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MOVING EQUIPMENT AND WORKERS TO MINE CONSTRUCTION SITE AT A LOGISTICALLY CHALLENGED AREA

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Abstract

Social sensitivity of habitants, minimal impact on the environment, low-grade infrastructure, high altitude, frequent rock slides combined with expectations for the timely moving of equipment and workers are some of the challenges emerging from the current construction of a mine. Starting with traditional planning, and experiencing issues in the early phase of the construction, a traffic simulator was requested by the Procurement Department in order to validate daily-weekly schedules and predict likely delays or blockages on the long-term.

The now available simulator captures the available routes and the applicable travelling rules. Traffic schedules are inputs to the simulator, which attempts to perform the planned movements of the vehicles of various type and size. The data collected is analyzed and recommendations are made to management thus providing the means of adaptive/responsive planning and dispatching of vehicles and convoys.

The simulator is undergoing real-life tests. It is expected that adaptive traffic planning will result in an improved usage of resources and will help maintain sustainable operation.

Introduction

The ongoing construction of a major, long-life mine is subject to a number of challenges. The pace of the construction work sets the daily-weekly requirements on cargo and workers' movement. Detailed traffic plans are generated for the weeks ahead by traffic and logistics (T&L) experts, carefully matching the forecasted demands and resources. However, the execution of a traffic plan is subject to countless, time-varying restrictions and limitations. These include, among others, the social sensitivity of habitants, a low-grade infrastructure, high altitude and frequent rock slides. It is rather difficult to project the true impact on the overall traffic performance and size the necessary countermeasures. The mine construction traffic was initially drawn on traditional planning, and T&L Specialists experienced issues in its early phases. As a result, a traffic simulator was requested by the Procurement Department in order to validate daily-weekly schedules and predict likely delays or blockages on the long-term.

To the mine construction site, the road crosses through the Andean region, at an elevation of 3,700 – 4,600 m above sea level, illustrated on Figure 1. The road is technically the only available road. It was intended to serve the local communities only: getting basic commodities to habitants and connecting neighbors and neighboring settlements. Then, industrial operations started in the region and recently the mine construction was started. The construction of the mine commenced around September 2011 with approximately 480 workers onsite. At peak construction, around October 2013, there will be approximately 6685 workers onsite. Towards the end of the construction phase, around December 2014, there will be approximately 2085 workers onsite. Once the mine is operational there will be approximately 1,350 permanent jobs.

Figure 1. Road to Mine Construction Site

This major development should meet high safety and health standards, handle human resource issues, manage community relations and limit environmental impact to assure long-term sustainability to the stakeholders. It was stated by the mine owner, that regarding workplace safety, health and risk management, the most sensitive issue was road traffic and helicopter operation. In this paper, attempts are made to underline some sustainability aspects related to road traffic planning and operation.

Sustainability Related to Road Traffic

Sustainability, as often applied to industrial activities, consists in balancing long-term economic, environmental and social considerations when managing the business and ensuring viability for all participants. Moving equipment and workers to mine construction over a long period of time is indeed a world in a drop of water when sustainability is addressed. Specifically, safety risk management and handling social/ community issues are particularly applicable to road traffic.

Managing safety and risk

Workplace safety and health starts with preventive screening of workers/ drivers for high altitude. A policy is implemented on internal authorization to drive vehicles, maintenance and vehicle age control, safe driving, en route control. Traffic organization is based on a *Road Management Plan*, what defines, among others, the followings:

- Operating times (normally daylight traffic is allowed only)
- Prohibitions under low visibility
- Minimal distances between vehicles
- Defining solo vehicles and grouping vehicles to convoys
- Zones for passing/ zones prohibited for passing
- Obligatory stopovers for slow moving vehicles

Travelling conditions – in general – are bad. Road width, curvature, slope and pavement impose constant risk on drivers; road improvement is a continuous support activity to road traffic. Building a new branch of road is planned to handle a great part of the traffic over a longer distance towards the mine. In Figure 2, the narrow bend of the road is under extension/ leveling by a bulldozer. It is obvious that the hut is "at a wrong place". Even after the bend is extended, it will stay extremely close to the heavy traffic. Relocating it seems plausible – but not doable in most cases, subject to the given circumstances, due to social and community issues.

