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Leveraging on Contemporary Drilling and Blasting Methods – A Case Study of the MTR Railway Project in Hong Kong

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Background

- Blasting generates vibrations and many restraints on Tunnel and Open Blasting
- The peak particle velocity (PPV) has been observed to be a good indicator of damage to structures and it is generally considered that structures in good condition can readily tolerate a peak particle velocity of 50mm/s without any risk of damage
- However, it is possible that there will be amplification between the peak particle velocity of the ground motion of a maximum 25mm/s which is usually adopted to prevent damage to buildings
- Different sensitive receivers have its own allowable vibration limits due to their own nature or Particular Specification in specific contract. However most of the specifications are not up-to-date and some of the limit are un-reasonable high so that the performance of blasting was hindered

Utility	Installation	Maximum Allowable Peak Particle Velocity , mm/s
Gas: **Hong Kong & China Gas Company**	All	**25**
Electricity: **China Light and Power Company, Hong Kong Electric Company**	Power Stations	**11**
	Sub-stations (major)	**13**
	Sub-stations (minor)	**25**
	Underground Cable Joints	**13**
	Underground Cables & Pylon Foundations	**25**
Water: **Water Supplies Dept., Hong Kong Government**	Non Water Retaining Structure & Water Mains	**25**
	Water Retaining Structures	**13**
Drains & Sewers: **Drainage Services Dept., Hong Kong Government**	All	**25**
Telephone: **Hong Kong Telephone Company**	All	**25**
Estates/Structure/ Schools/Private Properties	All	**25**
Computers	All	**5**
Fresh concrete: **Less than 2 days old** **2 and 8 days old** **More than 8 days old**		**5** **25** **50**

Background

- The pull length or the bench height for a tunnel blasting and open blasting was limited by the allowable vibration limits on those sensitive receivers and therefore limit use on the maximum instantaneous charge-weight (MIC) of explosives

- By optimize the blast parameters such as powder factor and pull length, new innovation and a detail study on the prediction of allowable vibration in order to achieve a better blasting performance

Optimization on Blast Parameters Using ANN and GA Modelling

Powder Factor (PF)

- PF is the amount of explosives required to break a unit measure of rock
- Since rock is usually measured in kilogram, there are several possible combinations that can express the PF
- A simple equation below shows the PF

$$PF = We / V$$

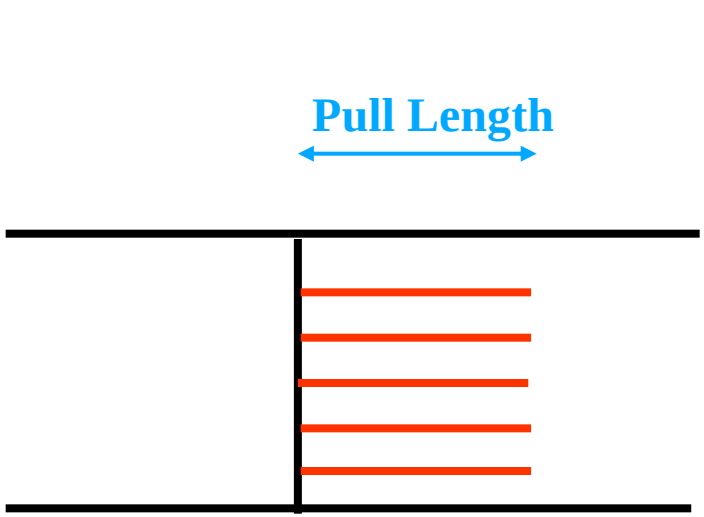
Where
PF = Powder Factor
We = Total Weight of Explosives used in Blast (kg)
V = Total Volume of Rock Generated in Blast (m^3)

Optimization on Blast Parameters Using ANN and GA Modelling

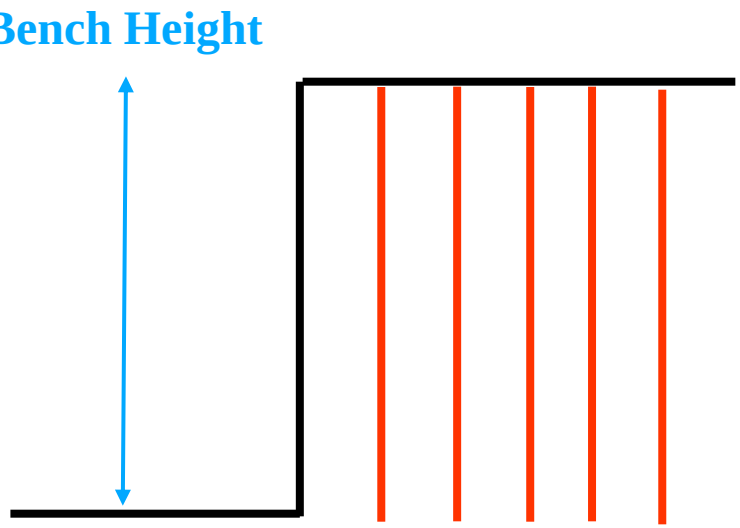
Pull Length

- The advanced length for each cycle of a tunnel blast
- The pull length of each cycle will mainly govern by two factors:
    - Geology of the tunnel, and
    - Charge weight

