

Article citation info: Ondov, M., Mudarri, T., Petrovský, J., Petrovský, R., Čerevková, K., Crossroads modelling methodology in ExtendSim. Transport & Logistics: the International Journal, 2023; Volume 23, Issue 55, December 2023, ISSN 2406-1069

## CROSSROADS MODELLING METHODOLOGY IN EXTENDSIM

**Marek Ondov<sup>1</sup>, Tawfik Mudarri<sup>2</sup>, Ján Petrovský<sup>2</sup>, Rastislav Petrovský<sup>2</sup>,  
Katarína Čerevková<sup>2</sup>**

<sup>1</sup> Technical University of Kosice, Institute of Logistics and Transport, Slovakia, EU,  
e-mail: marek.ondov@tuke.sk

<sup>2</sup> Technical University of Kosice, Institute of Earth Sources, Slovakia, EU, e-mail:  
tawfik.mudarri@tuke.sk, jan.petrovsky@tuke.sk, rastislav.petrovsky@tuke.sk,  
katarina.cerevkova@tuke.sk

### **Abstract:**

Modelling and simulation are essential activities in the field of logistics. Many decisions are based on analysis and results provided in the form of simulation model statistics. The ExtendSim simulation program found its use in modelling internal company processes such as production, storage, and internal transport. Other software is used for non-company transport, but these processes can also be modelled in ExtendSim. However, the modelling procedure is complex and requires knowledge of the software and the modelled object. The methodology is shown in the example of a crossroads model. The model is quite complex and uses elements of programming. Overall, the advantages and disadvantages of modelling the crossroads in ExtendSim are pointed out, and the possibility of practical use of the methodology is assessed, even with other simulation software.

### **Key words:**

Modelling, simulation, crossroads, ExtendSim

## 1 INTRODUCTION

Modelling and simulation are essential activities in the field of logistics. Many decisions are based on analysis and results provided in the form of simulation model statistics. Logistics includes many processes and activities. Transport is one of them. Transport is an integral part of logistics at every level, both internal and external. Road transport is so deeply integrated into business processes that it significantly affects economic growth. Transport systems are becoming increasingly complex and often cannot handle the pressure exerted (Dorokhin, 2020).

For this reason, the popularity of modelling and simulation of transport systems is increasing. These tools help in designing traffic networks or crossroads, increasing their

passability and, among other things, road safety. Simulation tools are characterised by saving time when designing transport infrastructures and the costs associated with this activity. Their supporting role in design processes is unquestionable (Fabianova, 2020).

Modelling of transport networks can be distinguished on three levels, while appropriate simulation software can be assigned to each level. The higher resolution level is microscopic. Crossroads, bridges, traffic nodes and terminals are often modelled at this level. The goal of these models is to statistically evaluate parameters such as flow, density, rows of vehicles, their speed and driving time, fuel consumption, the number of stops or even the destruction of the environment. Nowadays, Vissim, AIMSUN, SUMO, FRESIM, CORSIM, and Paramics are widely used (Dorokhin, 2020).

For example, the SUMO software supports the application of accurate open-access maps to the simulation software. Primarily, this software focuses on the simulation and assessment of city traffic conditions. Software users point out that even though using maps in this software is beneficial, manually entering routes and speeds is still necessary. This can be seen as the source of most errors (Dian Khumara, 2018).

The lowest resolution level is attributed to macroscopic models. In the macroscopic model, traffic flow is presented as a combination, measured in terms of speed, flow and density at a low level of detail. The main software products used in macroscopic modelling are Visum and Saturn. Mesoscopic models represent the middle ground between the outputs of the characteristics of traffic streams and the investigation of the movement of individual cars in the stream. Meso-models offer a high level of detail in the simulation system and a simplified analysis of traffic flow dynamics at a relatively high simulation speed. MEZZO, DYNAMIT, CONTRAM, and DTASQ software are used (Dorokhin, 2020).

In intra-company transport, we encounter less complex transport networks and manipulation simulations. In these cases, the ExtendSim software, among others, is used for modelling. Its advantage is the possibility of combining blocks focused on transport or manipulation with blocks of production or storage processes. ExtendSim was also used, for example, to analyse the process of loading and transporting material in a quarry. In this process, loading, transporting material, unloading material and driving the truck back to the loading station were simulated (Saderova, 2020). Fedorko et al. (Fedorko, 2014) also used the ExtendSim software to simulate a crossroads, i.e. an off-premise transport network in a city in Slovakia.

