

COMPARISON OF THE GENETIC ALGORITHM AND LINEAR PROGRAMMING APPROACHES TO OPTIMALLY LOCATE OREPASSES IN THE VENETIA UNDERGROUND PROJECT

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DECLARATION

I declare that this research report is my own, unaided work. Where use has been made of the work of others, it has been duly acknowledged. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before in any form for any degree or examination in any other University.

Signed:

Gangatha DABULA

On this _____ day of _____ 2019

ABSTRACT

In the process of optimisation and the need to get the best value from a mining operation, reducing hauling costs is a key requirement. The positioning of orepasses at Venetia Mine, which uses a sub-level caving underground mining method, will be of great importance. This will impact on the tramming distances that Load Haul Dumpers (LHDs) will have to travel from drawpoints to orepasses. This will also impact on the hauling distances for trucks from underneath the orepass to the underground crushers.

In the case of Venetia Mine, tramming is planned to require diesel, tyres and other consumables. This also uses up the operational hours of machinery during its commissioned life. This study aims at analysing the current positioning of orepasses in the Venetia Underground Mine design. The current position of orepasses at Venetia Mine is decided based on experience and geotechnical constraints. This study compares this positioning to positions optimised using a linear programming approach and the genetic algorithm approach. Other optimisation techniques were available but, these two were considered because these are the best-suited optimisation techniques for solving the orepass location problem and some research on optimal facility location has been previously done using these techniques.

A Microsoft Excel model was produced to calculate the equivalent cost per tonne metre for each orepass using the total tramming distance from the loading point to the orepass. This model was also able to determine the ideal orepass for each loading point by selecting the orepass with the shortest loading distance.

The Microsoft Excel model had been developed in house at De Beers to test whether the orepasses had been positioned in the correct positions in the design and to also determine what the total tonnage from each orepass was during the life of mine. This excel model was then optimised using Palisade Evolver ® software.

The OptQuest ® tool was used to solve the linear programming solution as one of the model constraints was not a linear function. The constraint in question is that the orepasses are not to be closer than 40m from the orebody based on geotechnical recommendations.

The optimisation results showed that the genetic algorithm optimisation resulted in a 12% improvement in the total tonne metre cost for the orepasses on the K01 orebody. The linear programming solution resulted in an improvement of 10.5% on the total cost per tonne metre in the model from a base value of R 20 941 per tonne metre.

The results indicated that optimisation could bring about an improvement in operating cost. However, there needs to be future work done to consider geotechnical and geological constraints which will be encountered in a real-world mine design scenario.

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DEDICATION

This work is dedicated to my late grandmother Ndlane and my late father in law Ndlovu. Gone but not forgotten. I also dedicate this work to my wife Sinaso Dabula.

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1. INTRODUCTION

1.1. Background of the research

In the mining process the first step is to identify an orebody that can be economically extracted. The next step is to determine the mining method that will be used to mine out that orebody and the associated design. The following step would be to schedule and cost that design and then gain approval from stakeholders to either fund the project or decide against investing. A planner needs to use as many tools available as possible to ensure that he or she recommends the best plan (Herselman, 2016).

It is important that optimisation techniques are used during the planning process to ensure that the best decisions are made during the planning phase. Optimisation in mine planning has developed from operations research (OR) techniques and its growth has relied heavily on the computing power available at the time (Musingwini, 2016).

During the design phase, in massive orebodies that use multi-level mining methods (e.g. sub-level caving (SLC)), consideration is taken on the design of orepasses in isolation. However, not much thought is put into where exactly orepasses should be located to maximise production and minimise costs (Herselman, 2016). Usually orepasses are placed considering mostly the geotechnical and ventilation constraints associated with locating the orepasses. The costs of hauling to the orepasses and productivity from the orepasses are sometimes neglected or determined through trial and error.

Usually incorrect decisions that have been made during the design phase may have an impact on allowing an operation to maintain steady state production and planned plant feed later in the life of the operation. This may also affect the planned operational expenditure and stay-in-business (SIB) capital that has been planned. The main consideration for orepasses and crushers is usually the geotechnical requirements to ensure that the excavation can be used for the required time during the life of mine. Although these criteria are usually met, consideration should also be given on whether these excavations are located in the correct position as the location of these has implications on costs and safety.

To save time and to more efficiently do this work it is necessary to investigate whether an optimisation can be performed. The optimisation should efficiently determine the optimal location for a planner to locate a life of mine excavation like an orepass or crusher based on the planned life of mine production from that orebody.

It was decided to conduct a study to determine the optimal position of orepasses at Venetia Mine, a diamond mine that is operated by the De Beers Group of Companies (DBCM). The Venetia Underground Project (VUP) is planned to produce 6 million tonnes of run-of-mine (ROM) production at peak production using the SLC mining method. Currently the mine is producing diamonds from its open-pit operations and the underground operations are planned to start sending kimberlite to the plant in 2022.

1.2. Venetia Mine Overview

This section discusses the general situation of the Venetia Underground Project. The locality is also briefly discussed, as well as the geology in the area and the selected mining method.

1.2.1. *Locality*

Venetia Mine is in the Limpopo province in South Africa, approximately 450 km north of Johannesburg and 80 km west of the town of Musina. The mine is owned and operated by De Beers Consolidated Mines. The Venetia Kimberlite Cluster (VKC) was discovered in 1980 and comprises of 15 diamondiferous kimberlite bodies, ranging from 0.1 ha to 12.5 ha in size (Herselman, 2016).

The orebody is currently being exploited utilising the open-pit mining method. The mine was constructed in 1990 and consists of a treatment plant, surface workshops and other infrastructure typical of a large open-pit mine. Since the beginning of operations in 1992, only the two largest kimberlites K01 (12.5 ha) and K02 (6 ha) have been mined (Herselman, 2016). Figure 1.1 illustrates the positions of the K01 and K02 kimberlite pipes that are currently being mined through the open pit operations and their vicinity to major mine infrastructure.

