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Integration of IT systems to support the tracking of dangerous goods transport routes.

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***Abstract*— The biggest challenge we face is the transport of dangerous goods. About 40,000 vehicles carrying dangerous goods travel on our roads every year. More than 70 percent of these fuels are gasoline, diesel oil and LPG, the rest are chemical compounds used in industry and economy. The number of accidents that occur is negligible, but the scale is incomparably greater than the case of a collision of a passenger vehicle with fuel leakage. The concentration of chemicals is much more difficult to remove and poses a huge risk to people and the environment. These types of transports should be tracked and supervised just as aircraft transporting people and goods are tracked.**

Keywords— RFID, simulation models, dangerous goods transport tracking.

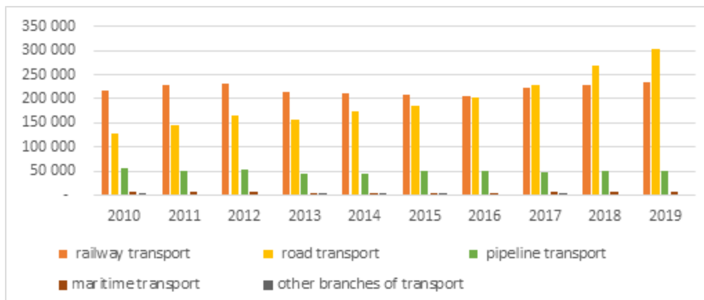
I. INTRODUCTION

The main factor affecting economic development is the movement of people and cargo. Transport has influenced the evolution of many sectors of the economy and social life. Currently, in order to compete effectively in the difficult transport market, it is necessary to respond flexibly to customer needs and offer them services that meet their requirements. One of the ways to achieve this goal is to collect "historical" information necessary for analysis and forecasting of market and customer needs. In recent years, road transport has become the main mode of freight transport, showing an increasing trend (Chart 1).

Chart 1 shows the period of the last 10 years, where we see upward trends for rail, road, pipeline, sea and other transport branches. It can be seen that in the years 2010 to 2016, rail transport was the leading branch in Poland. Since 2017, road transport has become dominant on the Polish cargo transport market. This is due to the development of road infrastructure and investments in the fleet of transport companies, most of which are private companies not subsidized by the state.

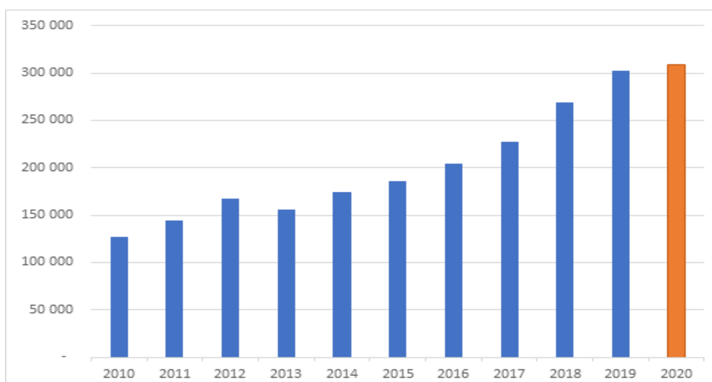
Polish road transport is a leading branch in the country and the European Union. It has the most modern car fleet. Despite the Covid pandemic, road transport recorded a slight increase in 2020 compared to 2019 (Chart 2).

CHART 1. GROWTH TRENDS IN THE TRANSPORTATION OF GOODS IN THOUSANDS OF TONS



SOURCE: HTTPS://STAT.GOV.PL/OBSZARY-TEMATYCZNE/INNE-OPRACOWANIA/INFORMACJE-O-SYTUACJI-SPOLECZNO-GOSPODARCZEJ/BIULETYN-STATYSTYCZNY-NR-12020,4,96.HTML PP. 155-156