Pull Length of Tunnel and Bench Height of an Opencast



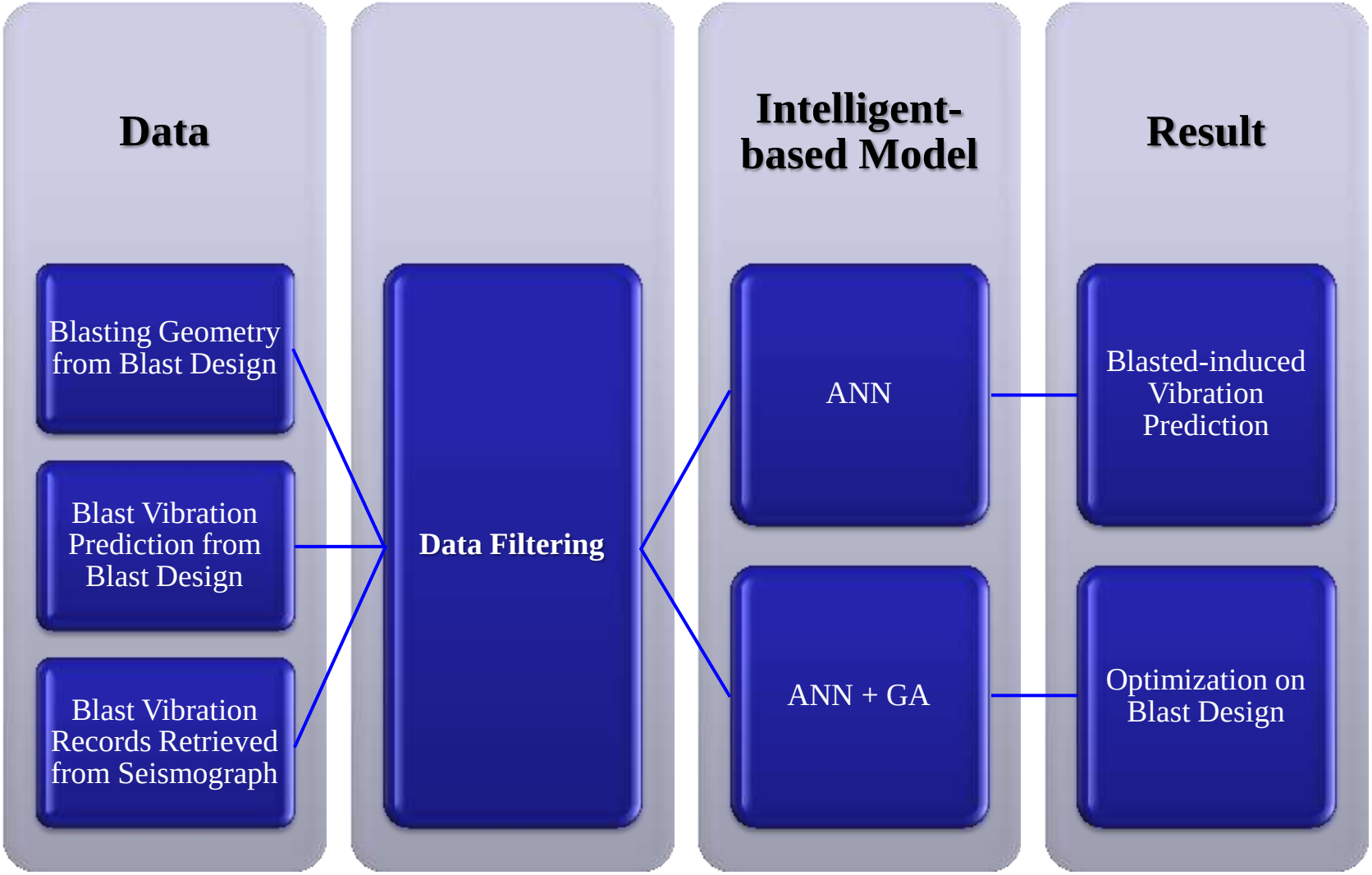
Tunnel Blasting



Opencast Blasting

Tunnel Blasting / Bench Blasting

Methodology



Blast-induced Vibration Prediction

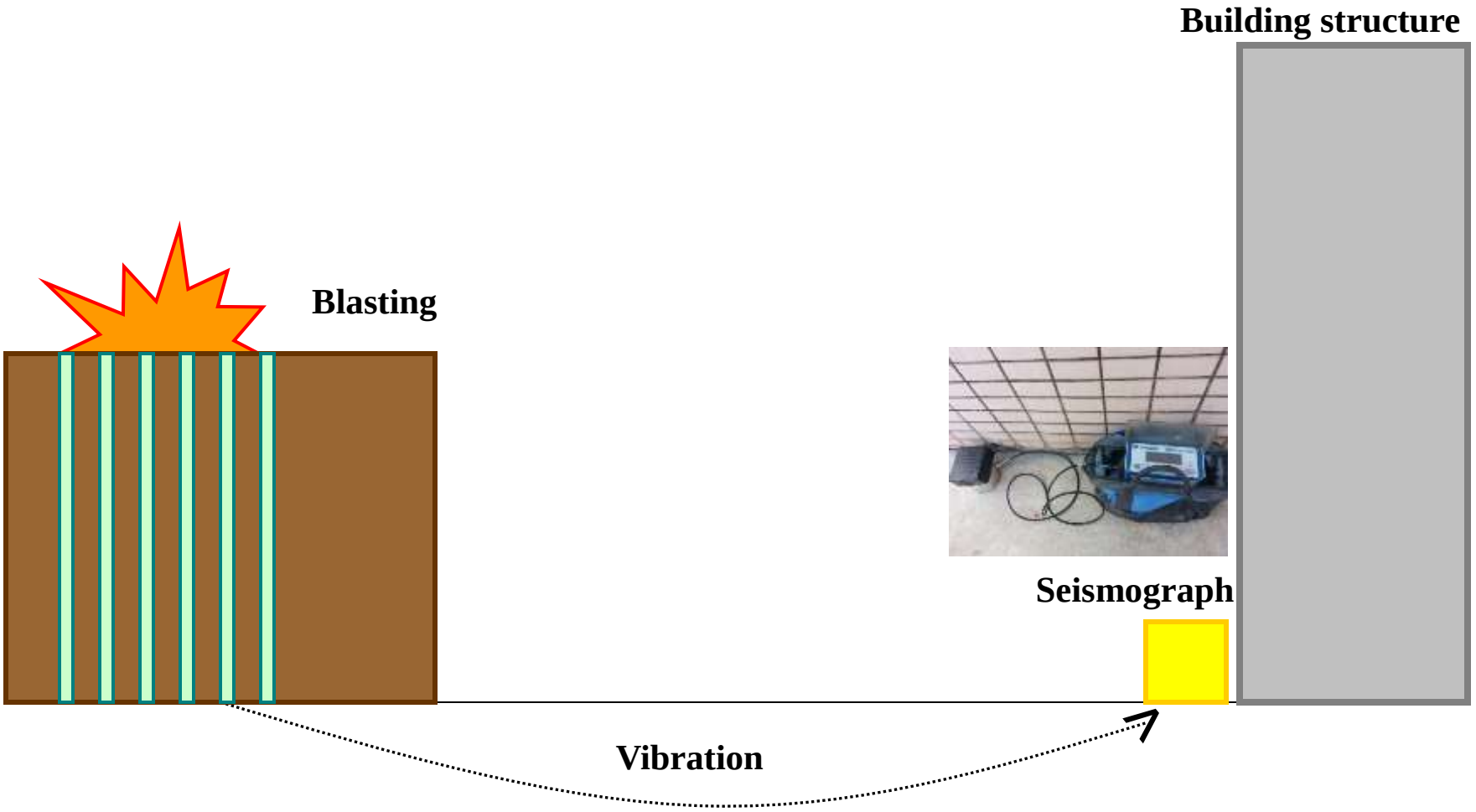
Ground Vibration

The magnitude of vibration induced by blasting is generally dependent on the maximum instantaneous charge (MIC) per delay, distance from the blast, geology / ground conditions and the type of blast undertaken (the degree of confinement of the blast). The induced vibration, in terms of PPV

