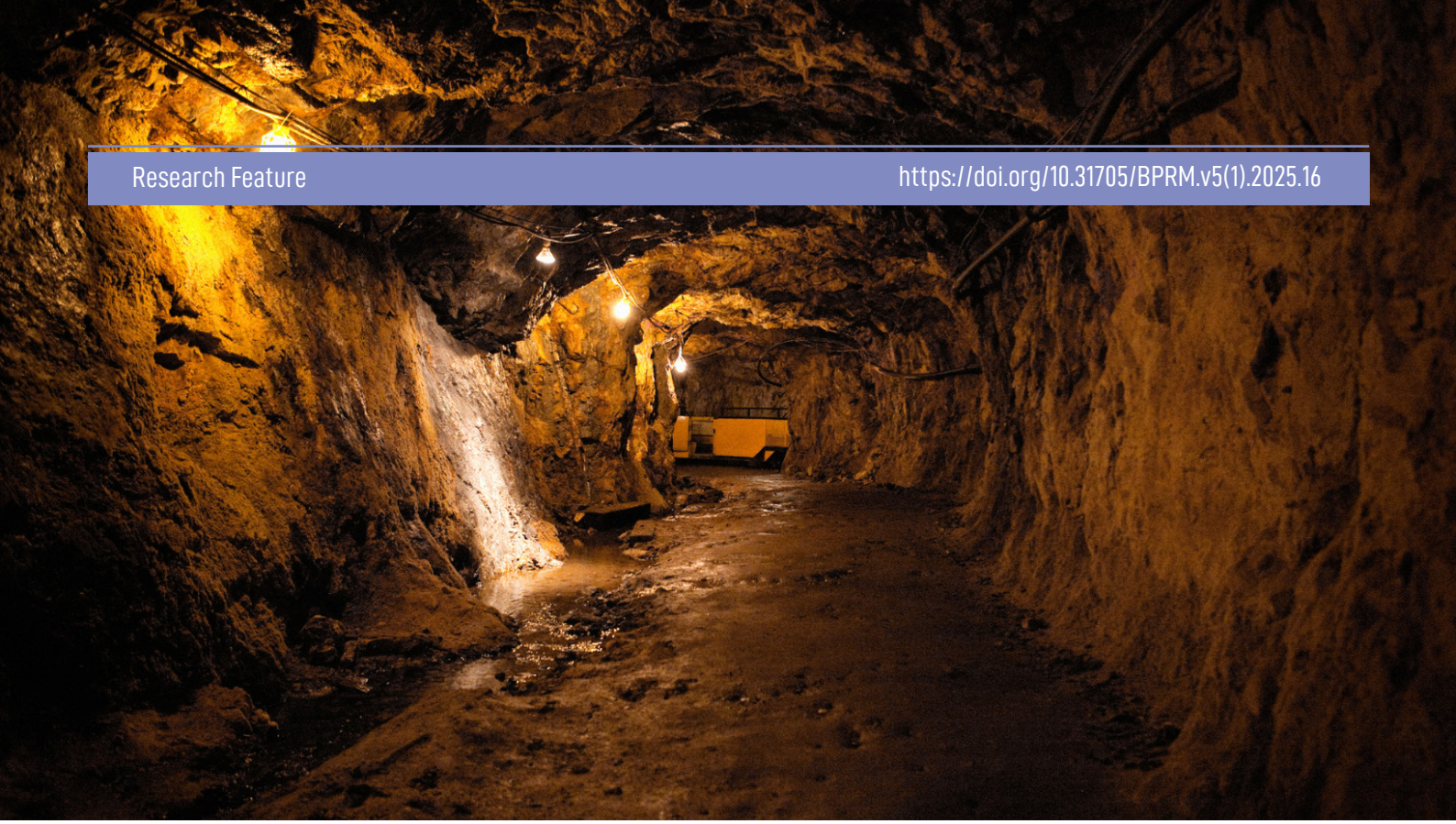

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Ventilation on Demand Systems for Underground Mining Environments

Intense consumption of resources is unavoidable to facilitate technological advancements and the needs of growing populations. Escalating concerns in the resources industry extend beyond environmental aspects to energy consumption, carbon taxes, and compliance with evolving regulatory frameworks. The mining industry also faces a similar challenge in the effective utilisation of energy, amidst the demand for increased production. In an environment where global energy consumption increases by 1.4% annually [1], adhering to sustainable mining practices has enforced restrictions on excess energy use and the types of energy sources. Therefore, mining operations are searching for optimised conditions in every aspect to comply with environmental, social, and governance (ESG) requirements.