CHART 2. ROAD TRANSPORT FOR THE YEARS 2010 - 2020 IN THOUSANDS OF TONS



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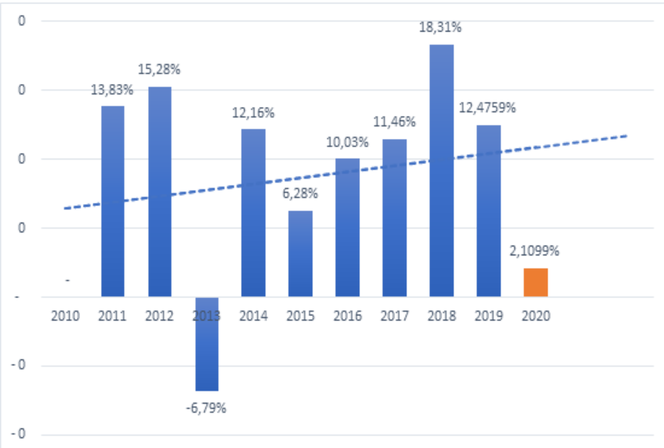
Source: https://stat.gov.pl/obszary-tematyczne/inne-opracowania/informacje-o-sytuacji-spoleczno-gospodarczej/biuletyn-statystyczny-nr-12020,4,96.html pp. 155-156The largest increase in road transport can be seen in 2018 (Chart 3). There was a slight decline in 2019, which was preceded by the announcement of the pandemic and restrictions on movement between cities. Restrictions related to the movement of goods and people have led to a decline in the transport of goods.chart 3. Percentage growth in road transport



Source: https://stat.gov.pl/obszary-tematyczne/inne-opracowania/informacje-o-sytuacji-spoleczno-gospodarczej/biuletyn-statystyczny-nr-12020,4,96.html pp. 155-156However, the trend line shows that road transport is returning to pre-pandemic levels. It is noticeable how the economy and industry are trying to make up for what they lost during the pandemic, which translates into the intensive use of road transport.

II. THE IDEA OF TRACKING THE TRANSPORT OF DANGEROUS GOODS

The amount of dangerous goods transported increases every year. The issue of increasing the level of safety during their transport is therefore still relevant. Legal acts regulating the transport of dangerous goods are amended every two years, but their changes are minor and do not significantly increase control over the transport process. The literature on this issue mainly focuses on describing the requirements regarding the obligations of transport participants, vehicle efficiency, driver training, documentation, certification and markings on packaging and vehicles. In practice, these requirements are the basis for the transport of dangerous goods in Poland.

It should be noted that legal regulations cannot ensure complete safety of the transport of dangerous goods (Szwarc & Kopczewski, 2017). Although the percentage of accidents involving hazardous materials among all road accidents is negligible, the uncontrolled release of chemical compounds into the surroundings may result in the loss of thousands of lives, especially in large urban agglomerations. The essence lies in monitoring the progress of transport of dangerous goods, which is currently practically not carried out.

The transport of dangerous goods is mainly based on road transport. There are three methods of transporting dangerous goods (Kwaśniowski & Kulczyk & Kierzkowski & Jóźwiak, 2014):

• Transport in packages, i.e. in certified transport packaging. It can be done using boxes, containers, platforms, and vehicles equipped with special bodies (Rogalski &Pyza, 2019).

• Bulk transport taking place directly in the vehicle's cargo bed or in a container. Applies only to solid materials of low risk and empty packaging.

• Transport in tanks taking place in tanks equipped with appropriate operating and structural equipment. Only certain liquids, gases, powdered and granulated solid substances are allowed for use. In the case of a liquid, the level of filling of the tank with it is important. In the case of a single-chamber tank, the permitted amount of liquid is from 0 to 20% of the load capacity or above 80%. Based on the thermal expansion of the analyzed liquid, the maximum degree of tank filling with a given liquid is specified in the regulations, which is always less than 100% of the capacity. The transport of dangerous goods using a tanker is shown in Figure 1.