This article aims to compile the sequence and methodology of modelling the transport network outside the enterprise in the ExtendSim software. Subsequently, apply this procedure to the model of the fundamental crossroads and determine the advantages and disadvantages of using the ExtendSim software in modelling transport networks.

## 2 METHODOLOGY

The simulation of traffic features in ExtendSim software, such as crossroads, is relatively unexplored. Only one match was identified from the literature reviewed. ExtendSim is a block simulation software that allows both discrete and continuous simulation. ExtendSim allows building models without knowledge of programming languages, thanks to its universal blocks divided into seven libraries. The advantage of ExtendSim is its detailed outputs in the form of statistical data, graphs or tables of individual blocks (Diamond, 2018).

In the case of modelling transport systems, blocks from the Item and Value libraries are essential for modellers. Blocks represent a real modelled system in the software. Each block has its dialogue window, with the help of which it is possible to set its parameters and options to bring it as close as possible to the modelled activity or process. The blocks have

input and output connectors, while only one connector can always be connected to the input connector to ensure a logical sequence of operations (Rosova, 2020).

The proposed methodology for modelling the transport network in ExtendSim must be based on a thorough knowledge of the elements and links of the given network. We call this approach the system approach and one of the main characteristics of logistics systems (Malindzak, 2015). The sequence must follow one another logically and thus prevent errors or overlooking any link between elements.

The methodology of modelling traffic nodes in ExtendSim begins with collecting data about the simulated process. It is necessary to focus on the driving direction, the number of vehicles, the length of the track, the road traffic rules, and other legislative documents regulating the modelled system.

It is easiest to model what is already visible to the creator in some state. Therefore, part of the preparation for modelling is also a sketch scheme of the model of the modelled object. The rules identified from the data collection were already applied during the scheme's construction.

Using the model scheme, a model is created in the ExtendSim software. Only minimal changes will occur during modelling if the scheme has been prepared correctly. However, it is crucial to identify and apply changes so the model comes as close to the real system as possible.

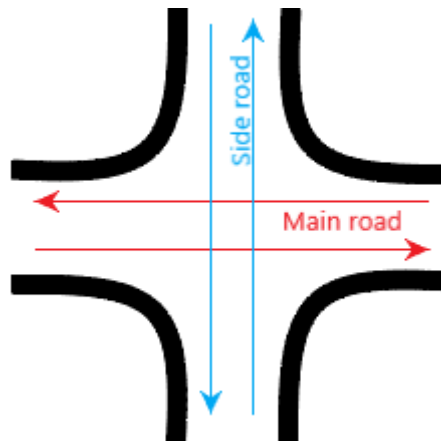
In ExtendSim, working with the blocks of the discrete library Item and the continuous library Value is necessary. Discrete blocks ensure the movement of entities, i.e. vehicles of the transport network, and continuous blocks are used to sell information essential for managing the transport network and its proper functioning without collisions. Of the discrete blocks, it is most appropriate to use the Information blocks to track the location of vehicles in the models and the Transport blocks to simulate their delay on the road. The most important of the continuous library blocks are the Decision and Equation blocks, which control the movement of vehicles using the relationships specified in their dialogues so that they do not collide.

After creating the model, the first simulation runs are verification runs. The simulation must run with animation to ensure that visual inspection identifies potential vehicle collisions. The model can be declared collision-free if no collisions have been identified after at least 15 consecutive runs. In the case of the identification of collisions, it is necessary to adjust control blocks such as Equation or Decision. Alternatively, check the Information tracking blocks.

It is then possible to perform experiments on the verified model to obtain the desired outputs from the simulation and to check possible modifications of the investigated system. In order to introduce the methodology, the following chapter is devoted to a model example of a crossroads without light signalling with theoretical values.

### 3 RESULTS AND DISCUSSIONS

The subject of this subsection is to practically use the proposed methodology in the previous chapter as an example of a theoretical nature. The goal of the example is to create a simulation model of the fundamental crossroads of the main and side roads. The main road will be shown with a red line, and the side road will have a blue line. In Fig. 1, there is a sketch of the crossroads.