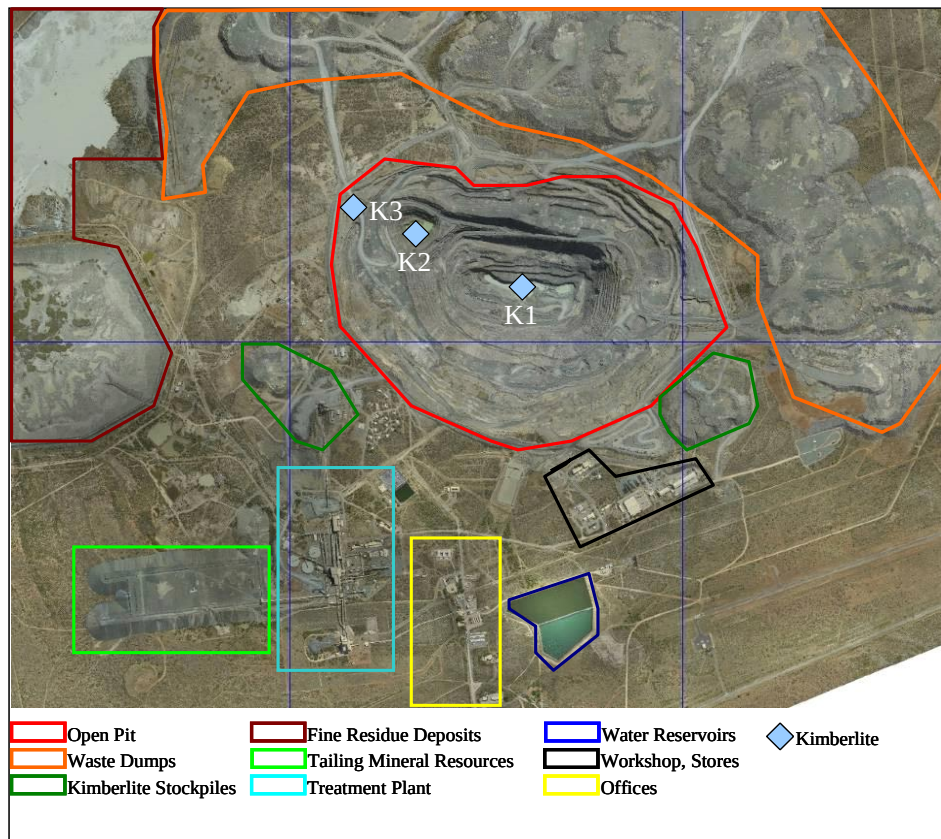


Figure 1.1 Venetia Mine aerial view (Source:De Beers Consolidated Mines, 2015)

Limpopo's main road artery is the N1 highway, linking Gauteng with Zimbabwe. Another main provincial road is the N11 between Mokopane and Lephalale.

1.2.2. Geology

The cluster of kimberlite pipes referred to in Section 1.2.1, comprising 15 known bodies (13 pipes and two dykes), outcrops over an area of approximately 4km² and is in the central zone of the Neo-Archaean – Proterozoic Limpopo Mobile Belt (approximately 3.3 to 2.0Ga old) (Tait, 2007). This cluster is hosted within the country rock comprising amphibolites, biotite gneiss, quartzite and quartzofeldspathic gneisses and metasedimentary package comprised of marbles, limestones, metapelites and calc-silicate rocks. Crosscutting these rocks are pegmatite and dolerite dykes and sills.

K01 and K02 are the largest kimberlite pipes in the VKC, followed by K03. These are the kimberlite pipes currently being exploited through open-pit operations.

In addition to the above kimberlite pipes, Venetia mine has other secondary resources. These are the Red Area Tailings, Blue Area Tailings and the Mix 03 stockpile. The mine has enough surface rights to enable the deposition of the fine residues, tailing Mineral Resources and waste rock for both the open-pit and the underground operation.

This study analysed production from the K01 Kimberlite pipe through the location of orepasses. According to Sivertsen, *et al* (2010), the K01 kimberlite pipe covers approximately 12.5 ha on surface and is the largest pipe in the VKC. The pipe has an irregular, asymmetrical geometry, elongated along its east-west axis, with a distinct NNE – SSW-trending elongation on the eastern pipe edge. The pipe is steep-sided with walls dipping at more than 80° and an irregular bulge identified protruding to the north, at depth, in the north-west corner of the pipe. Pipe contacts vary from sharp to intensely brecciated and have been modelled to 1000m below surface (Sivertsen, *et al.*, 2010). Figure 1.2 below shows a northern view of the K01 orebody and indicates the facies within the orebody.

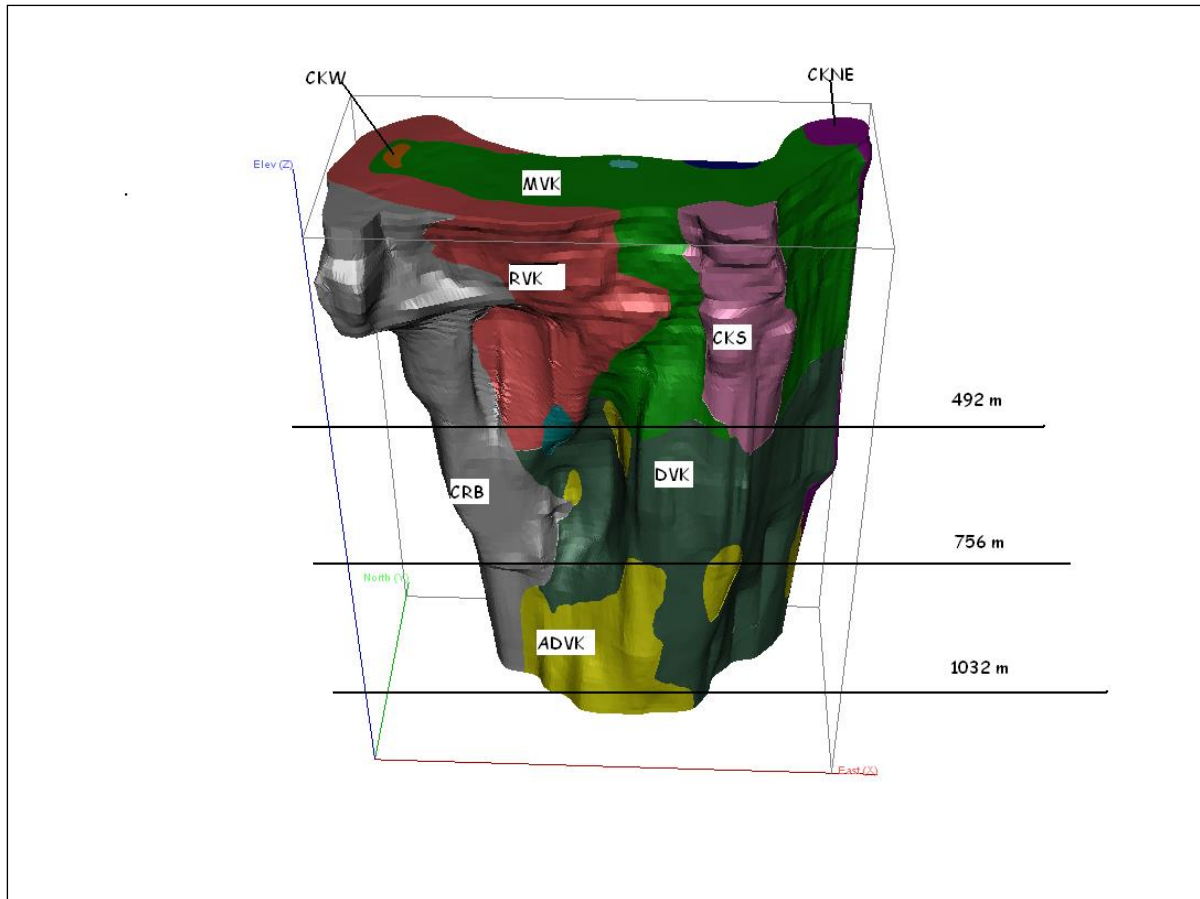


Figure 1.2 Northern view of K01 (Source: De Beers Consolidated Mines, 2015)

1.2.3. Mining method selection considerations

This research focussed on the positioning of orepasses around the K01 orebody for two main reasons. Firstly, K01 generates the most revenue compared to all other orebodies on the mine and most of the loading. Secondly, hauling is planned to be done in the K01 orebody. The following considerations were noted in selecting the mining method for K01. The SLC method works best with the rock properties encountered in K01. Other mining methods may work but, there will be a compromise in cost, productivity, recovery or safety.