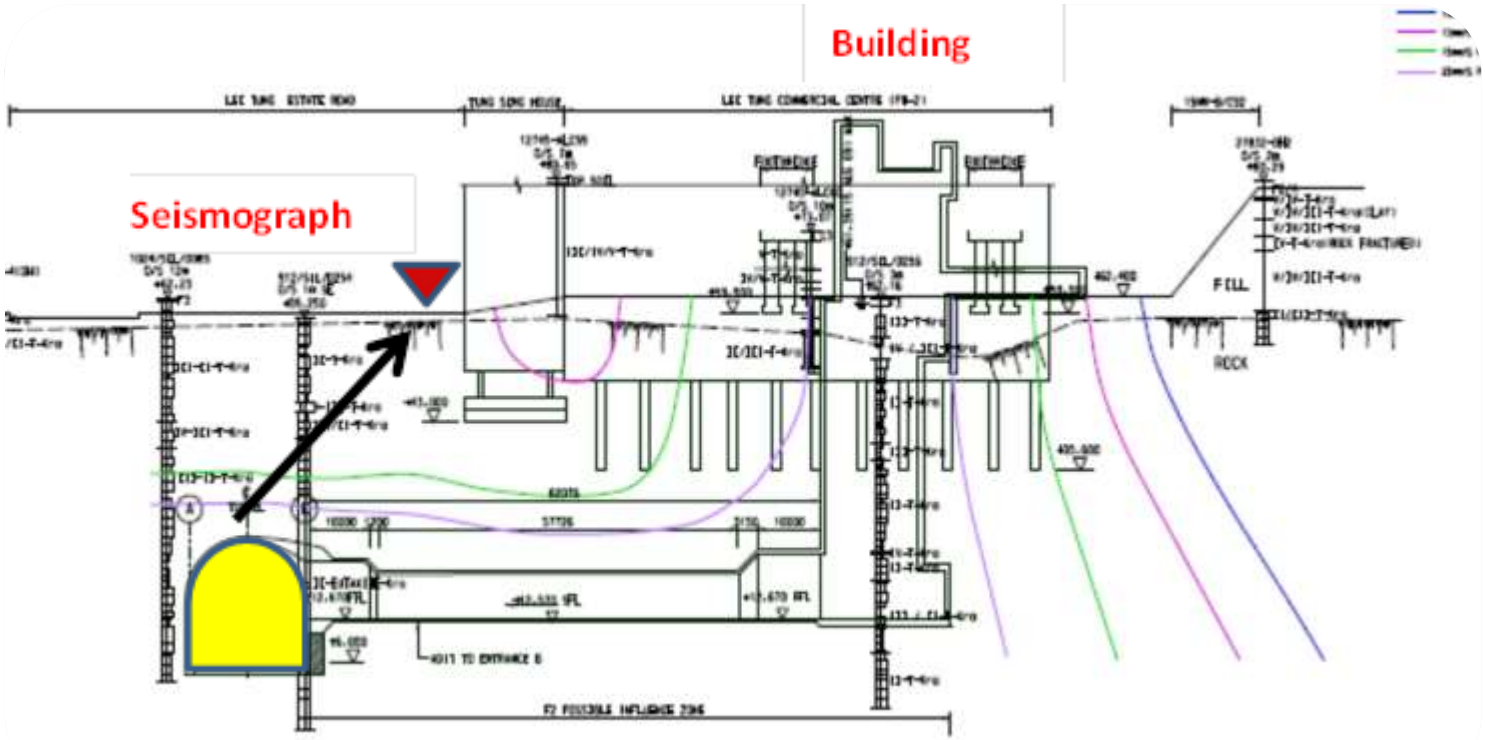
$$PPV = K\left(\frac{D}{\sqrt{W}}\right)^{a}$$

Where:	PPV	= peak particle velocity (mm/s)
	K	= rock transmission constant
	D	= distance between blast and measurement point (m)
	W	= maximum charge weight per delay interval (kg/delay)
	a	= attenuation exponent