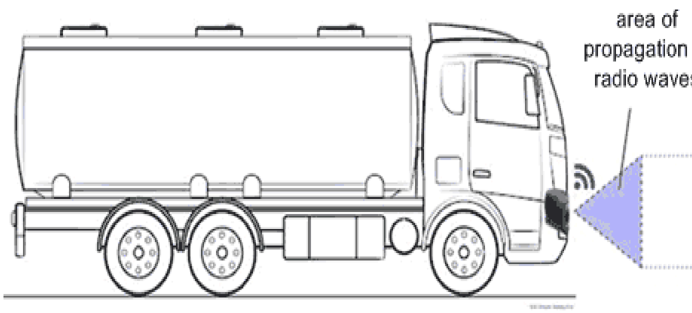
FIGURE 1 TANKER FOR TRANSPORTING DANGEROUS GOODS

Source: https://www.v4l.pl/cysterny-adr/ (accessed on 10.04.2023)

When determining the route for transporting dangerous goods, you should, whenever possible, try to travel on roads with good surfaces and relatively low traffic intensity. It is important to avoid built-up parts of large cities and streets located near the main urban transport hubs. Moreover, when planning the organization of transport, the need to stop should be avoided, especially in the city (Rogalski, Pyza, 2019 p.345). The presence of dangerous goods near large urban agglomerations dramatically increases the level of potential negative effects resulting from the uncontrolled release of hazardous materials during transport or an organized terrorist attack. In order to avoid accidents, collisions or terrorist acts involving dangerous goods, such transports should be monitored centrally using modern IT solutions supported by various technologies. Such solutions include RFID (Radio Frequency IDentification) technology, programs using GPS (Global Positioning System) integrated with data transmission, and spatial simulation models based on GIS (Geographic Information System) solutions.

RFID technology is used in logistics to identify items of goods that have an RFID transponder using radio waves. This type of solution uses 4 different frequency ranges that can read transponders from several centimeters to several meters. RFID technology consists of a control device, which is a reader equipped with software for identifying transponders, which we classify as passive and active transponders. A reader with appropriate software can send information to a database server via the Internet. Such a reader can be mounted on a vehicle that transports dangerous goods, Figure 2.

FIGURE 2 RFID READER LOCATION



Source: Own study

Transponders would be placed in the road infrastructure, i.e. in guide posts placed along the road, Figure 3.

FIGURE 3 RFID TRANSPONDER IN ROAD INFRASTRUCTURE

Source: Own study

Each road bollard would have its own unique address identifier stored in an RFID transponder, which would determine its exact location. A vehicle equipped with an RFID reader and moving at a speed of 150 km/h is able to read the transponder located in a road bollard. The possibilities of RFID technology include reading 600 transponders operating in the UHF band in 1 second.

Another solution that is already available is the ability to track vehicles using GPS technology and GSM (Global System for Mobile Communication) data transmission. This type of solution is used by transport companies to determine where their means of transport is.

The basic functions of a GPS receiver in a vehicle include: measuring the speed of movement, determining the exact location on the globe, and determining the height at which the receiver is located. To determine the position, the GPS receiver must receive and track satellite signals, i.e. measure pseudoranges and their increase, and record information, which is called navigation messages. Pseudorange is nothing else than a distance with an error caused by the receiver's clock error, which is the same for all satellites. The data reception process begins after bit synchronization of the carrier wave is achieved. After receiving signals from four satellites, achieving code and phase synchronization and reading the navigation message, the receiver begins to determine navigation data such as the position and speed of the receiver and time on the GPS scale. Typically, receivers update data on pseudoranges and relative velocities once a second (Drewek, 2011).

Disturbances in determining position in the GPS system can be divided into groups (Narkiewicz, 2007):