Figure 2. Road Extension at a Community

Respecting social sensitivity

The road was built to connect settlements, then settlements developed and further houses were built right beside the road. As of today, passing traffic is extremely close to residential buildings at certain settlements. Great effort is done to widen roads, add extra lanes, build bypasses or purchase properties and relocate them to a safe spot nearby.

The lodging, catering and health facilities are rather limited at the settlements. A rock slide, suddenly blocking the road at a random place, might order a convoy of buses to unplanned halt. Providing the basic needs for 30-40 extra people at settlements far exceeds local resources and disturbs the community; this requires immediate mitigation from T&L service.

A registry of events was compiled for holidays, fairs, ceremonial events and regular local activities in the involved settlements. The *Traffic Forecast Plan* considers these temporary traffic limitations (speed control, one-way traffic or no passing during the events).

Further, otherwise minor events, unrelated to mine construction or any above, might have serious effect on timely moving equipment and workers. Closing the pedestrians' crossing in front of a local school can completely paralyze traffic for hours. In Figure 3, local habitants are working on a building next to the road. First, the mine construction traffic was restricted to a "one-way" traffic, then ordered to complete halt, to provide time and access for residents to complete their work in a safe manner.

Figure 3. A Temporary Traffic Restriction

On the Road

The mine construction is ongoing. Road maps and settlement maps are available and it was possible to travel the road and collect data on vehicle movement (logging arrival/ departure at settlements, collecting GPS data etc.). A traffic model and simulator was requested by the Procurement management to aid traffic scheduling. During model testing and validation, model results were regularly compared to real, observed situations. To start with, the following Figure 4 and 5 illustrate - in pairs - the real conditions and situations and the simulated ones. The details of the modeling work are addressed in the subsequent sections of the paper.

Figure 4 shows a general traffic situation, vehicles pass through a regular road sector. In this case, the vehicles are regular-sized trucks, organized into convoys. The convoy is led by an escorting vehicle, with a board mounted to its top, marking the fact that a convoy is coming behind it, containing two (2) members (trucks). These are important pieces of information to counter traffic members, flagmen and road repair workers, equally. The simulated twin-pair shows a fraction of a map, road marked in red and the small boxes represent the vehicles.

Figure 5 shows a dedicated "rest site", real and simulated, respectively: medium-sized busses, organized to convoys, made a temporary halt at the roadside. The roads are generally barely wide enough for single-lane traffic; passing is prohibited at many road sectors. Parking, resting is allowed only at dedicated sectors.

Figure 4. Roads – General Traffic

Figure 5. Roads - Rest Site for Convoys

Travelling restrictions are categorized by the T&L experts as permanent and temporary restrictions. These restrictions and the applicable traffic rules are summarized in Table 1 and Table 2. Real and simulated situations at travel restrictions are shown in Figure 6 - Figure 8.

Table 1. Permanent Traffic Restrictions

Type	Time Duration	Traffic Rules
Bridges Road narrows Steep roads Settlements - roads	Permanent or regular, limited to certain periods of the day	Single-lane, alternating traffic speed limitation keeping convoys together

Table 2. Temporary Traffic Restrictions

Type	Time Duration	Traffic Rules
Road problems		single-lane, alternating traffic
Weather problems	limited to certain periods of a day	speed limitation
Settlements - events		keeping convoy together
Rock slides	several days	road blockage

Figure 6. Permanent Traffic Restrictions - Bridges

Figure 7. Permanent Traffic Restrictions - Settlements

Figure 8. Temporary Traffic Restrictions - Rockslides

Discrete-Event Traffic Modeling

There is a recurring need at Bechtel Mining and Metals (M&M) for modeling and simulation activities to complement various pre-feasibility and feasibility studies, design alternatives as well as ongoing plant/ mine transformation, demolition, construction and operation activities. The scope of the activities spans over industries, among others, addresses:

- Aluminium production
- Copper ore mining and processing
- Iron ore mining and concentrate producing
- Coal mining and transportation

Part of the processes and most of the complementary people, product and material movement that raised questions turned to be logistic-type problems; discrete event models (DEM) and process simulation were used to address the issues. During the years, the ever-growing M&M Center of Excellence (CoE) Process Model Library has been extended with Traffic Model components. These include:

- Routes, composed of sectors, determined by and set to the travelling characteristics of the real roads
- Parking/staying sites, bridges, narrows and intersections
- Settlements, with individual traffic restrictions (daily restrictions, holidays, events etc.)
- Parking/staying sites, bridges, narrows and intersections with rules for intended usage
- Road blockages
- Operation-related traffic, (scheduled, defined)
- Third-party traffic (random, estimated)

Model prototypes are built from these library modules. Then, the parameters of the model components are tuned to design values and specific traffic scheduling is applied (pick-ups, regular trucks, heavy trucks, buses etc.). Also, the simple, default blocks of vehicles could be transformed into 3D shapes better resembling the vehicles applied at a particular site. At this stage, the model starts to "work", and step-by-step model verification could begin.

