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A simulation model to access the impact of underground coal mine logistics strain on an operation

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A SIMULATION MODEL TO ACCESS THE IMPACT OF UNDERGROUND COAL MINE LOGISTICS STRAIN ON AN OPERATION

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ABSTRACT: A novel approach has been developed to strategically identify logistical bottlenecks and the impacts that mine planning parameters might have on these at any point in time throughout life of a mine plan. An XPAC-based model is employed at a macroscopic level to understand trends and shifts in logistical strain for a timeframe up to the entire life of mine. However, on a day-to-day basis the XPAC-based model cannot, at a very detailed level, provide information to analyse if logistical strain can be alleviated through finer adjustments. The finer adjustments that can be identified and rectified, can be determined using a discrete simulation FlexSim model. The paper presents details of the FlexSim discrete simulation model and its applications.

INTRODUCTION

An XPAC-based model has been developed by Walker (2023) at a macroscopic level to understand trends and shifts in logistical strain for a time frame up to the entire life of mine. Walker (2023) defined the term logistical strain to measure how many materials delivery LHDs are travelling on the roadway defined as “loads on road” at a given time. The higher the “loads on road” the higher the likelihood of delay as machines have higher rates of interaction with each other particularly in shared transport routes that exist along mains headings. However, on a day-to-day basis XPAC cannot, at a very detailed level, provide information to analyse if logistical strain can be alleviated through finer adjustments. Finer adjustments that can be identified and rectified, have the potential to transform and alleviate logistical strain back at a strategic level by taking these adjustments and changing baseline strategic assumptions within the XPAC model. When a problematic trend in logistical strain is identified within XPAC, the specific day is identified within XPAC and the face positions, deliveries required and the number of delivery LHD’s available are transferred into a discrete simulation FlexSim model. The FlexSim model enables closer examination of the travel path and potentially allow planners to address superfluous delays which in turn can reduce cycle time which in turn can be transferred back up to XPAC to recalibrate the model. This cyclical relationship is demonstrated in **Figure 1**, where a problematic trend in logistical strain is identified within the XPAC-based model, a specific day is identified within the XPAC-based model and the face positions, deliveries required and the number of delivery LHD’s available are transferred into a FlexSim discrete simulation model.

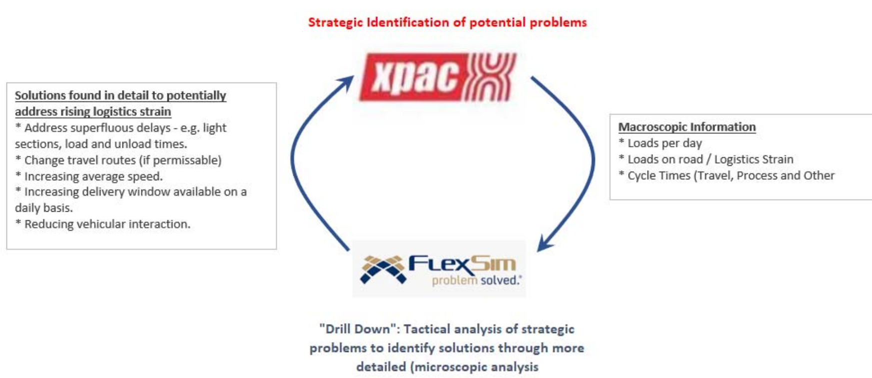

Figure 1: The cyclical relationship between the use of XPAC and FlexSim models

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THE FLEXSIM MODEL

In the FlexSim model, delivery LHD's must acquire the load at the portal, travel from there to the productive face, unload and then return to the portal. The required model inputs include vehicle speeds, acceleration, loading times and vehicle interaction.

Loads

Loads are assumed to have been previously delivered to the bottom of the portal / pit bottom area prior to the start of that day. This ensures there are no delays to delivery from surface to pit bottom which would delay the transport of the load and is outside the scope of this paper but identified as another potential bottleneck for future analysis. The loads are created in FlexSim and are colour coded to reflect the machine they are designated to be delivered to with Red for CM1, Blue for CM2, Green for CM3 and Yellow for Longwall. The pit bottom area in the FlexSim model is illustrated in **Figure 2**.

