digital technologies for artesian water logistics process management

Irina Kulibaba^{1*} and Vladimir Osmin¹

¹Moscow Polytechnic University, 107023 Moscow, Russia

Abstract. The paper defines the complexity of artesian water logistics processes between the production site and the consumer. The stages of the process and the conditions influencing the speed of its implementation and changes in its status are presented. The purpose of the research is to create a formal model necessary for the functioning of an information system for managing logistic processes and predicting their changes in order to effectively use the resources providing loading, unloading and delivery of finished products between the place of production and consumers (warehouses, sorting stations, etc.). The use of methods of structural analysis, synthesis and observation allowed to identify key objects and links between them, influencing the change of processes of the problem area. On the basis of the obtained results, an agent model was created using the methodology of simulation modelling, which allows to implement scenarios of behavior of delivery of finished goods depending on the given conditions of transport flows, external conditions and other parameters.

1 Introduction

Transportation of drinking water is a complex process, the realization of which depends on many conditions. Such water can be delivered to the consumer through the distribution network by trunk pipelines from storage facilities or in packaging from a factory that produces drinking water [1].

Factory production of water is a specific process, and the production cycle depends on the remoteness of the source, methods of filtration and treatment of water, used containers for bottling. Water transport in this case can be carried out from the source to the plant (this is due to the fact that most artesian or glacial sources are located in specially protected areas where production activities are prohibited) and from the plant to the consumer (to the warehouse of finished products, sorting centers or other points).

When transporting unpackaged water, many conditions are to be considered, which, for instance, include the cleanliness of the inside of the container; the material from which the container is made that is approved for contact with food liquids; the presence of thermal insulation to maintain a stable temperature (the liquid should not change its aggregate state during transport due to changes in weather); and pumping equipment [2]. If water is already packed in a factory way, then during its transport it is also necessary to comply with a number of requirements to ensure the safety of the packaging [3, 4].

*Corresponding author: elitprice@mail.ru

Current Russian legislation allows small businesses related to the delivery of drinking water. It can be organized in several ways: full-cycle production (the presence of a well, production equipment, carrying out full-fledged water purification and its pouring into containers, and sales of finished products); franchising (to carry out only water delivery according to ready-made business solutions or strategies in the presence of a customer base); dealership (only water delivery from the producer to the end consumer). These types of activities require the appropriate regulatory license.

Regardless of the method of business implementation, an effective approach to the organization of logistics processes is required, as it will reduce the time of delivery of raw materials, finished products or consumables, reduce the load on the transport used for delivery. All this is possible to implement with the help of information systems capable of creating a list of recommendations for operational management of the process, modelling the consequences of the developed concepts, etc. Such systems are based on simulation models, which have in their composition quantitative and qualitative characteristics of key objects and processes of the modelled area and rules of their interaction [5, 6].

Therefore, the purpose of the research is to create a simulation model of the organization of transport flows of the process of delivery of finished products from the manufacturer to the places of its storage and distribution. This requires performing the tasks of establishing the key elements of the process of transportation of drinking water and their characteristics; creating a formal model of the research subject, including the rules affecting changes in the states of processes.

Theoretical significance of the research consists in systematization of rules of transportation of drinking water with preservation of its properties and marketable appearance, systematization and unification of processes to provide conditions of their unified control. Practical significance is to support the organization and development of small businesses in the field of drinking water delivery.

2 Methods and Materials

In the research related to the creation of process models, a set of methods is used to obtain a description of the problem domain to describe it using a formal language. For this purpose, authors in their works use the methods of structural analysis, synthesis, observation, groupings and simulation modelling, regardless of the object of research [7-10].

Using the method of structural analysis allowed to decompose the process of water logistics and to establish all the objects involved in it, the links between them and the conditions affecting the change of their states. The methods of grouping, synthesis and observation made it possible to establish regularities to create universal rules for the implementation of the process, and based on the methodology of agent-based modelling, related to simulation modelling, a digital twin reflecting all its qualitative and quantitative characteristics was created.

3 Results

For transportation of water as a finished product, the following items are required:

- containers (can be represented by bottles, cans, jars, canisters or drums);
- secondary packaging (crates or cardboard boxes) for safe transportation of the finished product;
- receptacle (for instance, tanks) if the water is not prepackaged.