The 3D visualization is beneficial to demonstrate the forming traffic and to spot issues. The usage of the simulator is organized in three steps:

- Compilation of input data – vehicle parameters, traffic restrictions, traffic scheduling; data arrangement and pre-processing
- Simulation - performing scenarios, visual demonstration of the forming traffic; data collection
- Evaluation of output data – traffic analysis, vehicle utilization, progress with mine construction; post-processing and chart generation.

The DEM simulation shell is from Flexsim. The available development environment is shown in Figure 9. A road map serves as background; the real road is marked with red, the red lines mark the modeled road. Vehicles are color-coded (shown as blue, grey and yellow boxes). Poles (green and yellow ones) mark important segments of the road (speed limit zone, narrows etc.). A bridge is marked with a purple block. For ease of use, pre- and post-processing were developed in Microsoft Excel. Post-processing was kept open-ended, allowing further analysis on behalf of the T&L Specialists.

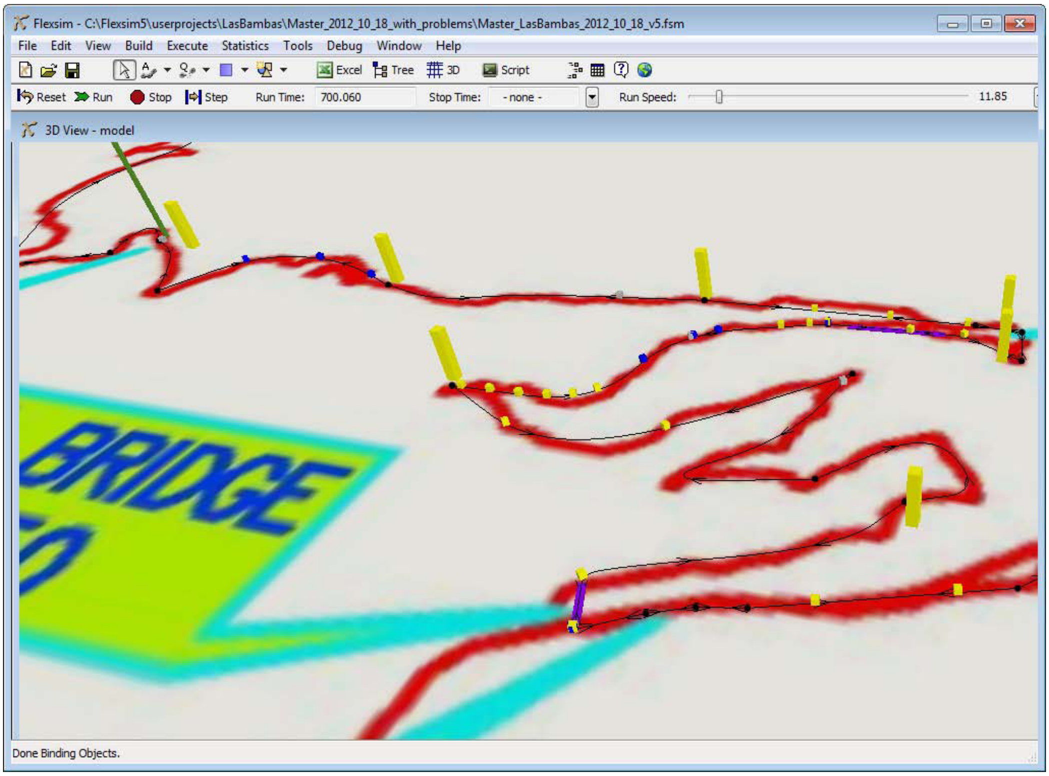

Figure 9. Flexsim DEM Environment

T&L experts measure utilization of access points, routes, intersections, staging areas, and control movement of vehicles on the road. The model allows having an "overview" of the ongoing traffic. As the road is about 200 km long, the blocks, representing the vehicles are not visible. The black lines, "electronic leashes" in Figure 10 are to spot vehicles and group of vehicles as they move.