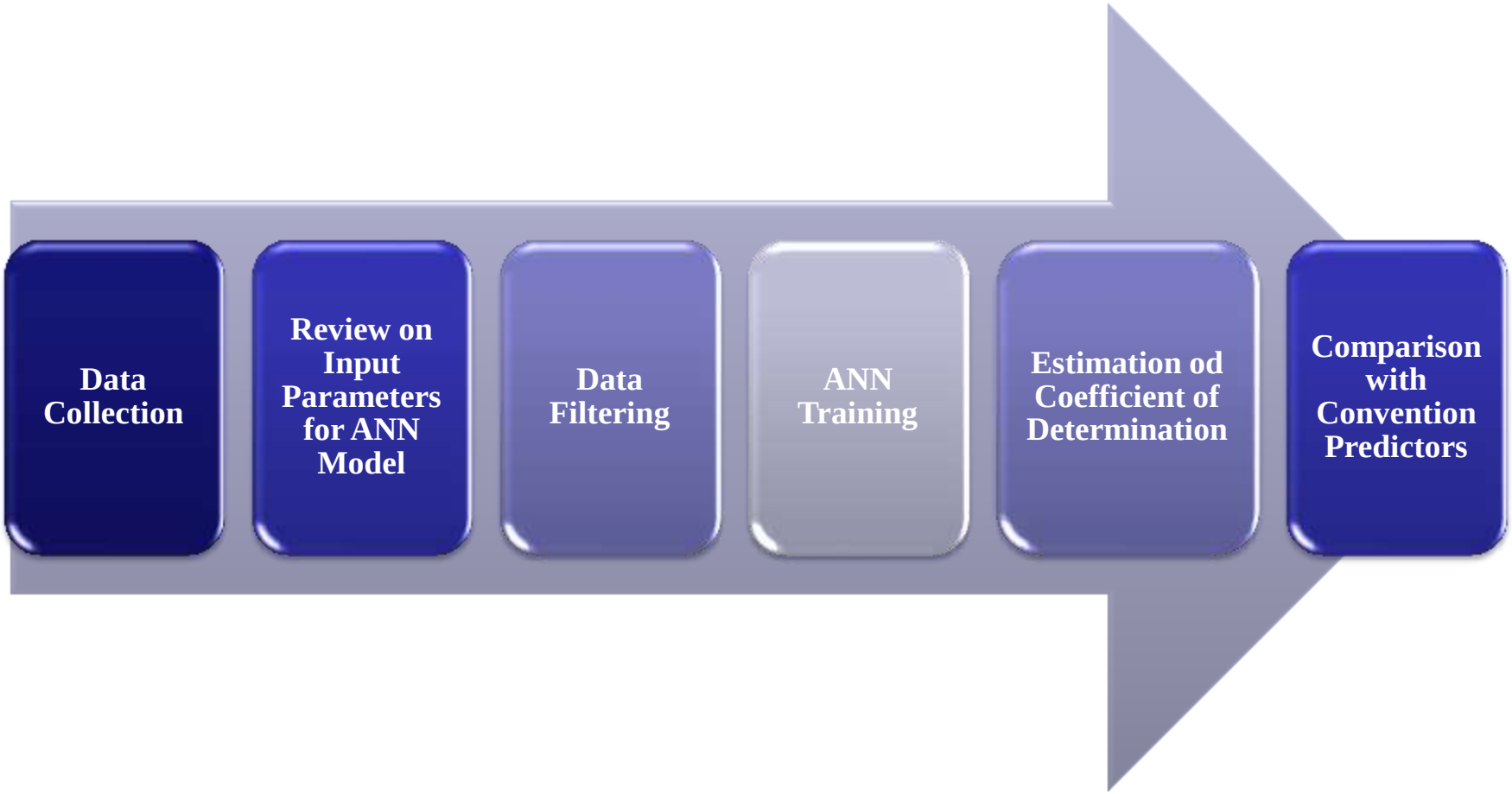
Site Description and Data Measurement



Measurement of Radical Distance



ANN Modelling on Blast-Induced Vibration



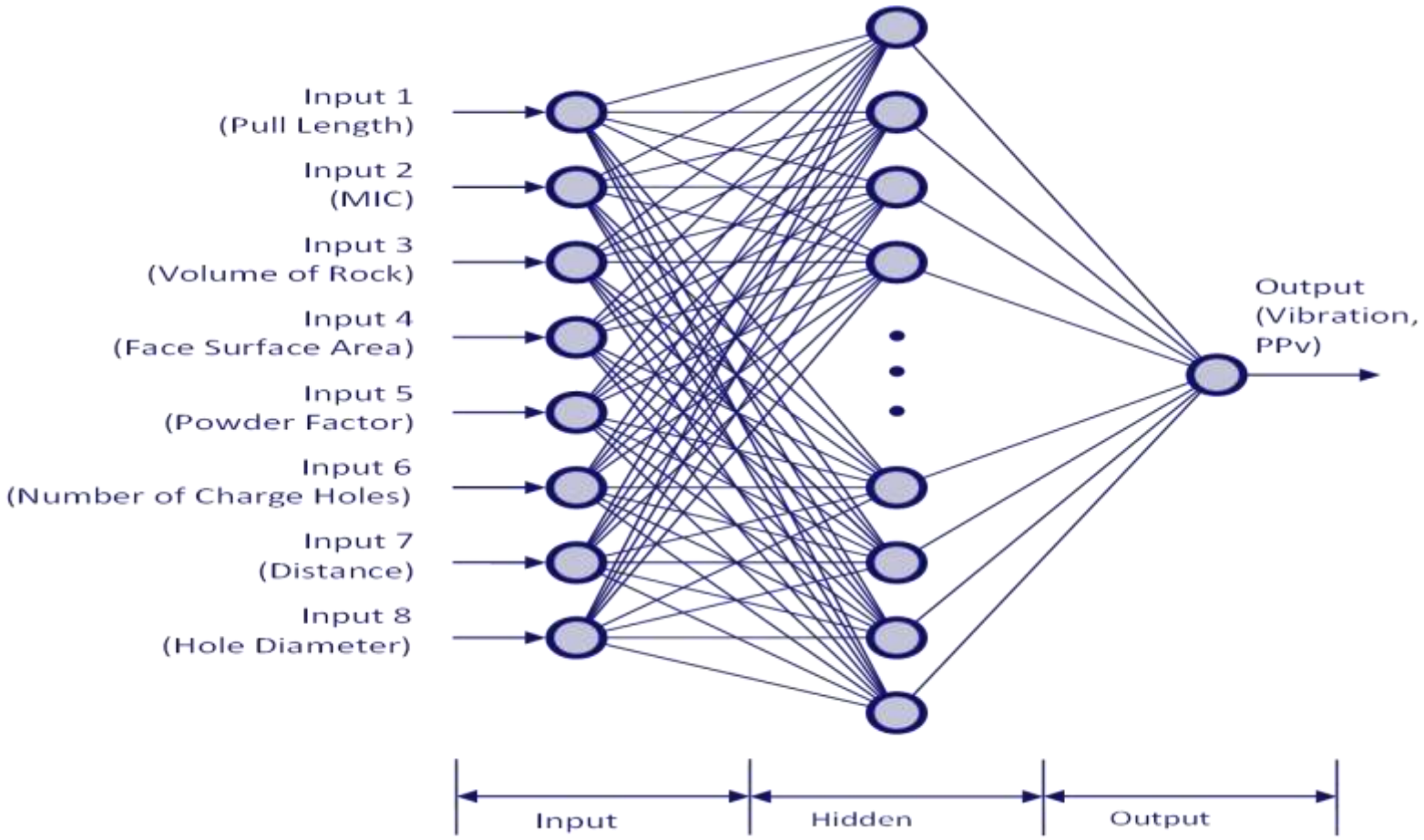
What is Artificial Neural Network

- Back propagation (BP) in Werbos PJ. (1974) is a traditional training algorithm used for the MLP model. It feeds back the prediction errors from the output layer to the input layer and the weights of the links between the neurons are adjusted according to the BP algorithm.
- Upon completion of the weight adjustments, a new prediction is carried out to evaluate a new prediction error for the next epoch of weight adjustments. These procedures are repeated numerous times until a satisfactory prediction result is achieved. In this study, the early-stop validation approach is adopted to monitor and stop the BP training

Artificial Neural Network Model

- Back Propagation Network with Multi-layer Perceptron (MLP) and 3 layers of neurons
- Input Parameters:
  - *MIC, Distance, Face area, Volume of rock, Powder factor, Number of holes, pull length*
- Output Parameters:
  - *PPV*
- Root Mean Squared Error (RMS) and Multivariate Regression Analysis (MVRA) on checking the performance of ANN

Architecture of MLP Model



Advantage on the use of ANN Modelling

- The advantage on employing of ANN model in which employ data-driven, self adaptive methods and can be used to perform non-linear modelling without the need of prior knowledge bout the relationship between input and output variables.

- The commonly used supervised neural network is MLP which has been applied to a variety of problems, and especially to forecasting because of its inherent and superior input-output mapping capability.

Optimization on Blast Parameters Using ANN and GA Modelling

Optimization two blast parameters:

Powder Factor and Pull Length

MTR

Optimization on Blast Parameters Using ANN and GA Modelling

- Powder factor and Pull Length demonstrates both geometry and energy approach of the blast design. They are linked together which means the increase of Powder Factor will directly lead to proportional increase of the Pull Length provided that the blasthole diameter remains unchanged