It is important to remember that the mining method determines what will be done, the mining methodology determines how it will be done and the access and infrastructure required to enable it. Thus, the mining method is selected first. The execution of the method is then determined in a second step (which is typically a trade-off between conventional and mechanised mining amongst others). Lastly, the best means of access and the infrastructure required are determined, based on schedule, cost, tonnage and logistics requirements (Sivertsen, *et al.*, 2010).

To select a mining method, the following data is required (Sivertsen, *et al.*, 2010):

- Orebody rock mass competency and geometry:
 - Uniaxial Compressive Strength (UCS), fracture frequency, joint condition, weathering characteristics and any significant geological structures;
 - Width, height, dip and strike, size, contacts (regular vs. irregular).
- Country rock strength:
 - Function of UCS, fracture frequency, joint condition, weathering characteristics and any significant geological structures.
- Grade distribution and value;
- Hydrogeology;
- Regional stress magnitude and orientation;
- Environmental concerns: Climate, fauna, flora, local community, etc.

1.2.4. K01 orebody characteristics

K01 is a massive, vertical orebody with competent rock strength (UCS averaging 100 MPa) but geotechnically, contains weak zones erratically distributed on the contacts and within the orebody. The orebody thus, has highly variable contacts even though it is a vertical pipe. The area of vertical continuity from 450 mbgl (metres below ground level) to 1000 mbgl is small with many waste overhang and kimberlite wedge areas.

The country rock has good rock strength but, is foliated with a south to north dip direction. Thus, when undercut, the southern slopes are expected to slide out into the excavation in the centre of the pit and the northern slopes are expected to topple into it. The western and eastern sides should remain reasonably stable. It is difficult to predict how the foliation will behave. Therefore, determining the pit break back and rate of failure is thus, a challenge. In addition, there are three massive dolerite sills which cut through the country rock but, not through the orebody (Sivertsen, *et al.*, 2010).

The grade varies throughout the orebody with zones of high and low value, but these zones are intermixed and difficult to separate, and the variance in grade between these zones is also low.

The open-pit operation is planned to be mined to 460 mbgl and the orebody is well delineated to 1000 mbgl. The Mineral Resource is indicated to 756 mbgl and inferred

to 1032 mbgl. The indicated Mineral Resource contains about 66.8 million tonnes and an estimated 81.5 million carats. The inferred Mineral Resource contains about 42.2 million tonnes and an estimated 51.9 million carats (De Beers Consolidated Mines, 2015).

There is very little groundwater but, small amounts are associated with some of the regional structural geological features. Of greater concern is the annual rainfall. The area has low average annual rainfall but the rainfall events, when they do occur, tend to have high precipitation rates leading to a risk of flooding if not managed. The average temperature is also high, creating heat stress management challenges (Herselman, 2016). The general regional stress has a principal orientation of NE to SW with a K ratio of 2. The high K ratio with a NE to SW orientation means that the orientation of large underground excavations and mining direction should be noted and designed to account for the stress environment.

The mine is already in operation as an open-pit thus, environmental damage has already been done. The underground operation will have a smaller environmental impact in terms of a visible surface footprint, compared to the open-pit.

1.2.5. Sub-level caving as a mining method for K01

Sub-level caving is applied to competent orebodies which are narrow and inclined with a waste rock hangingwall that will cave. Typically, parallel headings that are close together are developed usually along the short axis of the orebody and then long hole drilled and blasted on retreat to the rim tunnel from which the parallel headings were developed. The production rate is also high due to the relatively simple mining cycle and large tonnage released per blast (Sivertsen, *et al.*, 2010).

The challenge with the method lies in dilution management and resource recovery. Tunnel spacing, extraction sequencing and draw control is vital to ensure an acceptable recovery. The method is also associated with mud rush risks. This risk can occur when the muckpile contains clay rich material and when water ingress (rainfall or groundwater into the cave) occurs (Sivertsen, *et al.*, 2010).

Figure 1.3 shows a typical sub-level caving layout. In this instance, it starts as a sub-level retreat as there is no waste failure but, ore is left broken in front of the drawpoints to mitigate the risk of airblasts and ventilation short circuiting. Only after the waste

from the pit slopes have failed does it become a true SLC since there is material above the drawpoints (Atlas Copco, n.d.).

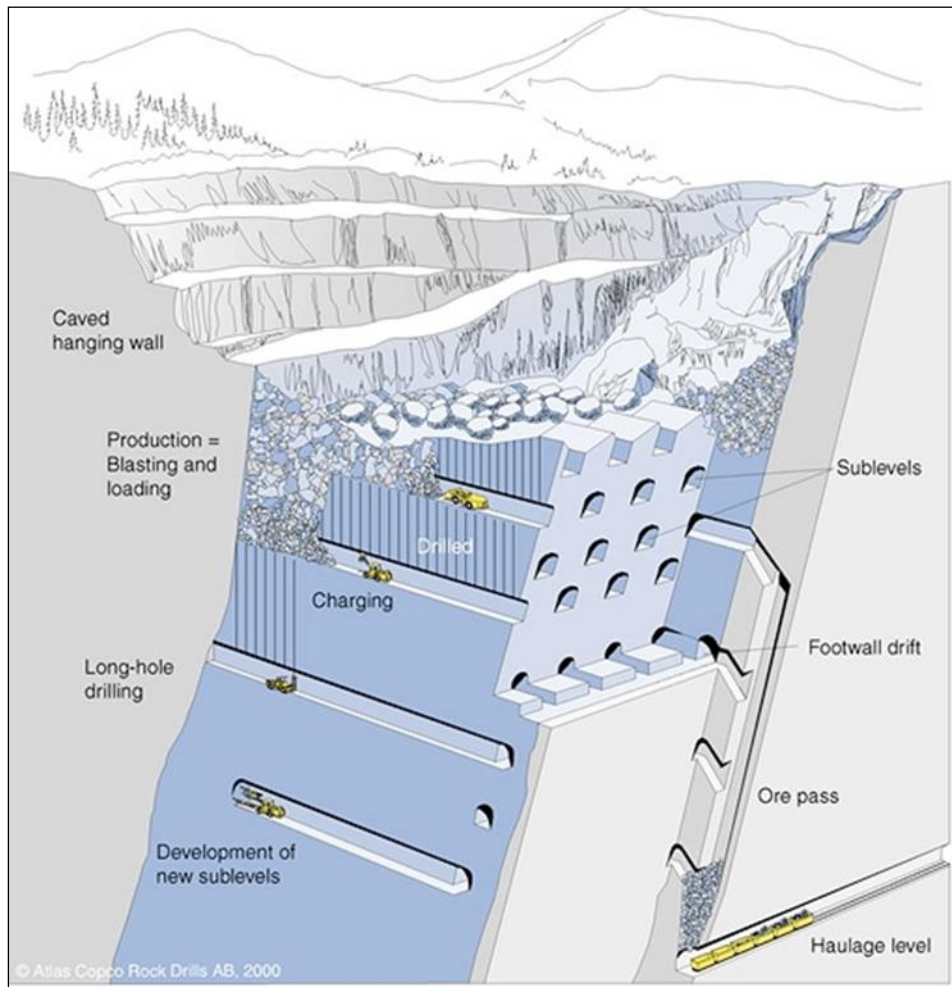


Figure 1.3 Typical sub-level caving layout (Source: Atlas Copco, n.d.)