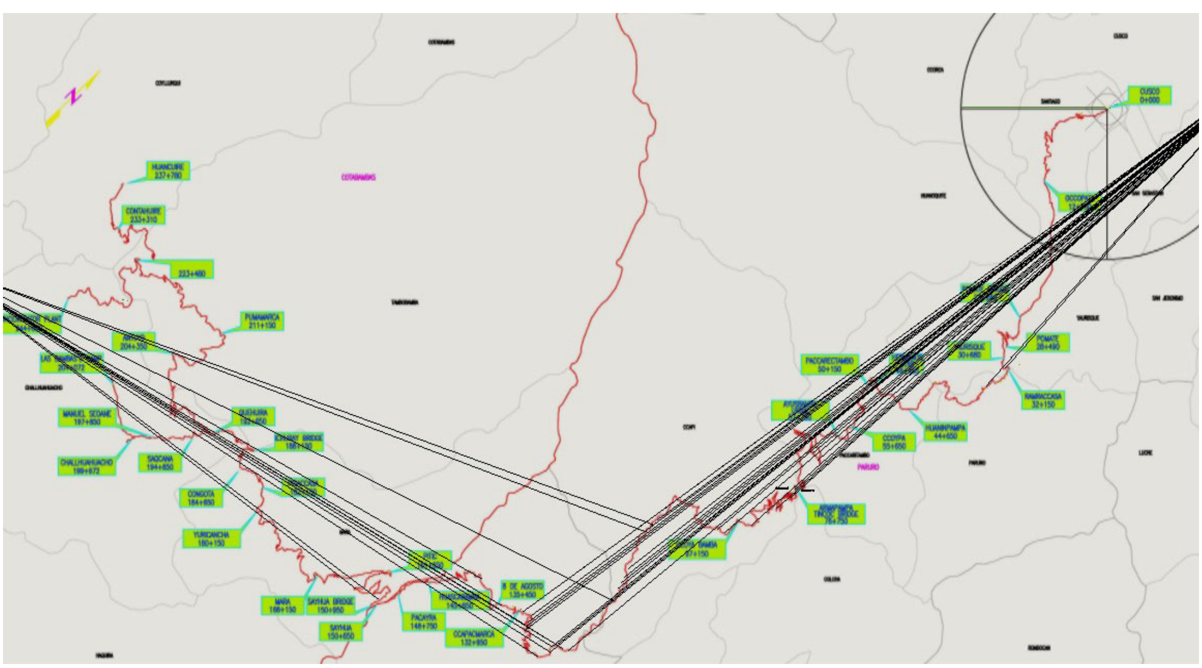

Figure 10. Vehicle Movement Overview

Model–Based Traffic Planning and Validation

During the construction of the mine, special care was taken in minimizing impact on the life of local habitants and the environment. As a result, a number of issues were captured in the model, such as limiting or even banning traffic on local and national holidays, allowing traffic only during daylight (adapting to sunset/sunrise times and to seasonal weather conditions). It was understood that sustainable operation during mine construction was primordial towards mine operation for the years to come.

The traffic simulation is based on the continuously updated *Traffic Forecast Plan*. When a time period of interest is set, a schedule is generated for that period (typically days, or a week). Then, using the traffic model, T&L experts could simulate combined effects of schedules and projected traffic restrictions. Figure 11 shows waiting times at a bridge, over a week-long period, where alternating, single-lane traffic is ordered. Figure 12 shows the travelling times for the groups of vehicles.