The burden on underground mines to run ventilation systems is long known to be inevitable. The majority of them are historically designed and subject to minimal alterations due to being an essential and integral element of underground operations. Originally designed to cater for peak demand and continuing operations for 24 hours, they may not have undergone energy audits and optimisations since the alternatives are limited. Therefore, a considerable amount of energy consumption, even up to ~ 40 - 50% of a mine's total energy consumption [2], can be observed. Contrarily, continuous ventilation of an entire underground network of access may not ensure an effective supply of air to the regions that are overcrowded with workers, potentially impacting health and safety.

Ventilation on Demand (VoD) Concept

Methods for optimising mine ventilation systems have been thoroughly researched in the areas of optimising fan operations, installing ventilation doors, minimising dust production, and introducing artificial intelligence. The VoD concept is a cumulative outcome of the above attempts that ensures continuous air flow where it requires sufficient amounts [3]. Studies have shown that energy consumption can be significantly reduced with VoD systems, even up to 70% [2], [4] in comparison to the traditional methods. Transformation from traditional to VoD requires a systematic approach and a comprehensive

understanding of the underground network, ongoing processes, and regulatory requirements. VoD integration has five stages, as in Figure 1 [3], and the selection of a suitable level(s) depends on the unique requirements of each underground environment and should be customised to comply with resources and infrastructure.

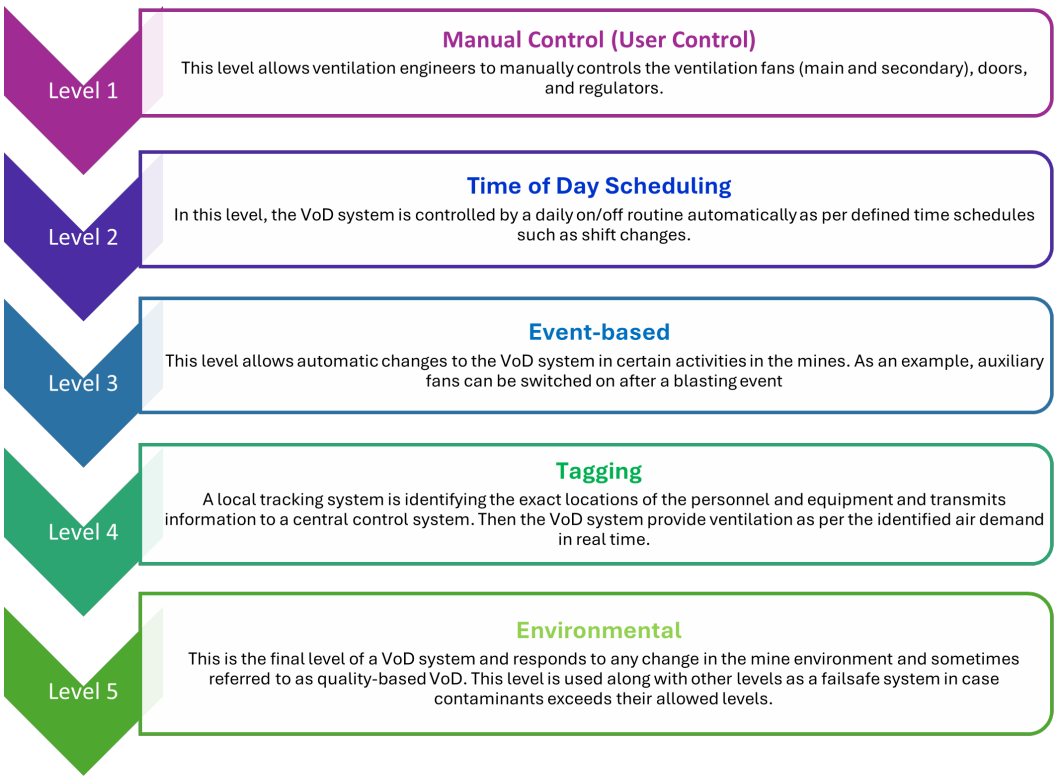


Figure 1: Main VoD levels and their control strategies [3]