**Fig.1** Crossroads roads definition

Source: Author's

### 3.1 Crossroads modelling

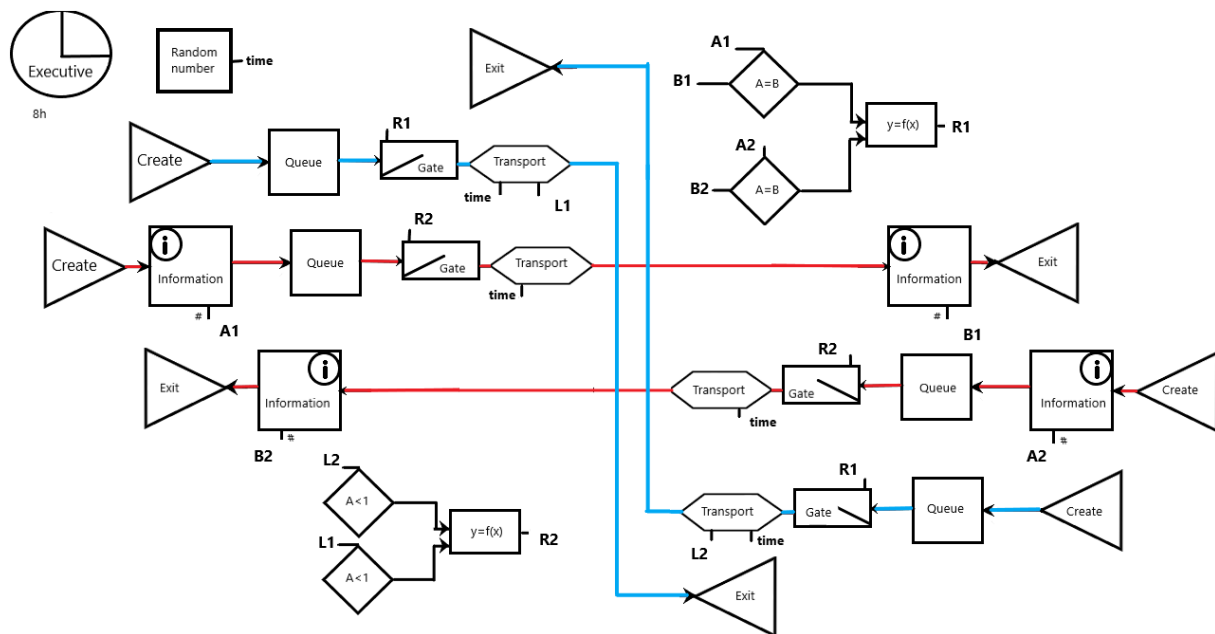
First, it is necessary to collect the data entering the model. Since this is a theoretical example, the data are predetermined this time. All the necessary data to create the crossroads model from Fig. 1 are shown in Tab. 1. The simulation duration is 8 hours, and the vehicles follow the traffic rules of the Slovak Republic.

**Tab. 1** Input parameters of the crossroads model

Parameter – main road	Value	Parameter – side road	Value
Driving direction	Both	Driving direction	Both
Vehicles arrival	$2 \pm 1$ min	Vehicles arrival	$4 \pm 1$ min
Passing through	25 – 30 s	Passing through	25 – 30 s

Source: Author's

The model consists of blocks Create generating vehicles, Information monitoring the passage of vehicles on the main road, Gate limiting the flow of vehicles, Transport simulating the time it takes to pass through a crossroads and continuous blocks Decision and Equation. The Decision blocks compare the input values from the blocks directly forming the crossroads, and the output is the values 1 or 0, with which the Equation block subsequently works and controls the opening and closing of the Gate blocks. Connections of the mentioned blocks are shown in Fig. 2.