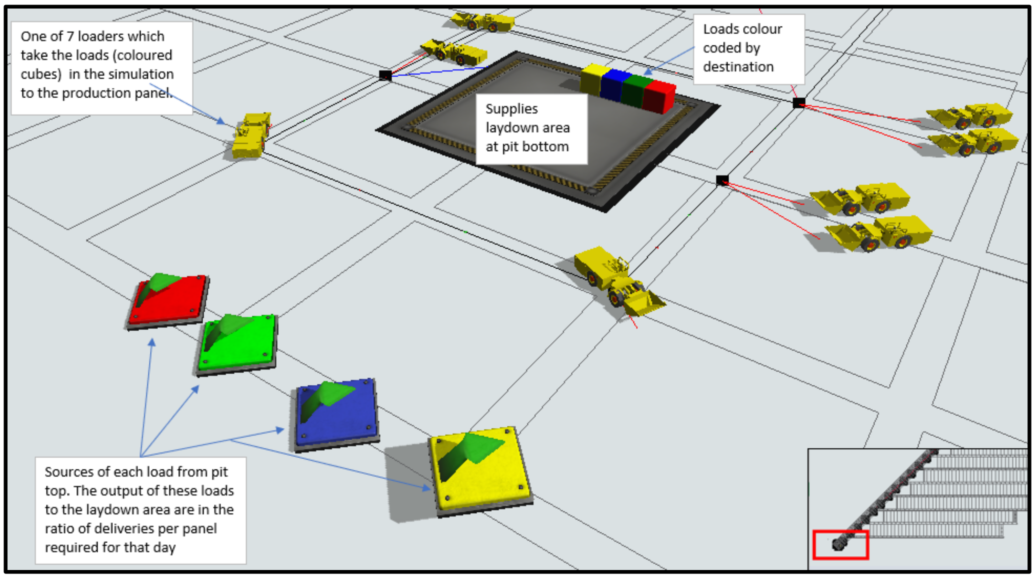


Figure 2: Pit bottom supplies laydown area. Colours of loads and sources of each load reflect their destination

LHD's

The LHD's take the colour coded loads to their respective production panel. The LHD key inputs are consistent with XPAC LHD parameters but with finer detail including acceleration and deceleration and using normal distribution for load and unload time ranges to reflect better on reality. The initial key inputs for each LHD are:

- Capacity = one load one per trip from the portal to the productive face and return.
- Maximum speed = 10 km/hr or 2.78 m/s.
- Acceleration and deceleration = 0.5 m/s2 or 5.56 seconds to reach 10 km/hr.
- Load and unload times = 900 seconds normal distribution with a standard deviation of 200 seconds.

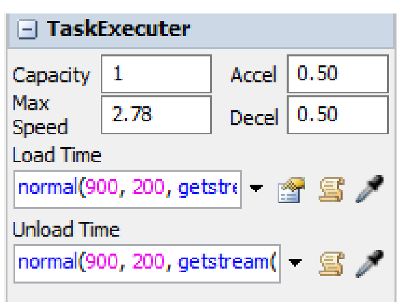


Figure 3: The LHD key inputs menu in FlexSim

It is important to note that the above parameters can be changed when addressing an occurrence of logistical breaking strain by changing the speed, the number of loads, or the time to load and unload if evidence exists that current or planned infrastructure can do so. Each mine will be able to obtain these parameters though time in motion studies, as lighting and concreting will affect speed and issues arising such as operator competence or pit bottom layout will affect load and unload time variability on a mine by mine (or even crew by crew) basis.

Vehicular interaction and traffic control

Traffic control is set up to either prevent vehicle interactions in a section of roadway or to set a flow direction for traffic such as areas which are one way. There are three major scenarios where traffic control is set up over the delivery route, Mains headings, Gateroads and controlling direction of flow of traffic.

In Main headings LHD operators will shunt out of the way if oncoming lights are seen, and therefore only one LHD could occupy a section of road at any given time whilst the other LHD would shunt into a cut through and wait for the machine already in the section to pass. In the FlexSim simulations, if a single transport route using a single roadway has been applied then the first machine to occupy the controlled section receives right of way status and the other machine must wait and shunt. **Figure 4** highlights the application of traffic control to enforce no passing along the roadway with shunting occurring every four pillars which would simulate a conservative recognition of a LHD in the section and time to shunt. Shorter sections may underestimate the delay to shunt, and longer sections may block the road for too long a time and overestimate delays for each LHD and provide a pessimistic view of total average cycle time.