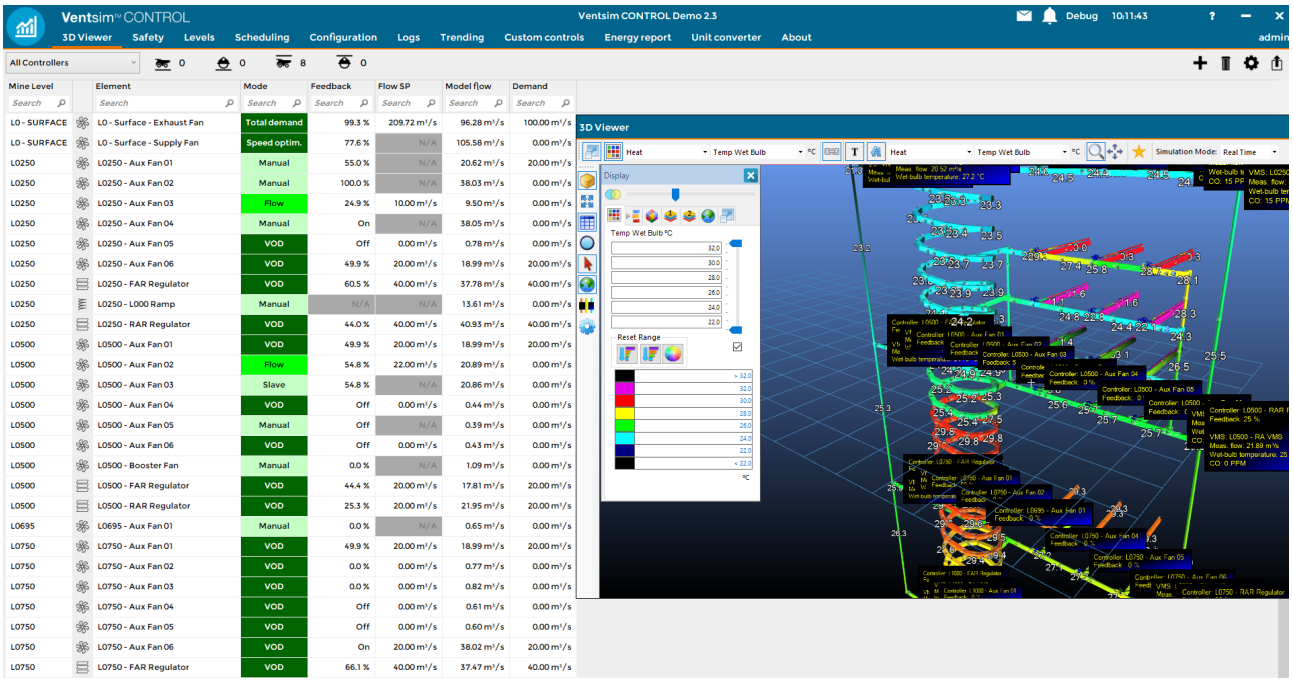


Figure 2: Generic dashboard of Ventsim CONTROL software [5]

Converting into VoD systems has been recognised to be effective for optimising energy consumption in mines. Major mining companies from Canada, Sweden, Brazil, South Africa, Finland, China, Australia, and India are leading the VoD adoption. Barrick's Gold Bousquet Mine, Totten Mine, Coleman, Creighton, and Nickel Rim South are some of the Canadian mines that have succeeded with the VoD transformations. Despite the challenges, the VoD concept has been successfully utilised in the Kristineberg and Malmberget mines of Sweden [4]. The Ipueira Mine in Brazil has been able to reduce its energy consumption by 71% upon VoD implementation, and it has a fully automated ventilation system (level 5) that was developed over three years. Vazante and Extremo Norte Mines in Brazil have also successfully deployed Level 1 and 2 VoD systems [2].

Figure 3: VoD system adaptation for underground mines in the world [1], [2], [3], [4]

Transformation amidst the challenges

The local mining industries are also in a constant attempt to attain sustainable and cost-effective mining operations due to increasing energy costs. They have identified VoD systems as a sustainable solution despite the initial capital requirements for essential infrastructure. Bogala Graphite Lanka PLC is leading this transformation in Sri Lanka, facilitated by ventilation surveys, energy audits, and modelling of ventilation networks with the expertise of local mining engineers. This transformation process has created numerous research and development opportunities for the students. Postgraduate research activities in this regard are ongoing at the Department of Earth Resources Engineering, facilitated by Bogala Graphite Lanka PLC. Transformation from conventional ventilation systems to technology-enabled sophisticated mechanisms is challenging and demands substantial research to address the emerging concerns. The studies conducted so far have identified the following as the main challenges encountered in achieving the given VoD levels.