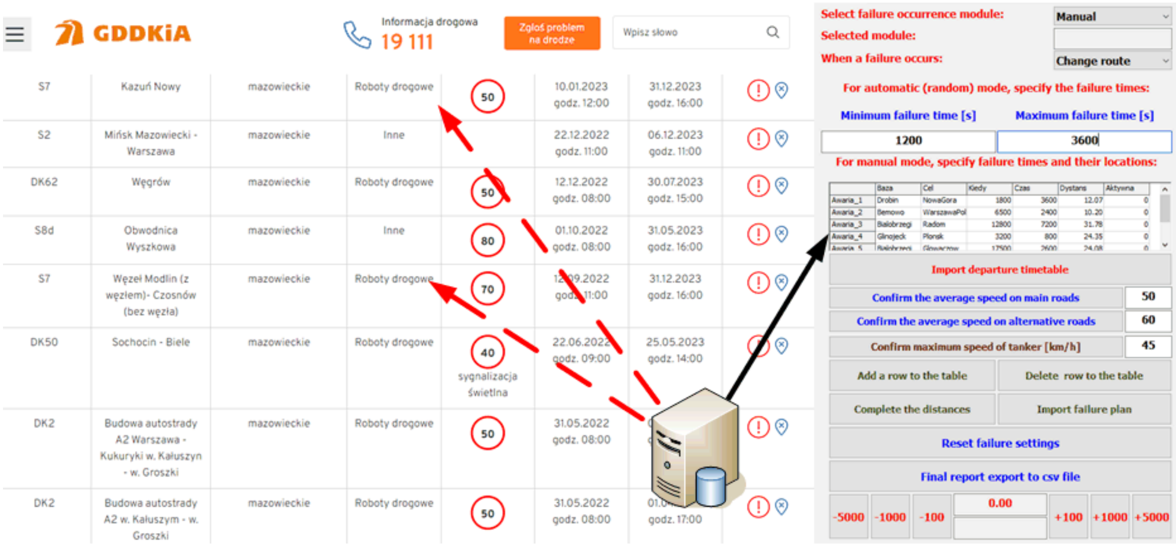
- satellite orbit errors (satellite perturbations), including Earth's gravitational field, atmospheric resistance, gravitational influence of the Sun and Moon and other celestial bodies, cosmic radiation pressure, tides of the Earth's crust and ocean tides, the influence of electromagnetic forces, relativistic effects,
- propagation disturbance including ionospheric refraction, tropospheric refraction, tropospheric delay, atmospheric and cosmic noise, interference of secondary waves, multipath signals,
- errors in transmitting and receiving devices: instability of frequency patterns, receiver own noise, satellite clock error, phase center variations of GPS antennas, geometric errors of DOP (Dilutions of Precision) satellite alignment,
- systematic errors of phase observations: phase uncertainty, phase discontinuity.

These interferences are eliminated by using ground reference stations that observe the same satellite clock error, which is fully compensated.

Another element of the cargo tracking system is a GSM mobile phone. Mobile telephony infrastructure consists of base stations with antennas and wireless telephones at users' premises. Each working telephone receives a signal from base stations called cells and sends its own signals, thanks to which the network is able to locate through its base stations and in which cell the user's phone is located. A characteristic feature of this type of telephony is that it provides the user with mobility and the ability to establish calls to and from the user in an area covered by the radio range associated with all base stations in a given network. For such a structure to function properly, each mobile phone must also be a transmitter and receiver device with a computer function.

Another IT solution to support the transport of dangerous goods are spatial simulation models using GIS solutions. Using simulation programs, you can create simulation models based on failures and accidents that have occurred or are currently occurring. Data on road accidents and incidents can be downloaded from the information databases of GDDKiA (General Directorate for National Roads and Motorways). An example database with information about road incidents is the database available on the GDDKiA website (Figure 4). Using the database server, you can download data (red arrows) from the website about events and enter it into the simulation program (black arrow). The simulation program, based on data from the database and algorithms, can determine the most optimal solution at a given moment.

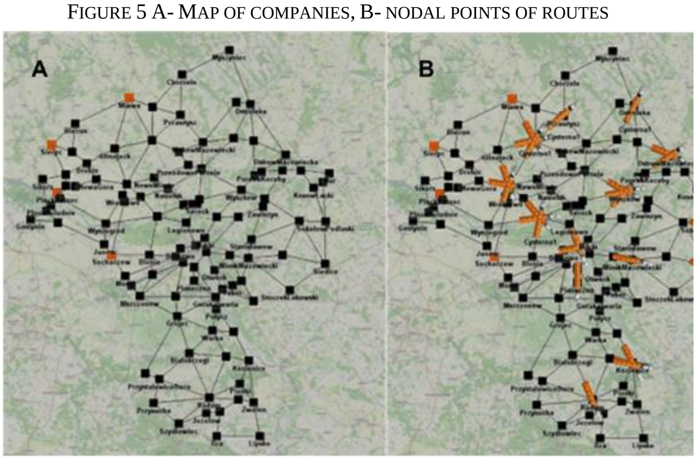
FIGURE 4 GDDKIA FAILURES IN MASOVIA



Source: Own study & https://drogi.gddkia.gov.pl/informacje-drogowe/lista-utrudnien?odcinek=&odcinek_id=&od=&do=&woj=mazowieckie&nr=&rodzaj=