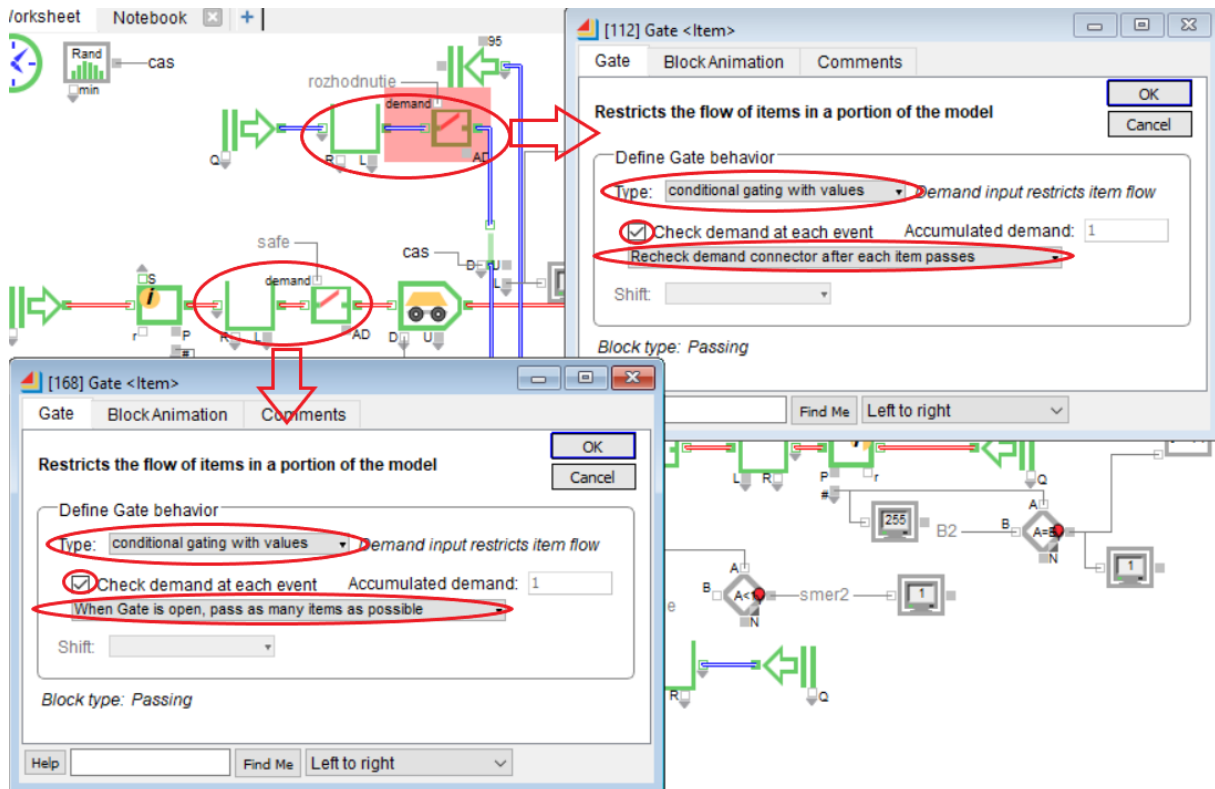


**Fig.2** Scheme of the crossroads model

Source: Author's

Now, according to the scheme, the creation of the model is simplified thanks to the display of connections in the scheme. First, it starts with modelling the main road in the direction from left to right. The Create block will generate vehicles according to a normal distribution with a mean of 2 and a deviation of 1. Next, other blocks are inserted according to the scheme, which can be set later. The exception is the Transport blocks, in which we will set the time unit of the crossing time, and the numerical values will be generated by the Random Number block set to the uniform real function from 25 to 30. The output connector of the block is then connected to the D connector of the Transport block. Then, in the Gate block, he selects the Conditional gating with value option, which opens the Gate if the value 1 comes to the connector demand and closes it when the value is 0. Regarding the main road, we choose to let as many entities as possible pass through if the gate is open.

The opposite direction of the main road consists of identically set blocks. Therefore, the blocks created so far are copied and pasted in reverse, changing their orientation from right to left. The option can be found in the menu after clicking the right button on the block. Then, the blocks are arranged according to the scheme. Also, in ExtendSim, it is possible to change the colour of the connectors to red in the menu on the left side of the screen, the penultimate button from the bottom. The setting of the Gate blocks is shown in Fig.3.



**Fig.3** Setting the Gate blocks of the main road and the side road  
Source: Author's

The same modelling procedure is applied to the side road, where the blocks need to be arranged according to the scheme so that a visual inspection of collisions is possible later. In the case of the Create blocks on the side road, we must change the normal distribution values to 4 and 1. In the Gate blocks, the maximum possible number of vehicles cannot pass, but each vehicle must first check whether the value 1 is on the demand connector.