Since K01 is a vertical orebody it does not fit a typical SLC orebody type. The waste in the K01 scenario is predicted to enter the cave after the pit slopes start to fail as they are undercut by the SLC. The advantage is that there will be no cave back to manage. Ideally the longer the pit takes to fail, the better. Thus, the SLC is predicted to start as an open bench, with very close tunnel spacing, using a strategy very similar to a sub-level retreat. This implies that a muckpile of ore will be left in front of the drawpoints until such time that the pit waste enters the cave (Herselman, 2016). This is done to prevent any airblast or major inrushes of water into the mine.

The K01 rock is also twice as strong as a typical kimberlite which will make long hole drilling easier and allow for the tunnels to be close together. The K01 orebody and surrounding country rock have a low clay content thus, reducing the risk of mudrushes.

In addition, the groundwater is minimal, and rainfall is limited to a few events a year thus, the probability of the orebody retaining water and becoming saturated is low (Sivertsen, *et al.*, 2010).

Sub-level caving is the most appropriate mining method for the K01 resource and most likely to meet all the criteria.

1.3. Problem statement and research question

In mine planning it has been seen that tramming distances influence the costs, efficiencies and safety in a mining operation (Herselman, 2016). Since the position of orepasses at Venetia Mine was determined empirically only considering the geotechnical constraints and safe distances from excavations the main question is: *“can genetic algorithm and linear programming approaches be used to determine the location of orepasses at Venetia Mine to derive a benefit in costs?”* LP and GA were chosen because there has already been work done to solve the facilities location problem using the GA and LP optimisation methods. The literature review in Chapter 2 discusses the research for the location problem in both LP and GA. Section 3.1 explains the research methodology and discusses why the GA and LP optimisation methods were chosen.

The study looked at observing whether orepasses positioned at optimised positions from the orebody loading points would influence the parameters listed below:

1. LHD tramming costs from drawpoints (loading points) to orepass tip;
2. Truck hauling costs from orepass feeder chute to crusher;
3. Cost saving in tramming for LHD and truck loading and hauling.

The results were used to determine whether the initial position of orepasses in a multi-level SLC was cost effective and to determine the magnitude of difference between the above-listed parameters.

1.4. Significance of the research

No analysis has been done on the optimal positioning of orepasses in a multi-level mining environment or a massive mining environment yet loading and hauling of material represents a significant component of the operational costs associated with mining. It is the hope that some of the results of this work can then be used by mine planners and designers as a tool for optimising this part of infrastructure design.

Eventually this could also possibly be refined and considered as a feature that can be incorporated into mine design software.

1.5. Report structure

The first chapter of the report defined the problem statement, posed the research question, provided a background for the research and stated the significance of the research. The report is structured into six chapters. Chapter 2 discusses the literature review and the optimisation techniques that are used to obtain the solution to the problem stated. Chapter 3 then discusses the information required to set up a model to test the problem and looks at the assumptions and inputs into the model developed to test the problem. Chapter 4 then looks at the results of optimisation and the results and solutions from optimisation are also discussed with a focus on observing the implications to the obtained results to the question posed. Chapter 5 discusses the results from Chapter 4 and draws conclusions with recommendations being made for future research work.

1.6. Chapter summary

In this chapter the locality and geology of Venetia Underground Mine was discussed. The problem statement was also introduced, and the scope of the project was stated. The following chapter will focus on a review of the literature that discusses best practice for orepass location.

2. LITERATURE REVIEW

2.1. Introduction

It has been noted that there is an absence of a strategy when it comes to orepass planning, design and management (Hadjigeorgiou & Stacey, 2013). This means that it is difficult to find literature that deals specifically with the positioning of orepasses. This could be mainly because a study has not been done on the cost impact of poorly positioned orepasses (Hadjigeorgiou & Stacey, 2013). It has been observed that orepass geotechnical failures and orepass losses can be attributed to a lack of geotechnical information in the planning and design phase before constructing an orepass (Hadjigeorgiou & Stacey, 2013). A similar principle can be applied to the location of crushers.

In an SLC operation, the loading and haulage cost can be around 35-40% of the overall variable mining cost (Quinteiro, *et al.*, 2001). The loading process can be defined as consisting of four parts, namely (Shekhar, *et al.*, 2016):

- Loading criteria;
- Transportation;
- Loading issues;
- Machinery.

Ore pass construction is a capital-intensive process but, increases in haulage distance are often equally cost intensive and energy intensive. The impact of these costs over the life of mine should be considered (Nilsson, 1982).

The SLC mining method was considered as this was the mining method that was most likely to have production happening on multiple levels. Open stoping and other massive mining methods were considered. The scope of the literature review was limited to all mining methods that involve the use of an orepass, and tramming from a loading point with Load Haul Dumpers (LHDs) and tipping into an orepass.

2.2. Previous studies on orepasses

Most existing literature refers to large orepass systems that are located near the shaft complex. This is done to allow for easy transfer of rock from the silos to the skips as shown in Figure 2.1.

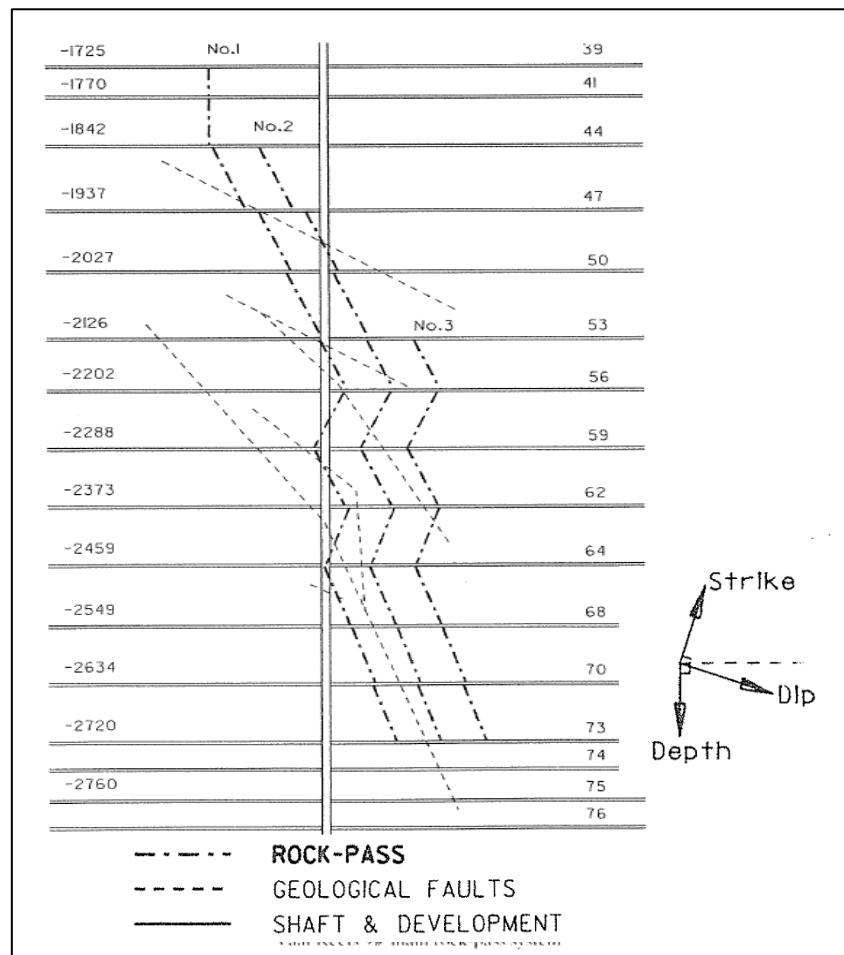


Figure 2.1 Typical orepass layout next to vertical shaft (Source: Tarr & Cook, 1995)

Most literature has not shown a focus on the actual positioning of orepasses with a focus on maximising ore throughput or minimising tramming distances and costs. The literature is extensive if one is focussing on designing and constructing an orepass and chute arrangement that will ensure the most efficient flow of rock between levels and minimise the occurrence of blockages. For the purposes of this study it was assumed that all orepasses are designed to minimise blockages and allow the efficient flow of ore from their chutes in line with best practice (Tarr & Cook, 1995).