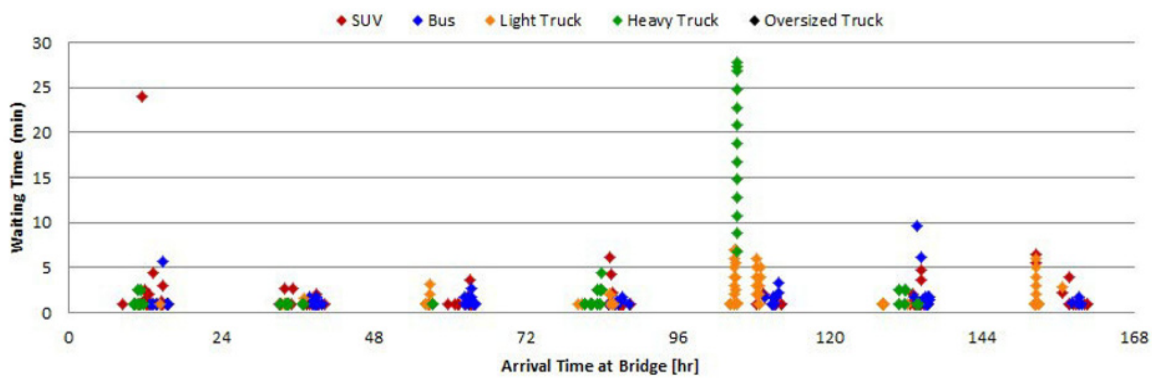

Figure 11. Vehicles' Waiting Time at a Bridge

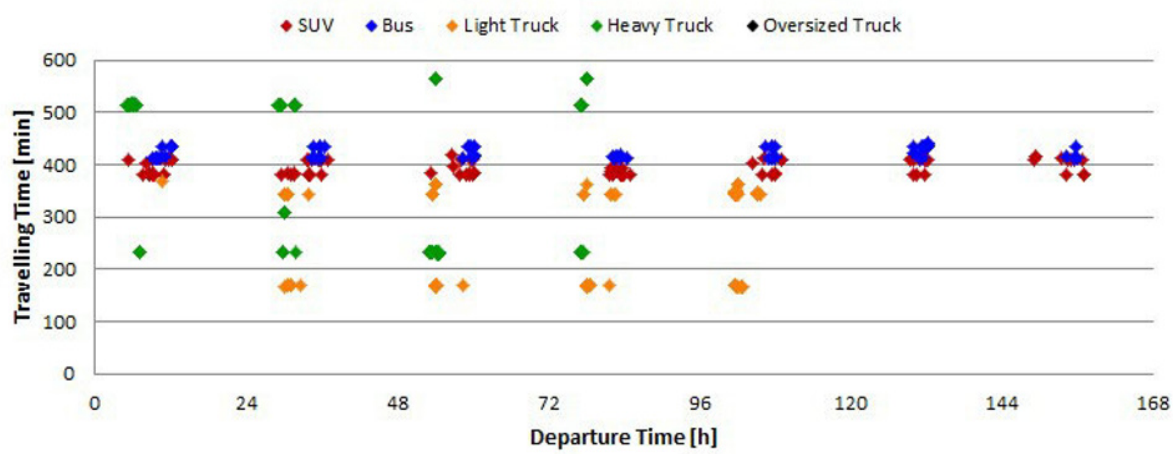

Figure 12. Vehicles' Travelling Time

In general, the model execution is fast. It could be up to 100 times faster than real time, depending on model granularity as well as animation and reporting overload. It was found, that results for projected one-week traffic could be generated within minutes, i.e. still in real-time with the ongoing process. This means that in critical situations, a T&L Specialist, weighing options, first could apply the possible changes to a model, then run the model and compare the outcomes. It could be, indeed, a model-based "calculator" to traffic planning and validation.

The simulator could be extended with data collecting/ recording utilities. Those data then could serve for formal traffic density and road capacity analysis. A time-space diagram is given in Figure 13. Trips of selected vehicles (color-coded lines for vehicle #1, 7, … 65) are shown. Traffic stream properties, density (number of vehicles over a unit length of the road) and traffic flow (number of vehicles passing a reference point per time unit) can be derived from the curves.