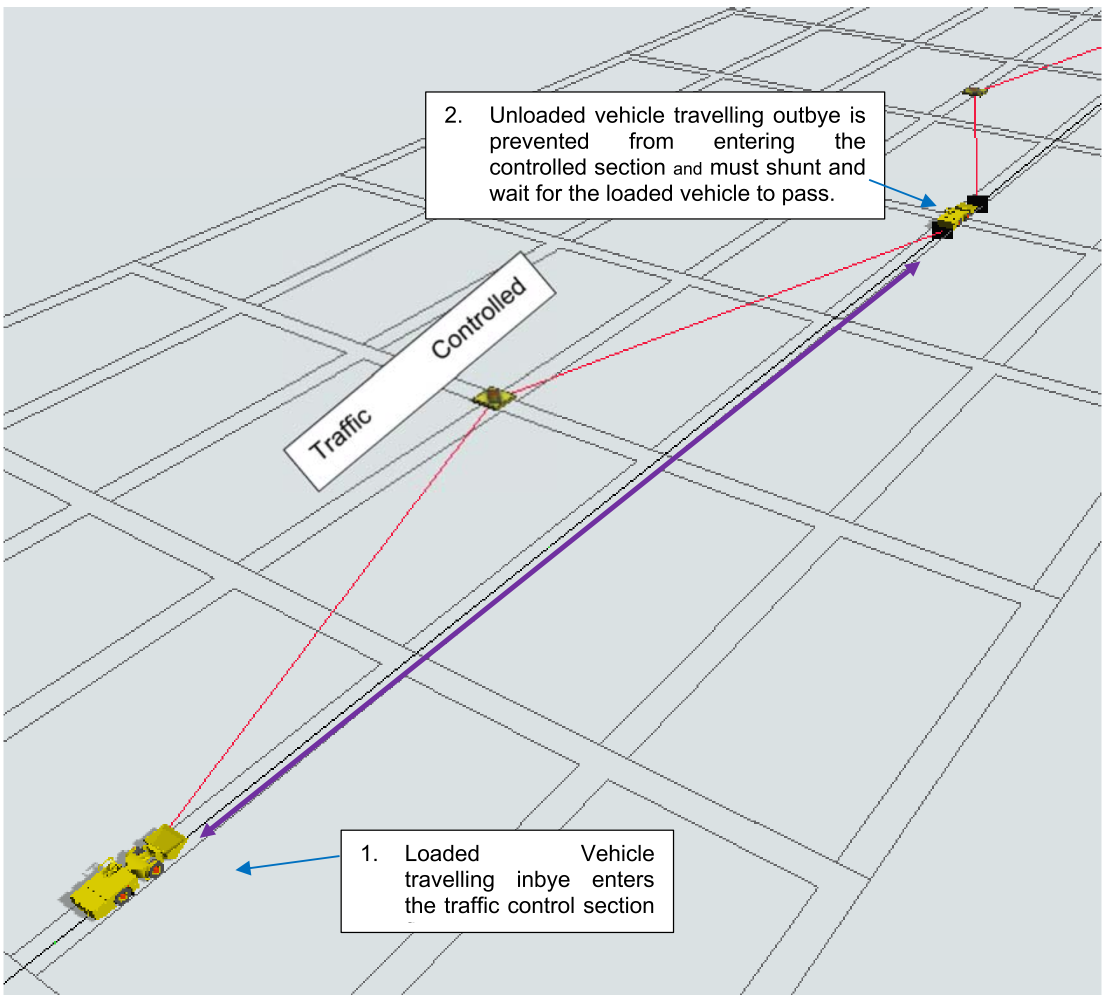
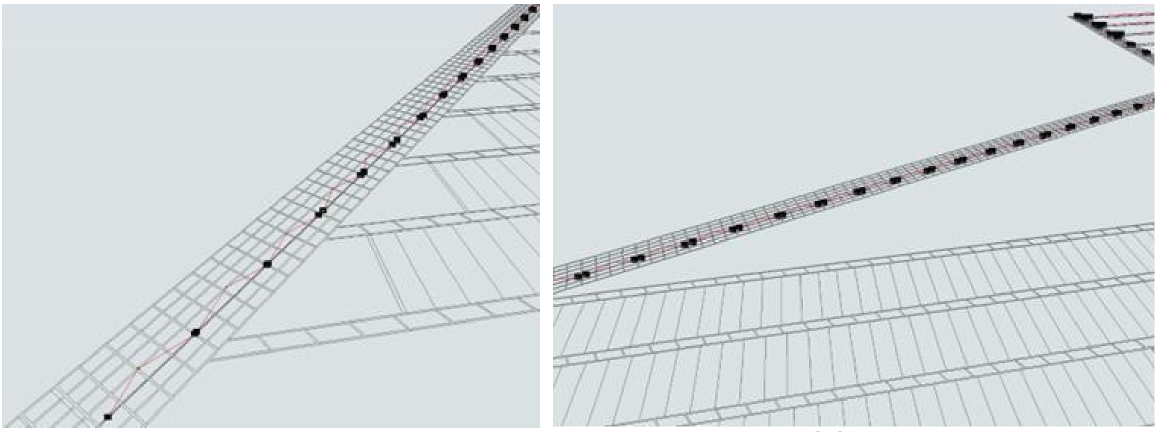


Figure 4: Traffic Control preventing passing in roadways and forcing vehicles to give way and shunt

In the FlexSim model, a traffic-controlled section is signalled by a traffic light symbol. The physical extent of the section is bound by two black travel network nodes along the roadway which are connected to the traffic light symbol using a RED object connection line as shown in **Figure 5**. Adjacent network nodes which are not connected are designated passing shunt areas.