2.3. Planned SLC mines

There are quite a few SLC mines planned for production all over the world. Many of these mines are expected to produce more than 1 million tonnes per annum of run-of-mine material, with the De Beers Venetia underground project expected to produce around 6 million tonnes per annum (including 4 million tonnes per annum from K01). Trojan Nickel Mine in Zimbabwe was expected to produce from 2016 (SRK Consulting, 2013). Zeta Mine in Botswana is planning to produce 1.3 million tonnes of run-of-mine copper ore per annum at a grade of 1.2% copper (Discovery Metals Limited, 2014). Table 2.1 shows some of the SLC mines that are planned in the future.

Table 2.1 Proposed sub-level caves to be constructed worldwide (Source: Shekhar, et al., 2016)

Mine	Company	Location	Layout	Deposit	Status
Syama	Resolute Mining Limited	South of Mali, West Africa	To be planned	Gold	Future
Tingyang	Los Quenuales S. A	Western range of Andes, Peru	Longitudinal and Transverse	Zinc	Future
Trojan	Bindura Nickel Corporation	Bindura, Mashonaland, Zimbabwe	To be planned	Nickel	Future
Zeta	Mining Plus Pty Limited	Botswana	Transverse	Copper	Future

Venetia Underground is excluded from Table 2.1 but, is expected to produce around 6 million tonnes per year at full production (Breed, 2016). The construction of the Venetia Underground project has been underway since 2013 (Breed, 2016). It should be noted that poor drilling, blasting, mine design and other mining constraints

contribute to poor ore recovery in SLC mines compared to other mining methods (Hustrulid & Kvapil, 2008). In this research it is assumed that good drilling and blasting practices are followed and thus, the planned production schedule is achieved.

2.4. Current practice

Currently the positions of orepasses in a multi-level SLC operation are generally determined using empirical methods and rules of thumb when it comes to mine design (Herselman, 2016). This involves determining what the geotechnical parameters are i.e. distance from reef contact and minimum distance of orepass from nearby excavations. The general rule of thumb for the safe distance between excavations is taken as 1.5, 2 or 3 times the width of the largest excavation (Vergne, 2003). Another method is to also take the widest length of the orebody to be mined and space out the orepasses evenly along the length of the orebody, as illustrated in Figure 2.2. This method poses a problem if the orebody is irregular and ore extraction differs based on the thickness of the orebody along its length, as is the case at Venetia Mine.

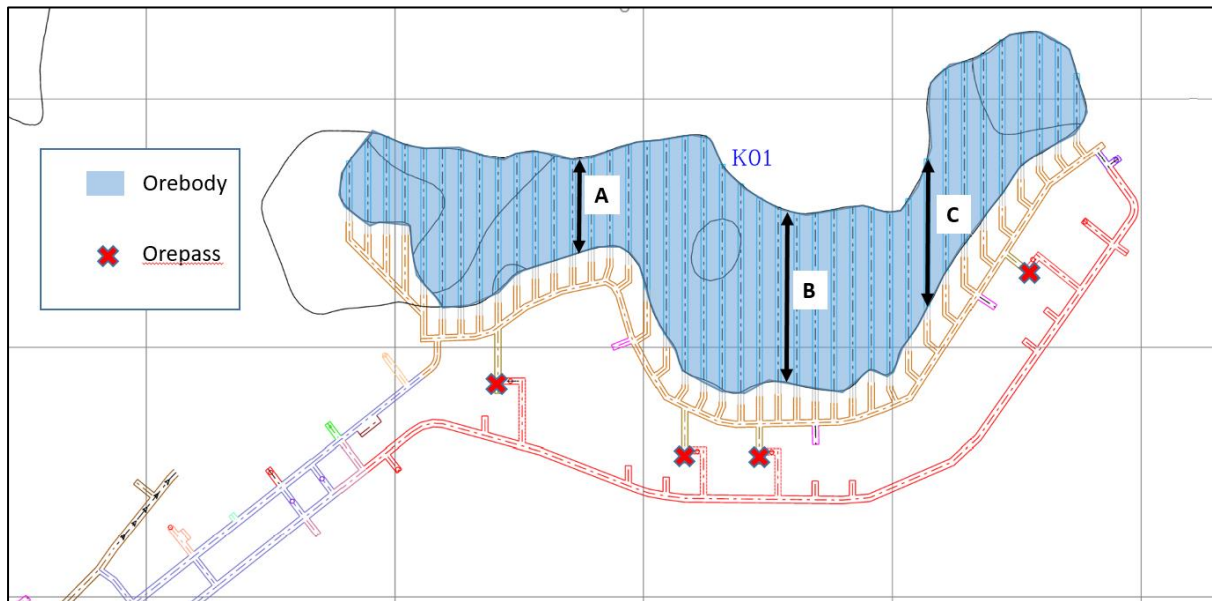


Figure 2.2 Layout of Venetia K01 orebody (Source: Breed & Dabula, 2015)

As seen in Figure 2.2, all orepasses are located to the south of the orebody and the orebody has a varying thickness, with area B being the thickest part of the orebody and areas A and C having shorter tunnels. There is a possibility that the orepasses could be grouped closer to area B since most ore tramming would be done from this area. This consideration requires optimisation techniques with a focus on the location

problem which is then used to determine the ideal location of these orepasses to minimise LHD tramming distances, truck hauling distances and cost.

2.5. Linear programming

Linear programming (LP) can be used to find the optimal location based on an objective function (Jensen, 2014). Jensen studied the use of linear programming to determine the optimal location of fire stations such that they could be located to cover the largest area, given a set of constraints. This can also be applied to a production section where an orepass could be positioned to collect the most ore from that production section. The assumption that was made was that there were unlimited resources to construct each fire station and the fire stations would be able to handle every call within its coverage area (Jensen, 2014). Similarly, these assumptions can also be applied in a mining environment and this type of formulation can be useful at a strategic level (Li, et al., 2011).

The following mathematical formulation was used for the model (Jensen, 2014). Variables from the formulation are defined below as follows:

$$V = (I, J)$$

$$I = \{1, 2, 3 \dots n\}$$

$$J = \{1, 2, 3 \dots n\}$$

$$X_j = \begin{cases} 0 & \text{if no facility is established at a point } j \\ 1 & \text{if a facility is established at point } j \end{cases} \text{ where } j \in J$$

where I is the set of demand nodes;

where J is the set of supply nodes;

S = maximum response time;

N_i = Set of potential facility locations j , within s time.