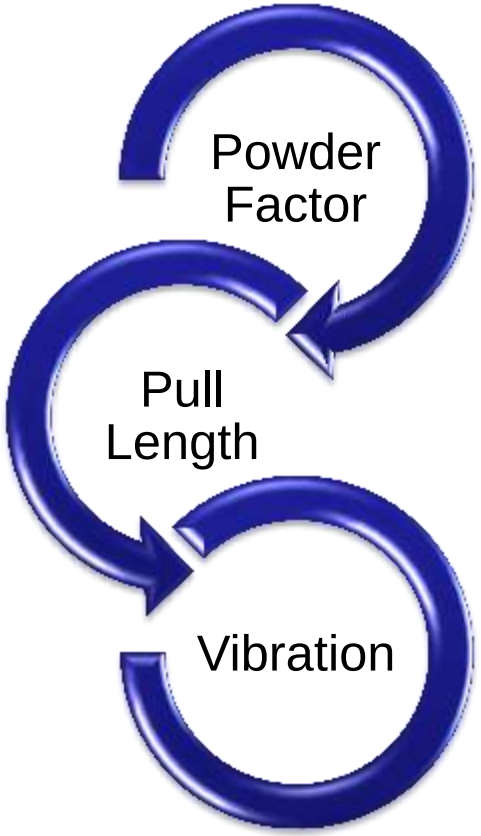
- It is no doubt and reasonable to select both Powder Factor and Pull Length for optimization due to the cost-production effectiveness on underground tunnel blasting

Relationship between Powder Factor, Pull Length and Vibration

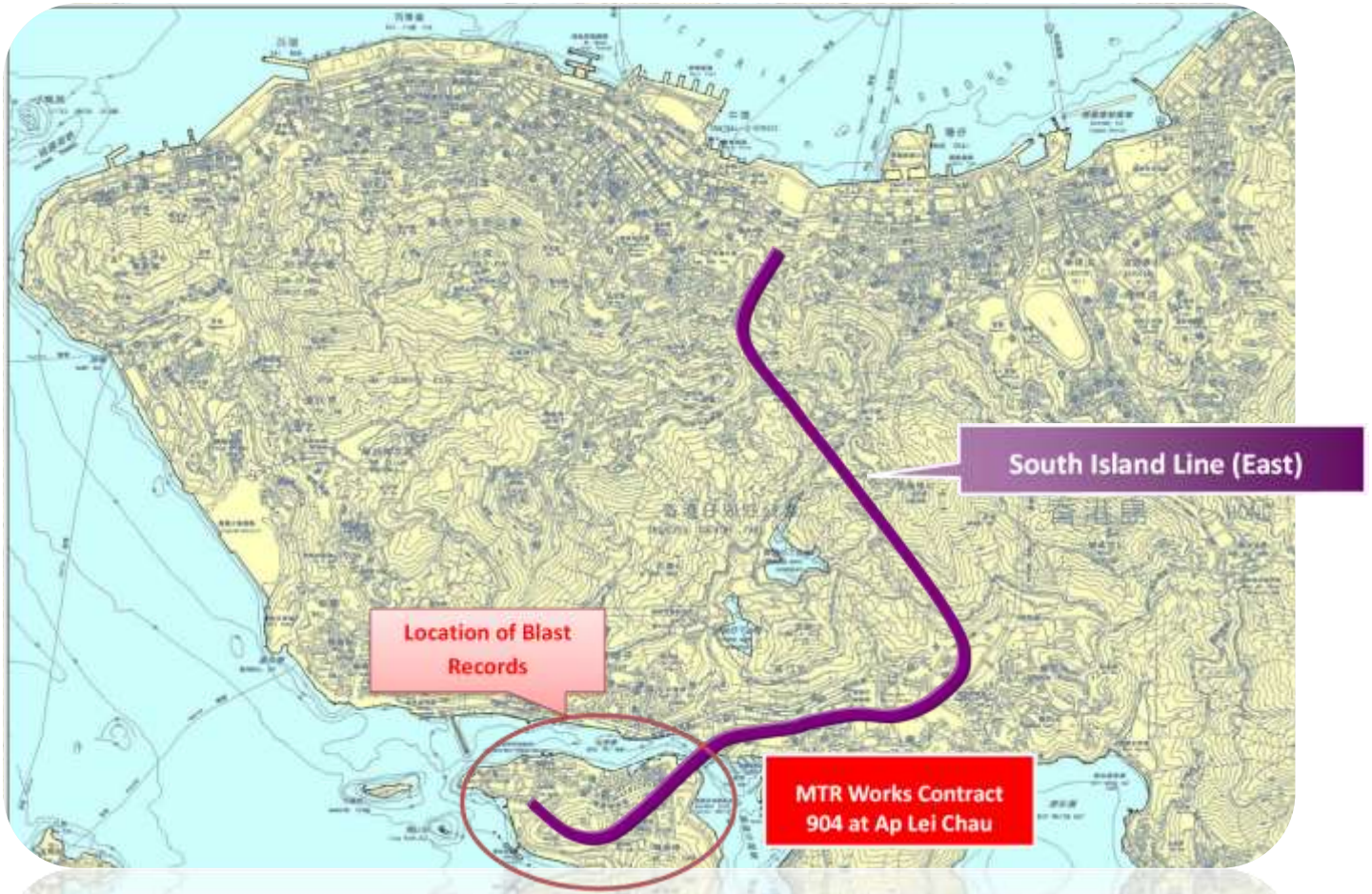
Two stages on the Optimization:

- Stage 1 – To optimize the Powder Factor with the allowable vibration prediction limit of 25mm/s

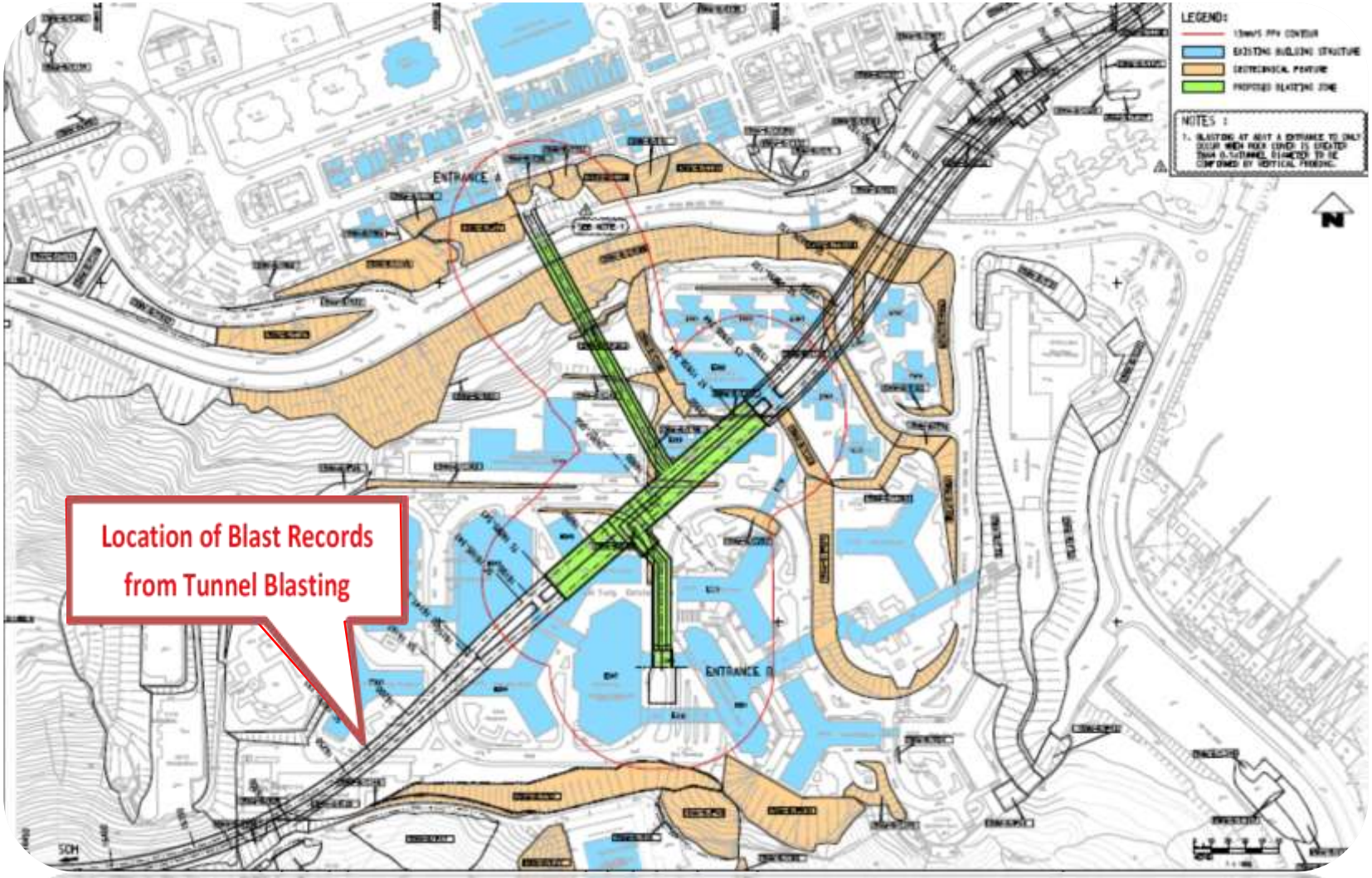
- Stage 2 – To optimize both Powder Factor and Pull Length with the allowable vibration prediction limit of 25mm/s



Data Collection – MTR SIL(E)



Contract 904 – Ap Lei Chau Tunnel



Thank You

Network Training

The Early-stop Validation Approach Stops the Back Propagation Training