Outbye **Inbye**

Figure 5: Traffic Control Sections connected by red object connection lines for Outbye (left) and Inbye (right)

When ventilation is limited to a single large delivery LHD for development, unlike the mains, a single traffic-controlled section is defined from the gateroad entrance through to the continuous miner which prevents more than one unit from travelling down a gateroad in the same ventilation circuit and breaching diesel particulate matter threshold limit values. If there was a convoy of two units then the second unit would wait at cut through # 1 until the delivery unit exited the panel or shutdown whilst unloading inbye as shown in **Figure 6**.

Figure 6: A single Gateroad traffic control section to allow only one large diesel delivery LHD to travel down it

Traffic can be controlled to only travel in a single direction in certain circumstances such as travelling around pit bottom or when utilising a dedicated inbye and outbye travel road. Controlling direction of flow will mostly prevent vehicle shunting as no passing of inbye and outbye vehicles occurs. Single direction roadways are shown in **Figure 7** with a green arrow showing the direction of forced travel and a red arrow showing the impassable direction.

Interference of other machines

Depending on the scenario, other machines such as faster personnel transport (Driftrunners, etc.) during shift change or other itinerant vehicles can be encountered during the delivery cycle of a supply machine. The philosophy adopted in this paper is consistent with mines visited and is that these other vehicles give the delivery LHD priority that deliveries during this period follow in the incoming shift and shunt for the outgoing shift leading to minimal interruption.

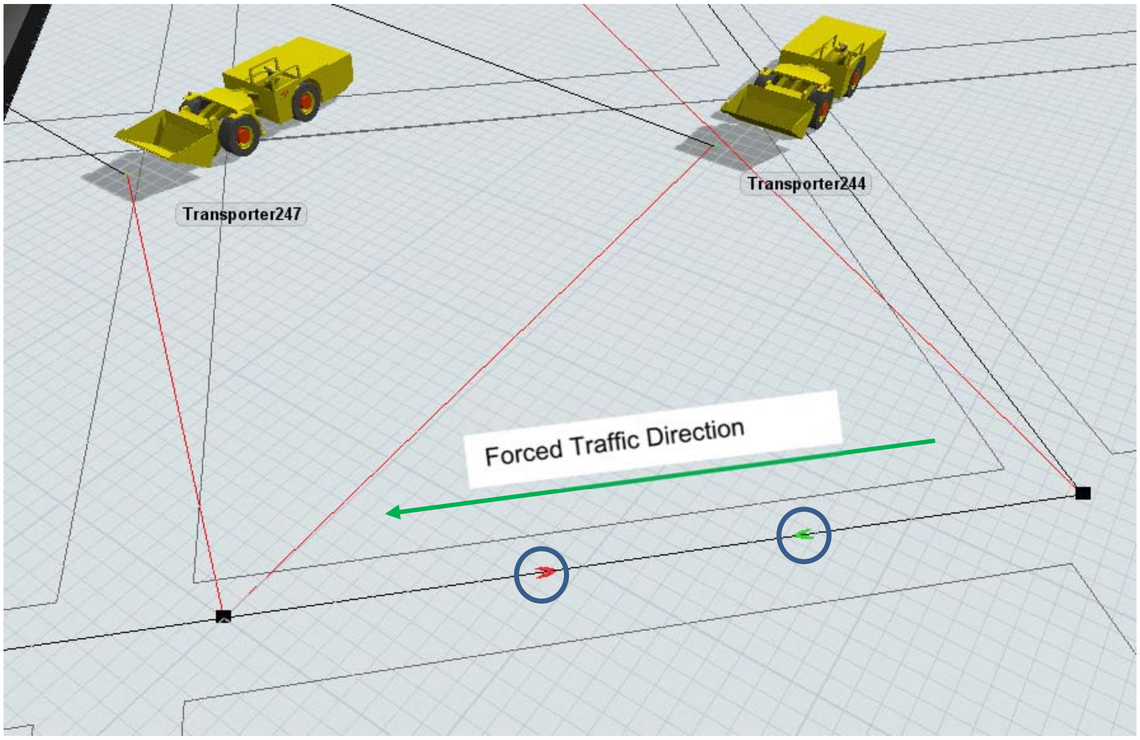


Figure 7: Traffic Direction. A red arrow means you cannot travel in that direction. (LHD = Transporter in FlexSim)

CONCLUDING REMARKS

XPAC-based model has been developed to identify at a strategic level the number of material delivery loads required to maintain planned productivity for a mining operation. Once an event has been identified, a discrete simulation FlexSim model presented in this paper, is used to further drill down to a tactical level to confirm the predicted impact and understand if a solution can be transferred back as a long-term solution.

REFERENCES

Walker, D 2023, 'Integrating materials supply in strategic mine planning', PhD Thesis, University of Wollongong, NSW, Australia, 249 pp.

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