Objective function to be minimized is as follows:

$$1) \text{ Minimise } Z = \sum_{j=1}^n X_j$$

The variable X_j is such that subject to:

$$2) \sum_{j \in N_i} X_j \geq 1, \quad i \in I$$

$$3) X_j = (0,1), \quad j \in J$$

$$4) N_i = \{j | d_{ij} \leq s\}$$

where d_{ij} is the distance from node i to node j .

In 1) the objective function was formulated to minimise the amount of X_j which refers to the amount of open facilities within possible site locations ranging from 1 to n (Jensen, 2014). The objective function is subject to two constraints 2) and 3). 2) states that the sum of open facilities will be more than or equal to 1, so it is required that any demand point, i , must be served by at least one station (Jensen, 2014). 3) is a binary constraint, making sure that each X_j is either closed, 0, or open, 1 (Jensen, 2014). Toregas, *et al.*, (1971) had formulated the model such that it determined the sets of N_i within the minimum time requirement, s , and grouping those using the formulation below, as stated in 4) above:

$$N_i = \{j | d_{ij} \leq s\}$$

As stated earlier, this tool is useful for the determination of stations at a strategic level. However, one must be fully aware of the limitations that the assumptions place on the model i.e. each station can handle every call within its range and there is unlimited access to the funds required to place each station (Jensen, 2014). This optimisation model could be used to determine the best location for orepasses that need to serve multiple production sections on many levels at Venetia Underground mine.

2.6. Genetic algorithm

The genetic algorithm (GA) technique was developed in 1975 by Holland (Ali, 2015). It works by embracing the biological theories of natural selection and the principle of “survival of the fittest”. This technique has seen applications in (Ali, 2015):

- Scheduling;
- Routing;
- Adaptive control;
- Game playing;
- Cognitive modelling;
- Transportation problems;
- Travelling salesman problems;
- Other problems involving optimisation in general.

The steps used to apply the GA technique are as follows (Ali, 2015):

1. Generate an initial population G of size N ;
2. Generate offspring:
 - Selection: Selecting $m \leq S$ strings as parents, with the probability of each string being selected proportional to its fitness;
 - Crossover: the parents are paired and generate m offspring, which replace the m least fit strings;
 - Mutation: each string has a probability β of being mutated.
3. Repeat Step 2 until the function values of the points $(f(x_i), i=1,2,3,\dots, N)$ are close to each other and the standard deviation is very small.

Figure 2.3 provides a graphical representation of the process followed when applying the genetic algorithm technique.

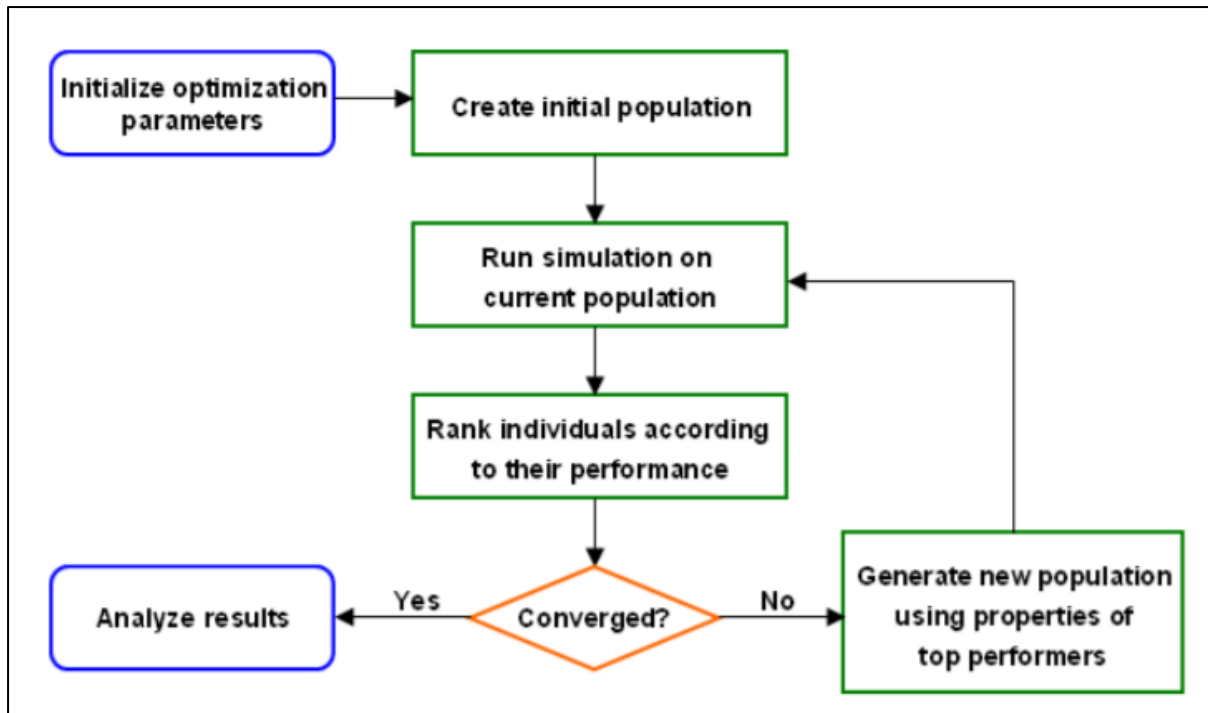


Figure 2.3 Optimisation procedure for GA's (Source: Abukhamzin, 2009)

The GA technique was used to determine the optimum well locations in a real oil field and Bittencourt & Horne (1997) reported a project profit improvement of about 6%. In their paper Bittencourt & Horne (1997) optimised the proposed position of 33 new oil wells in a real oil field using an adapted GA. Their findings represented a saving of about US\$70 million (Abukhamzin, 2009).

GA's have been used in production scheduling and production blending from different mining locations in a central processing facility to maximise net present value (NPV) (Musingwini, 2016). As such this method can also be used to determine the optimal location for orepasses in an SLC mining operation for the Venetia Underground Project.

2.7. Chapter summary

In this chapter the literature related to linear programming and genetic algorithm were discussed. It was noted that there is not much literature available that deals with the optimisation of the location of orepasses and as a result the location problem has been used as a proxy to solve the problem of optimal orepass location. In the next chapter the research methodology used to obtain data will be discussed.

3. RESEARCH METHODOLOGY

3.1. Introduction

The study first established a multi-level orepass design that is planned to be executed. Since the author had access to the Venetia Underground Project, the latest approved design and production schedules were used as source data to test the parameters discussed in the previous chapter. There are other optimisation techniques available but, the study focussed on only LP and GA optimisation due to the relevance of application of these techniques. These other optimisation techniques are namely:

- Heuristic approaches;
- Dynamic programming;
- Particle swarm optimisation;
- Simulated annealing.

These optimisation techniques were seen to not be appropriate as they are usually used in other mine planning applications because of the reasons discussed in Sections 3.1.1 to 3.1.4.

3.1.1. *Heuristic methods*

The heuristic method sacrifices optimality to save in time compared to classical optimisation techniques (Ali, 2015). The heuristic methods were thus not suitable for application in this study because the optimal solution might not be completely reached.