This type of solution will allow the transport company's dispatcher to make the right decision about sending a transport with dangerous goods. The simulation may have many variants that can be saved on the server of the institution responsible for tracking and safety of the transport of dangerous goods. The simulations will be compared to see if other transport companies are planning to transport dangerous goods at the same time. Dispatchers of transport companies will be able to determine on the map the nodal points through which their transport will pass (Figure 5B) and whether there are other companies nearby that transport dangerous goods (Figure 5A - red squares).

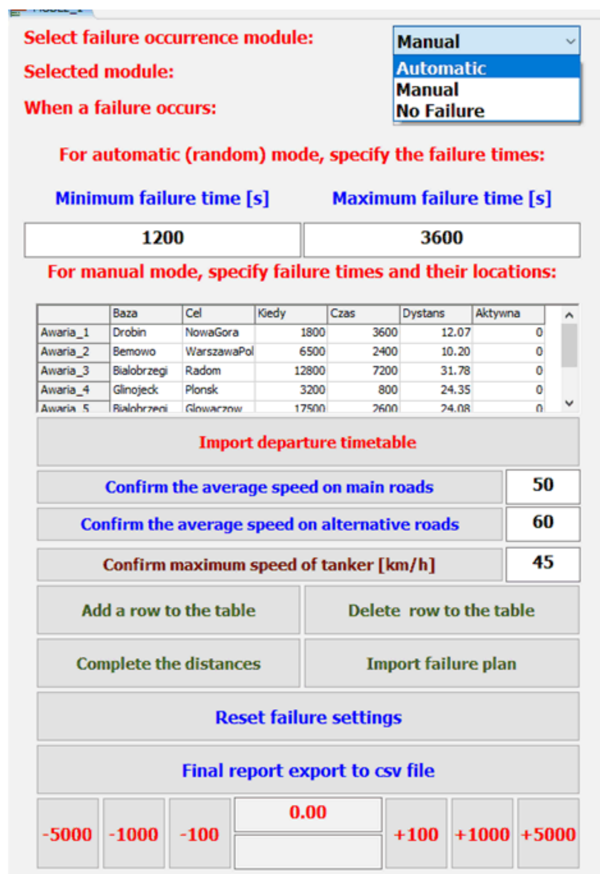
FIGURE 5 A- MAP OF COMPANIES, B- NODAL POINTS OF ROUTES



Source: Own study

The dispatcher, through the panel in Figure 6, will be able to determine various variants of events and adapt solutions to them. The dispatcher will be able to receive information from the driver about events that have just occurred. Based on information from the on-board system equipped with an RFID reader, the dispatcher will be able to perform simulations in order to change the route and determine the safest solution. This type of simulation will be sent to the server of the institution responsible for the tracking and safety of dangerous goods and will allow steps to be taken to solve the situation with a road incident. The institution will be able to investigate whether the road accident was so serious that the dispatcher made the right decision to change the route. The dispatcher may consult with the institution in order to approve changes to the route.