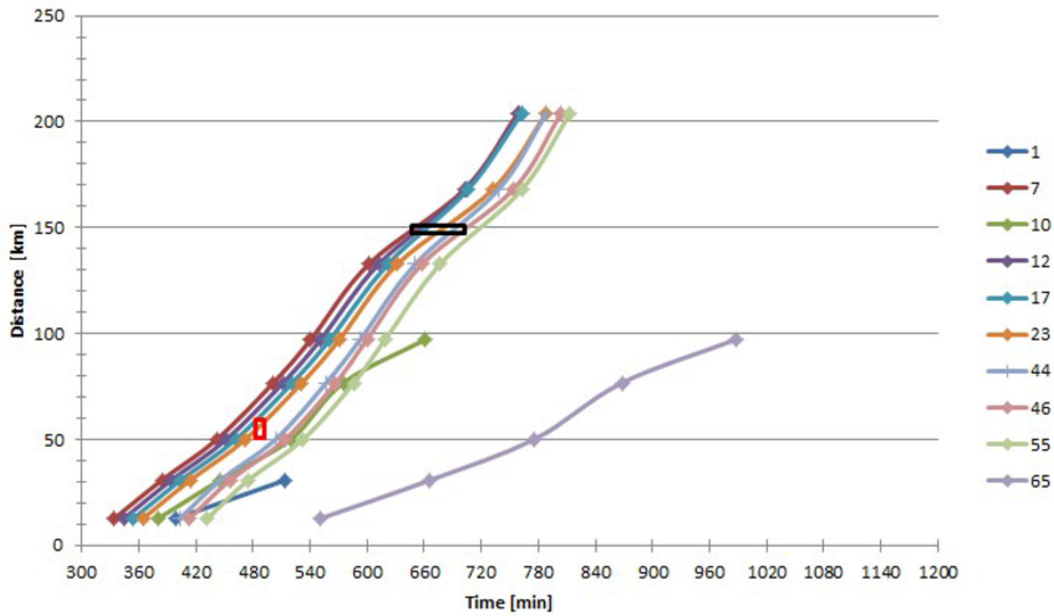

Figure 13. Time-Space Diagram

N-cumulative curves are shown in Figure 14. At selected sites of the road (coded as 100, 200,… 800), number of passing vehicles were counted over the day. Travelling times between sites, delays, total number of vehicles on the road, congestions could be derived from the curves.

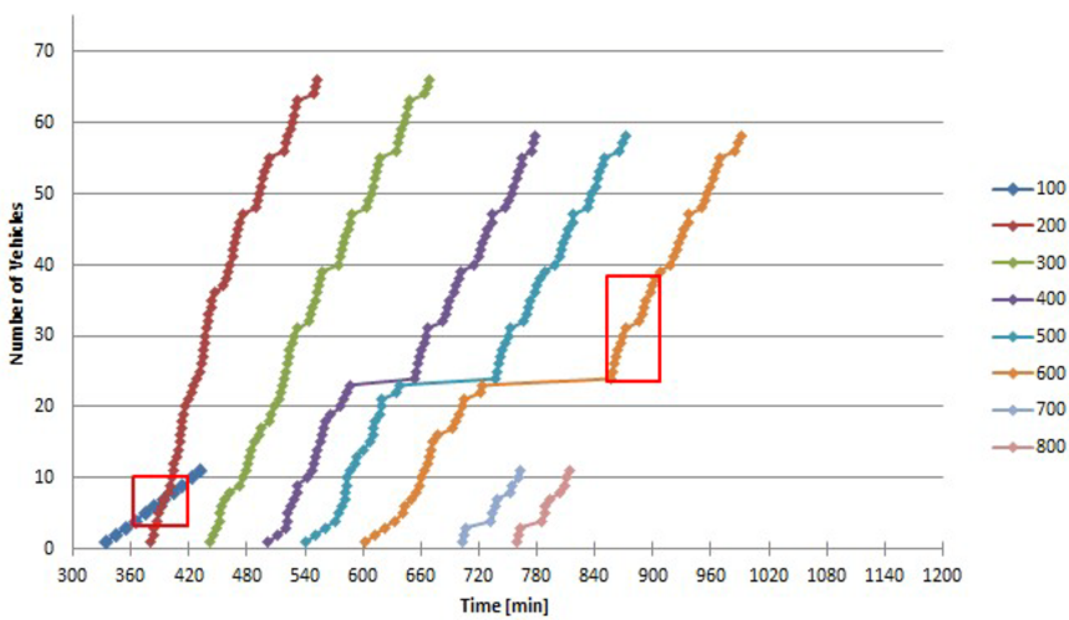

Figure 14. N-Cumulative Curves

Conclusions

Sustainability is key measure for an ongoing mine construction project. A traffic simulator is provided to aid planning/ validating movement of workers and cargo.

Testing, maintaining, extending and improving the simulator are ongoing. As the mine construction progresses, roads will be altered and new roads will be added to the existing ones. Traffic rules will be added and adapted to evolving site conditions. The modular structure of the model/ simulator provides more flexibility such as the capability of adding elements to the model to represent new scenarios.

T&L experts are gradually including the traffic modeling approach to their daily traffic planning routine. Their comments on data preparation (planning), traffic analysis (data collection, reporting) and interfacing with other applications (GPS-based vehicle monitoring) will be captured to the new model release in the coming months. Further results are expected to be published at coming TMS conferences.

Trademarks

Flexsim is registered trademark of Flexsim Group. Excel is registered trademark of Microsoft.

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