All the decision-making, closing, and opening of gates is a continuous simulation of values. The Decision blocks for decision R1 compare whether there are the same values in the two Information blocks in one direction and the other direction, i.e. whether  $A=B$ . These are the values from the output value connector #, which are increased by one if a vehicle passes through the block. If the values are the same, then the same number of vehicles passed through the Information block at the beginning and the end of the crossroads, so no vehicles are in. The decision of both Decision blocks is 1, so in both main directions, the crossroads is free, and vehicles from side road directions can pass. Therefore, the equation in the Equation block must exclude combinations of values from the decision blocks 00, 01 and 10. Thus, two connectors will enter the Equation block, and one will exit, while the equation will be as follows:

$$\text{if } ((\text{direction1} == 1) \text{ and } (\text{direction2} == 1))$$
  

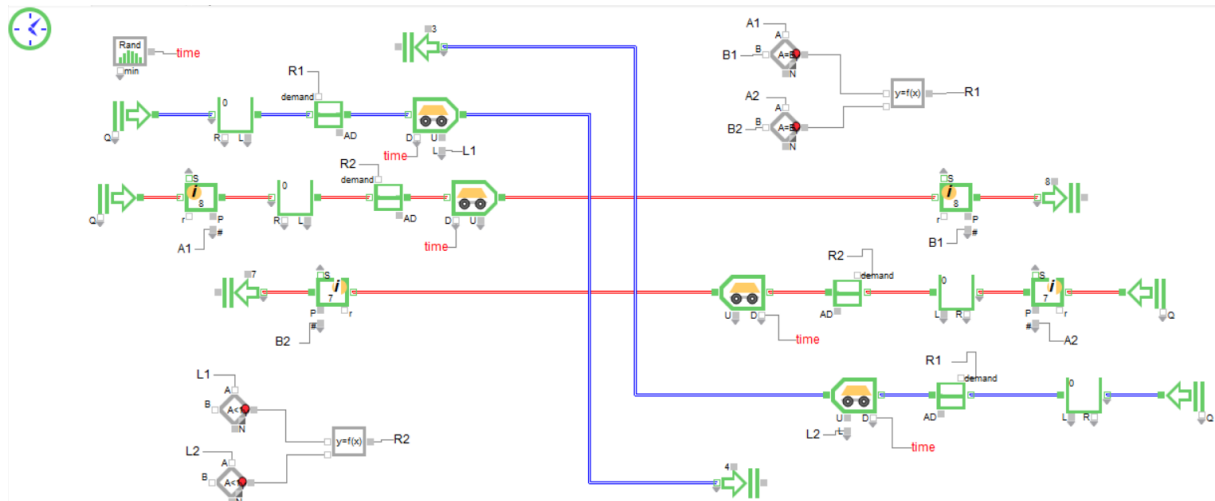
$$\text{decision} = 1;$$
  

$$\text{else decision} = 0;$$

Therefore, the Equation block output is R1 and controls the Gate blocks on the side road through the demand connector.

Gate blocks must also be located also in main directions because if a vehicle in one of the side road directions completes a crossroads in the Transport block, the vehicle from the main direction must adjust speed or stop to avoid a collision. In this case, the Decision blocks check whether the number of vehicles in the Transport blocks on side road directions is less

than 1,  $A < 1$ . Again, there are four combinations: 11, 10, 01, and 00, while the vehicle can enter the crossroads only in case 11. According to a suitable combination of Decision outputs, the setting and equation of the Equation block do not need to be changed, and the block is only copied, and the output is called R2. This time, the output is connected to the demand connector of the Gate blocks in the main directions. The entire model of a no-light crossroads is shown in Fig. 4.



**Fig.4** Crossroads model in ExtendSim 10

Source: Author's

Verification simulations and visual inspection during the simulation confirmed the absence of collisions in the model and allowed experiments to be carried out. From the model experiments, we can conclude, for example, that the average waiting time for vehicles on the side road is 8 seconds at a crossroads set in this way.

### 3.2 Discussions

In the previous subsection, the methodology of modelling the traffic network in ExtendSim was applied to a theoretical example of a fundamental crossroads. The crossroads consisted of only a main and a side road, and vehicles did not change direction. The model appropriately simulates the crossroads according to the assignment but at a low level of detail. ExtendSim is not primarily used for transport nodes but rather for logistics and production processes in enterprises. It is rather difficult to influence the speed of vehicles or other characteristics of transport networks microscopic modelling in the model.