Cisterns, barrels or other airtight containers of different volumes and made of material that does not change its chemical composition can be used as tanks [2].

Road transportation is used for transportation of finished products, which may involve trucks of different makes and models that meet the requirements of transportation. For small businesses at the initial stage is characterized by the use of a limited number of vehicles for transportation. Effective logistics requires taking into account not only the volume for transportation, but also the time of delivery to the end point and return, downtime (for loading or unloading, difficulties on the route), vehicle maintenance, etc. [11].

Based on the results of the research, the parameters and characteristics have been determined to characterize the transport flows occurring between the drinking water production facility to the warehouses or distribution centers that sell the products produced. Fig. 1 shows a fragment of a two-dimensional simulation model corresponding to the terrain over which the studied transport flows are realized (located in the Orenburg Oblast, Russia).



Fig. 1. Fragment of two-dimensional simulation model of transportation flows between production and finished goods warehouse

The graphical visualization has been simplified to improve the performance of the calculations: there are no road network objects that do not affect the flow intensity (for instance, infrastructure objects, green spaces, etc.). The model reflects all aspects affecting traffic flow formation parameters (for instance, gradients, number of lanes, road surface, turns, etc.). The statistical data of traffic density depending on the day of the week and time of the day are investigated as parameters characterizing traffic flow density.

Fig. 2 shows a fragment of behavior models of the main agents of the studied traffic flows.

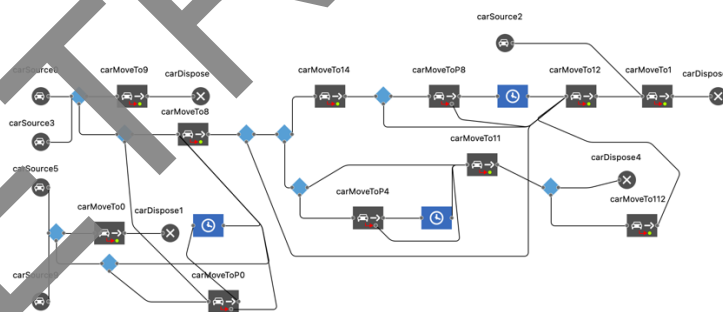


Fig. 2. Fragment of the diagram of changes in traffic flow states

The agents of the traffic flow include personal automobile (carSource0) and public (carSource3) transport, cargo automobile transport (carSource5), and transport used in the logistics of finished products (carSource9).

The developed models allow creating scenarios that simulate the density of traffic flows in order to predict the delivery time and downtime of transport selling finished products. Based on the obtained forecasts, it is possible to develop methods for effective management of logistics processes, maintenance periods of used transport and formation of work schedules for specialists involved in transportation, loading and unloading of goods.

4 Discussion

Simulation models are used when it is impossible to create an analytical model due to the presence of time intervals, multiple causal relationships, nonlinearity, a system of consequences or stochastic variables. This is, for instance, characteristic of processes in ecology [8, 12], transportation [5, 6, 13], dynamic systems [10, 14], etc. In such research, the main goal is to reproduce the system under study based on the results of analyzing the most significant interrelationships between its elements.

The use of the stated research methods made it possible to establish all key elements and connections between them that provide changes in their states. Application of simulation modeling methodologies to the obtained results allowed to create a formal model, which is the basis for conducting digital experiments. The results of digital experiments are used to create strategies for effective management of different processes (for instance, crop yields [12], reduction of harmful emissions into the environment [11], organization of road traffic formation of sustainable development [5, 6, 13]). The created transportation model meets the requirements for the development of management decisions for the effective implementation of the water logistics process.

5 Conclusions

Freight transport is of great importance for the economic development of regions and the country as a whole, supporting and stimulating business. It requires adherence to the principles of optimality and efficiency for fast and safe transport of goods from the producer to the consumer. The complexity of the process is justified by the solution of a number of tasks that ensure the coordination of the transport and warehousing process, the development of routes, the selection of vehicles, the control of the condition of the goods during loading, unloading and en route, the execution of documentation at all stages of transport, etc.

In order to reduce costs (time or financial) to reduce the influence of the human factor in the realisation of these tasks, a universal tool based on artificial intelligence technologies is required. This requires the development of formal models that describe the properties and behaviour of real objects or transport logistics processes.

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