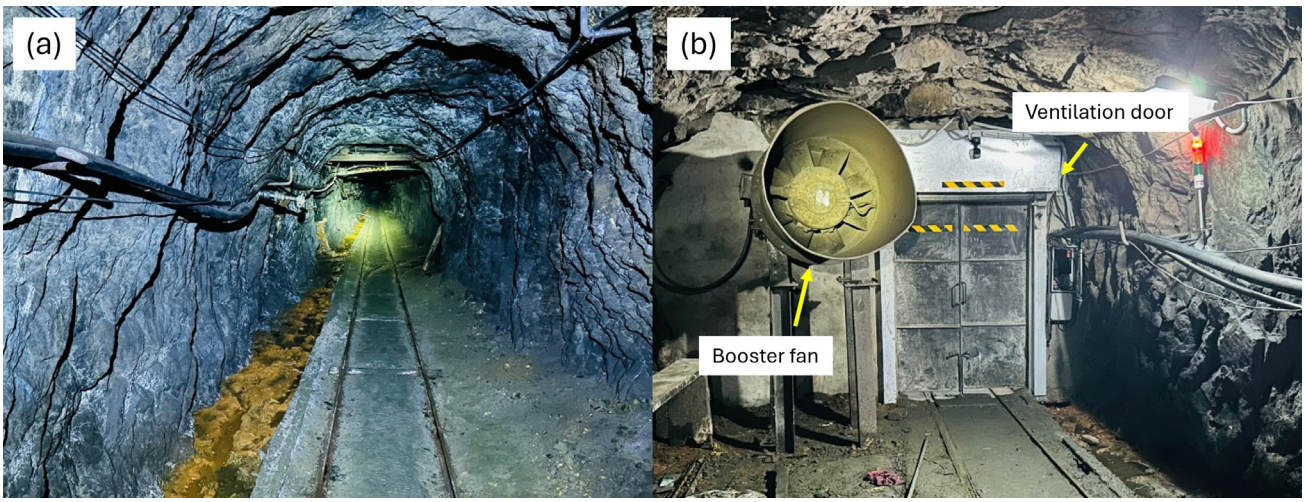
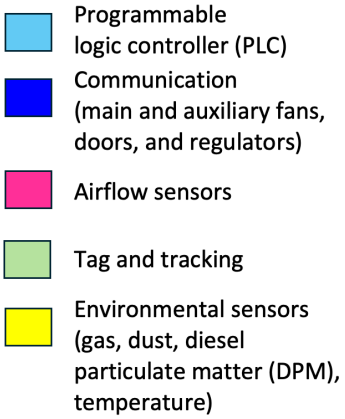


Figure 4: (a) Environment of Bogala underground mine (b) Existing underground ventilation arrangement

Table 1: Challenges and requirements to reach VoD levels

Level	Essential infrastructure/ resources [3]	Challenges/limitations
1		• Fans and doors are not yet integrated into a communication system, and this challenge similarly impacts the implementation of other levels as well. • Considerable human interventions are required. • VoD software cannot provide solutions to unique requirements at this level. • Limited energy savings.
2		• Predefined schedules are not available yet. • Considerable human interventions are required.
3		• Human interventions are required at some points.
4		• No air flow sensors installed in the mine yet. • No tag and tracking system installed in the mine yet (e.g. RFID). • Maintenance and acceptance of the tagging system by the workforce can be challenging.
5		• No environmental sensors installed in the mine yet.



A stepwise approach to study the existing underground ventilation network is essential to gather accurate information to compute ventilation requirements. For this purpose, ventilation surveys and digitally constructing the ventilation network have been established. Performance optimisation of the existing ventilation network under the given circumstances will be completed before performing different scenarios to determine the ventilation on demand parameters to cater for sub-optimised conditions. Upon establishing the VoD parameters and operational conditions, essential resources and infrastructure requirements shall be developed as indicated in Table 1 to accomplish VoD levels.

The above efforts shall ultimately ensure that the underground ventilation network operates under optimised conditions for energy consumption and production requirements to maintain the business operations. The benefits are expected to appear from reduced energy consumption, customised air flows strictly to the required underground spaces, and complying with the standards of underground worker health and safety.

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