The created model does not allow vehicles to change direction because each new direction the vehicle could choose means a significant increase in the number of Decision and Equation blocks and, thus, more lines of equations. Creating traffic node models in ExtendSim is time-consuming and requires thorough and flawless preparation. Other disadvantages include the relatively weak flexibility of blocks for traffic activities outside of enterprises, the absence of 3D animation or the impossibility of working with real maps in the software.

On the other hand, among the advantages of modelling in ExtendSim, we can include its block structure, which set boundaries for operations and clearly defines the data required for a given operation, which is invaluable for beginners in modelling. Simulations in ExtendSim take a relatively short time, and the model is easily modifiable.

At the real crossroads, the model in ExtendSim was used in the city of Vranov nad Topľou. The entire traffic junction was modelled in an older version of ExtendSim in an urban environment (Fedorko, 2014). The publication is resulting in high complexity and low clarity of the model. Therefore, the authors had to proceed with creating hierarchical blocks to make the model more accessible and understandable for people who do not work with ExtendSim.

Compared to the capabilities and outputs of the software mentioned in the introduction, ExtendSim is inflexible in the case of traffic node modelling and cannot reach the set level of the mentioned software in introduction. An example can be the application of the VISSIM program, intended for road traffic microsimulations, in designing and testing a light-controlled intersection model (Fabianova, 2020).

## 4 CONCLUSIONS

This publication aimed to present the methodology of modelling traffic nodes in the ExtendSim software and to identify its advantages or disadvantages and its position compared to other simulation software. The methodology was tested on a theoretical example of a no-light crossroads, the model of which was successfully constructed. The methodology is based on a system approach generally applied to logistics processes.

Among the positives is that it is possible to include a thorough preparation for modelling, thanks to the compilation of the scheme, and a block simulation solution highly suitable for beginners. However, based on experience with model creation, the negatives prevail. The model consists of several blocks in which it is easy to get lost, and with the modelling of real crossroads, the number of blocks and the complexity of the display increase rapidly. The model also fails in flexibility and detail, as it cannot follow or correct the characteristics typical for micro or mesoscopic transport network models.

It is unnecessary to look for errors in the methodology but in the choice of simulation software. ExtendSim is suitable for modelling transport and handling activities on a smaller scale in an intra-plant environment while providing connections to other logistics or production processes. This methodology can find application in teaching new modellers and students thanks to the simplicity of ExtendSim and thorough preparation for modelling, which can give students a solid foundation for modelling in more suitable software.

## Acknowledgement

*This paper was supported by research project VEGA 1/0430/22.*

## REFERENCES

- Diamond, P., 2018. *ExtendSim 10 Help System – User Reference*. USA: Imagine That Inc.
- Dian Khumara, M.A., Fauziyyah, L. and Kristalina, P., 2018. Estimation of Urban Traffic State Using Simulation of Urban Mobility(SUMO) to Optimise Intelligent Transport System in Smart City. In: *2018 International Electronics Symposium on Engineering Technology and Applications (IES-ETA)*.
- Dorokhin, S., Artemov, A., Likhachev, D., Novikov, A. and Starkov, E. 2020. Traffic simulation: an analytical review. In: *IOP Conference Series.Materials Science and Engineering*, 918(1), pp.1–6.



- Fabianova, J., Michalik, P., Janekova, J. and Fabian, M., 2020. Design and evaluation of a new intersection model to minimise congestions using VISSIM software. In: *Open Engineering*, 10(1), pp.48–56.
- Fedorko, G., Rosová, A. and Molnár, V., 2014. The application of computer simulation in solving traffic problems in the urban traffic management in Slovakia. In: *Theoretical and Empirical Researches in Urban Management*, 9(3), pp.5–17.
- Malindzak, D., 2015. *Metódy analýzy logistických systémov*. Košice: TU, p.41.
- Rosova, A., Behun, M., Khouri, S., Cehlar, M., Ferencz, V. and Sofranko, M., 2020. Case study: the simulation modeling to improve the efficiency and performance of production process. In: *Wireless Networks*, 28(2), pp.863–872.
- Saderova, J. and Ambriško, Ľ., 2020. Computer simulation as one of the tools for modelling of the work cycle of loading and transport of the raw material at a quarry. In: *Mining Science*, 27, pp.199–208.