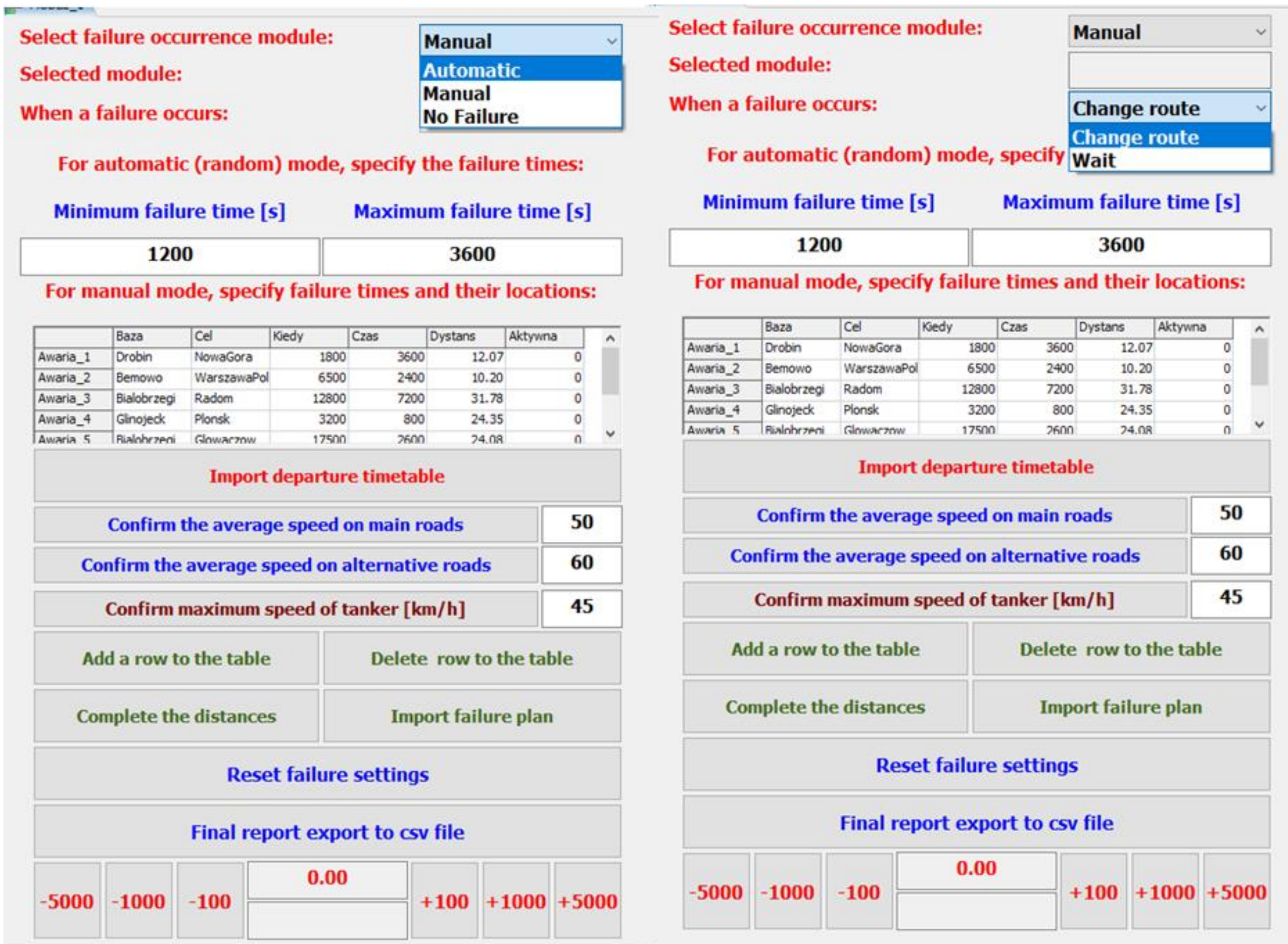
FIGURE 6 PROGRAM CONTROL PANEL



Source: Own study

Using the simulation tool, the dispatcher can determine various transport variants, such as changing the route or waiting for the failure to be removed (Figure 7A and B). This type of simulations would feed the database of a government institution, which, based on the data, could improve methods of safe transport of dangerous goods. Generating simulation reports allows you to choose the best solution and at the same time determine the route along which the dangerous cargo should move. By using the ability to track the transport of dangerous goods based on RFID technology, the dispatcher will be able to respond to failures that may occur on the road on an ongoing basis. The created algorithms, Figure 8, may in the future be used by artificial neural networks and artificial intelligence (AI) to support the decisions of the transport operator. In the future, artificial intelligence will be able to modify algorithms and support the operator managing the transport of dangerous goods. .