3.1.2. *Dynamic programming*

Dynamic programming is a multi-stage optimisation technique. Each stage has a certain state and each state describes the outcome of each decision (Ali, 2015). This method is possibly not suitable because a fixed production schedule is used and the orepasses are in the same place for that schedule run. There are not any decision points leading up to the solution for the orepasses. The problem is to minimise the total cost of the eight orepasses on K01.

3.1.3. *Particle swarm optimisation*

Particle swarm optimisation (PSO) uses many agents interacting locally with one another to collectively behave and interact to determine the solution of the collective

(Ali, 2015). This optimisation technique will possibly not be suitable because these agents would need to be a set distance from each other (geotechnical constraint of proximity of orepasses) and many agents is required to determine a global minimum or maximum.

The swarm optimisation would run until there is a global optimal position or state for all particles in the system (Musingwini, 2016), this process is repeated until the stopping criteria is met, which would be the minimum cost per tonne metre. When the optimisation begins, the minimum tonne metre for the optimal orepass layout is unknown. Therefore, it would be impossible to determine the stopping criteria for the PSO problem without first running the optimisation. This method was not considered as the optimisation would need an unknown stopping criterion (minimum tonne metre cost).

This technique could be used to determine the optimal location of the eight orepasses on K01 but, this follows a similar methodology to the GA. The GA would be more effective because offspring are generated, and each successive generation produces a better solution compared to the previous generation.

3.1.4. Simulated annealing

Simulated annealing optimisation uses the analogy of strengthening metals using annealing. This involves heating up the metal to a high temperature and slowly cooling the metal until it cools to a ground state (Ali, 2015). Table 3.1 describes the process of annealing and the simulated equivalent that can be applied in optimisation.

Table 3.1 K01 mining production parameters (Source: Vigeh, 2011)

Physical Annealing	Simulated Annealing Equivalent
Arrangement of particles in a system	Solution to optimisation problem
Changes in the system (i.e. a new configuration of particles)	Neighbouring solution (i.e. making a small change to current solution)
Energy of the system at current configuration	Cost Function of current solution
Temperature of the system	Control Parameter or Annealing schedule

Since there will be a time limit on how many solutions will be run, the GA is also preferred compared to simulated annealing as the literature suggests this (Arostegui, et al., 2006).

The Venetia Underground design as at 2015 was used to test the empirical methodology that was used to determine the current approved orepass positions. Two methods that were then used to optimise the location of the orepasses were:

1. Linear programming method;
2. Genetic algorithm method.

These techniques are applicable as they have been used before to locate facilities (Jensen, 2014) and the optimal position of oil wells (Abukhamsin, 2009). There have not been many studies on using these methods to locate orepasses subject to mining constraints.

Linear programming was used determine the orepass positions that would give the lowest total cost for hauling to the tip and tramming to the crusher considering the geotechnical constraints to the location of orepasses to minimise the objective function tramming distance and cost.

The GA technique was used, where each X and Y coordinate was determined in different iterations until the optimal location for each orepass was determined. The differences in tramming distance and cost were then compared for each of the techniques discussed above. The same data set was used, namely the production schedule and the mine design for production areas, only the position of orepasses changed in each scenario or optimisation run.

The positioning of orepasses is driven by the production required, the location of common infrastructure and geotechnical constraints. For example, an orepass cannot be located within the orebody and two orepasses cannot be located within a certain distance from each other. The assumptions were used to produce a model that shows the material flow through orepasses and the source information for this model is discussed in the next chapter.

3.2. K01 orebody depletion methodology

In an SLC mine, mined tonnes are made up of kimberlite tonnes, which have a grade and value and external waste rock dilution tonnes (Herselman, 2016). A sub-level cave schedule is determined using a combination of input parameters such as (Breed, 2017):

- Percentage extraction per level;
- Face shape;
- Sequence of the rings blasted.

Based on the schedule, the draw rate and using cave management principles the ore mined can be safely and consistently and extracted with predictable carat recovery rates (Breed, 2016). Draw control limits include the use of an economic cut-off grade and a maximum allowable average waste rock dilution percentage constraint for run-of-mine to be treated in the ore processing plant (Breed, 2016).

The process of cave mixing derived from the schedule is depicted in Figure 3.1. As ore is mined from the production rings the caving process feeds the drawpoint with ore from the rings above.

A kimberlite crown buffer has been included in the K01 mine plan to mitigate the risk of early waste rock ingress from pit slope failures (Breed, 2017). As the production rings extract blasted kimberlite ore, the crown buffer will act as a buffer between the failed waste rock from the pit and the blasted kimberlite. This will defer the waste dilution ingress and maintain high ROM grades leading to an improved kimberlite recovery from the production rings (Breed, 2017). The size of the kimberlite crown buffer determines the effectiveness of the buffer at preventing waste ingress into drawpoints. As depicted in Figure 3.1; the waste failure, crown buffer and production rings are mixed and depleted using the caving mining method to determine the ROM ore tonnages and grades.

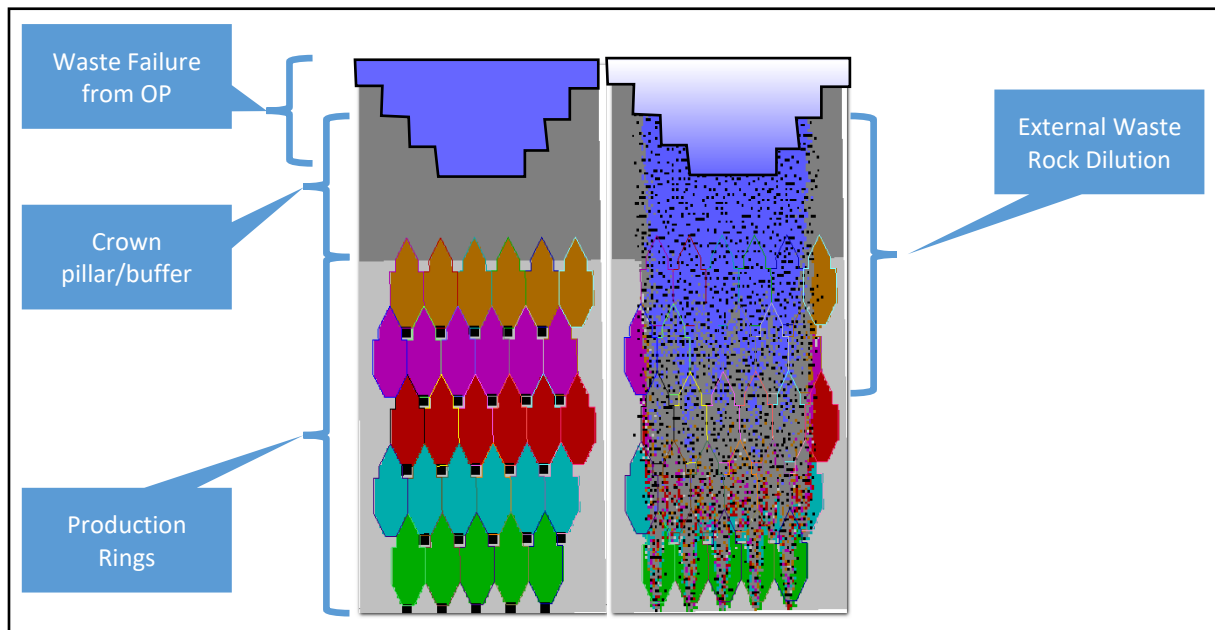


Figure 3.1 Orebody depletion schematic (Source: Breed, 2016)

3.3. K01 production scheduling

To simulate and schedule the production from K01 and maintain draw control and reconciliation, Production Computer Sub-Level Cave (PCSLC) software was used. This software was developed by Gemcom Software Int. and was specifically designed for mine planning of sub-level caving projects and operations. PCSLC has a set of tools that assist in the whole design and planning process and it also uses mixing algorithms that simulate the material flow observed in caving mines using the template mixing (TM) technique (Diering, 2000).