FIGURE 7 A,B TRANSPORT VARIANT



Source: Own study

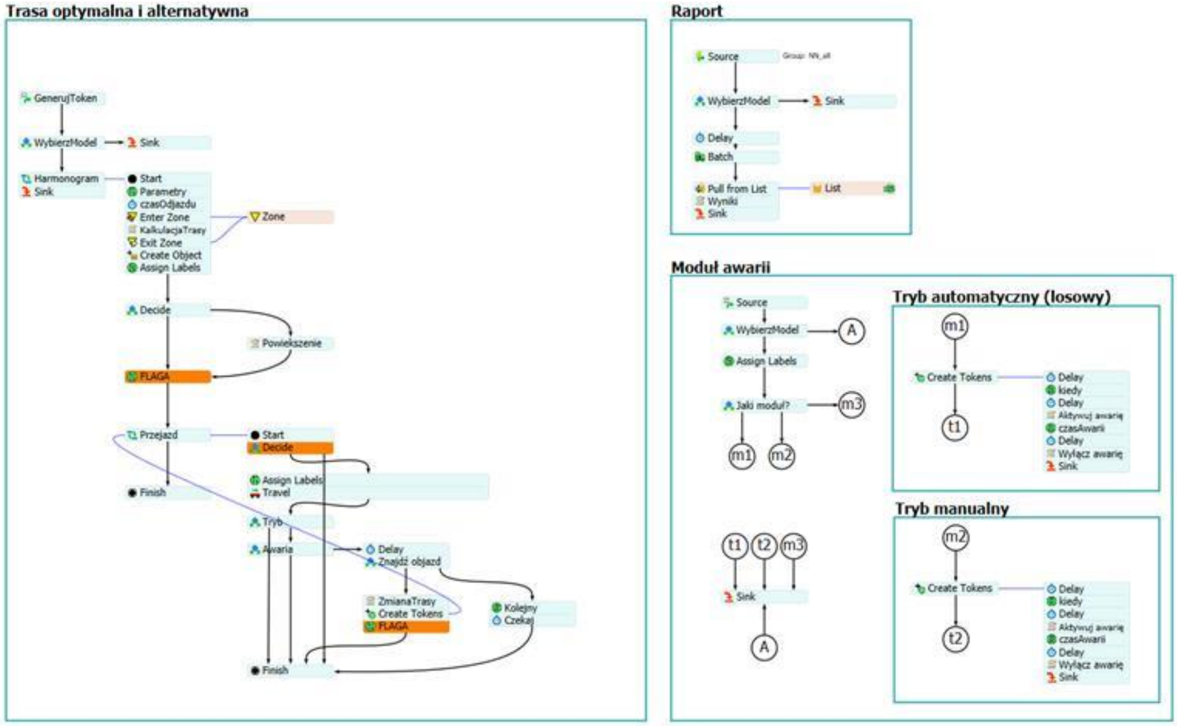
III. CONCLUSIONS

Integration of RFID, GPS, GSM technologies with a program enabling the creation of simulation models with the platform in an environment using a GIS geographic information system, supported by artificial neural networks and artificial intelligence (AI). RFID technology, which is part of the road and transport infrastructure, will be intended to transmit information about the real-time location of the means of transport using GSM data transmission. GPS will be a redundant system that will complement RFID technology. Programs for creating spatial (3D) simulation models using GIS solutions will improve the safety of transporting dangerous goods. They will allow conscious planning of dangerous goods transport routes, bypassing urban agglomerations. An integrator of all the above-mentioned tools will be able to speed up the process of gaining experience and facilitate making good decisions. Building global awareness by observing various simulation models and collecting data on the movement and transport of hazardous cargo can result in better solutions affecting road transport.

Strange behavior of the transport of dangerous goods that is not reflected in the models sent to the central server may increase the vigilance of services responsible for state security.

This type of awareness will impact safety, ecology and the quality of our lives.

.FIGURE 8 ROUTE SELECTION ALGORITHM IN THE SIMULATION MODEL



Source: Own study

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