Template mixing is the methodology applied in the mixing model in PCSLC that uses mixing logic applied to a block model with a combination of the positioning of designed rings in order to simulate the grades and recoveries as best as possible in a caving environment (Herselman, 2016). The process that the TM technique follows is described in Figure 3.2 and Figure 3.3.

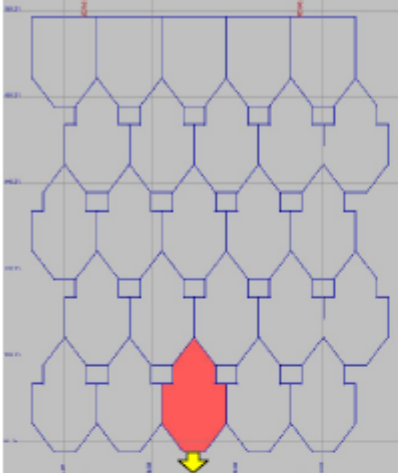
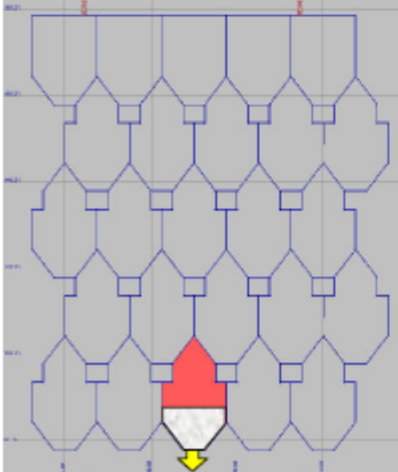
 Step 1 in Template mixing (TM)	a. Material is extracted from one ring (red ring)
 Step 2 in TM	b. The extraction generates a void inside the ring and this void needs to be filled from other material.

Figure 3.2 Steps 1 and 2 in Template Mixing (TM) (Source: Villa Salinas, 2012)

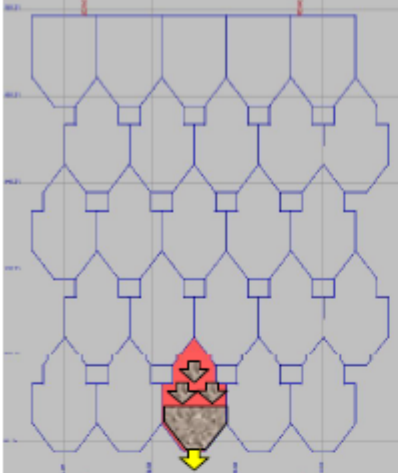
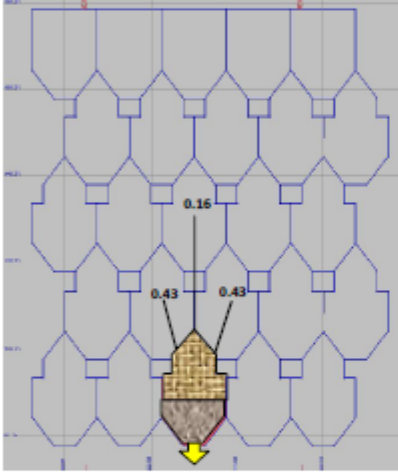
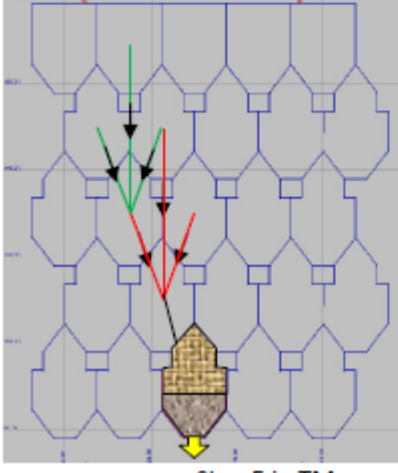
 Step 3 in TM	c. The first option to fill the gap is with material from the same ring.
 Step 4 in TM	d. When material from the same ring is not enough to fill the void, material from rings in the levels above start moving into the gap. The portion of the material moved from one ring to other depends of the links and weight created previously in the neighbor definition. For example in this case 64% of the material can flow from one level above and only 14% can migrate from two levels above to fill the empty space in the lower level.
 Step 5 in TM	e. If material is depleted from one ring it generates a movement in the entire area close to the zone extracted, since there are links created for all rings and then material from upper levels are replenished originating mixing for the whole layout.

Figure 3.3 Step 3 – Step 5 in Template Mixing (TM) (Source: Villa Salinas, 2012)

Once template mixing was done in PCSLC a production schedule was produced. This schedule adhered to the caving rules to ensure that all material is extracted from the cave as safely as possible. The rules were:

- Lead lag between rings is to adhere to the proposed face shape as shown in Figure 3.4;
- The level below a level that is currently being mined should be more than 25m behind the face that is being mined on that level. This is to prevent undermining from the level below.

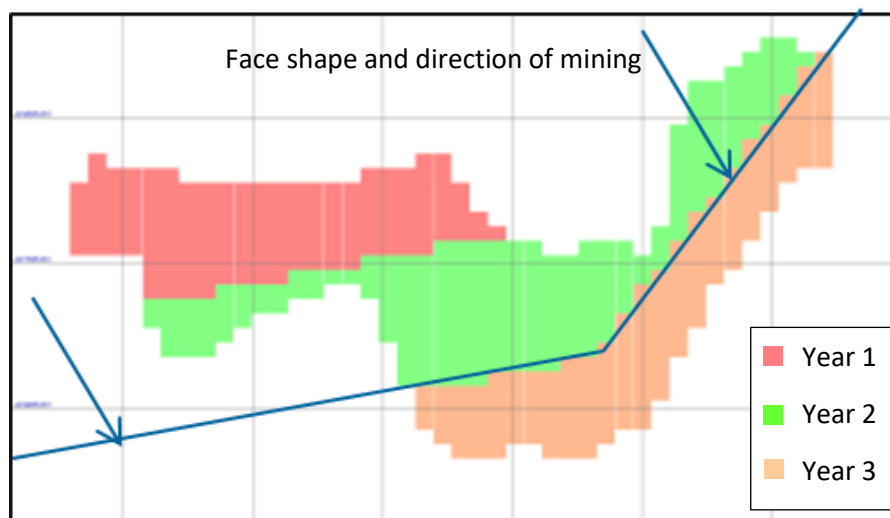


Figure 3.4 Step 3 – K01 mining direction and face shape (Source: Breed, 2016)

In Figure 3.4 the rules are that the opening of rings on a level is meant to follow the face shape. PCSLC ensured that these rules were followed among others so that a realistic production schedule was produced.

The production profile in Figure 3.5 was used as an input for the tonnage required in the model.

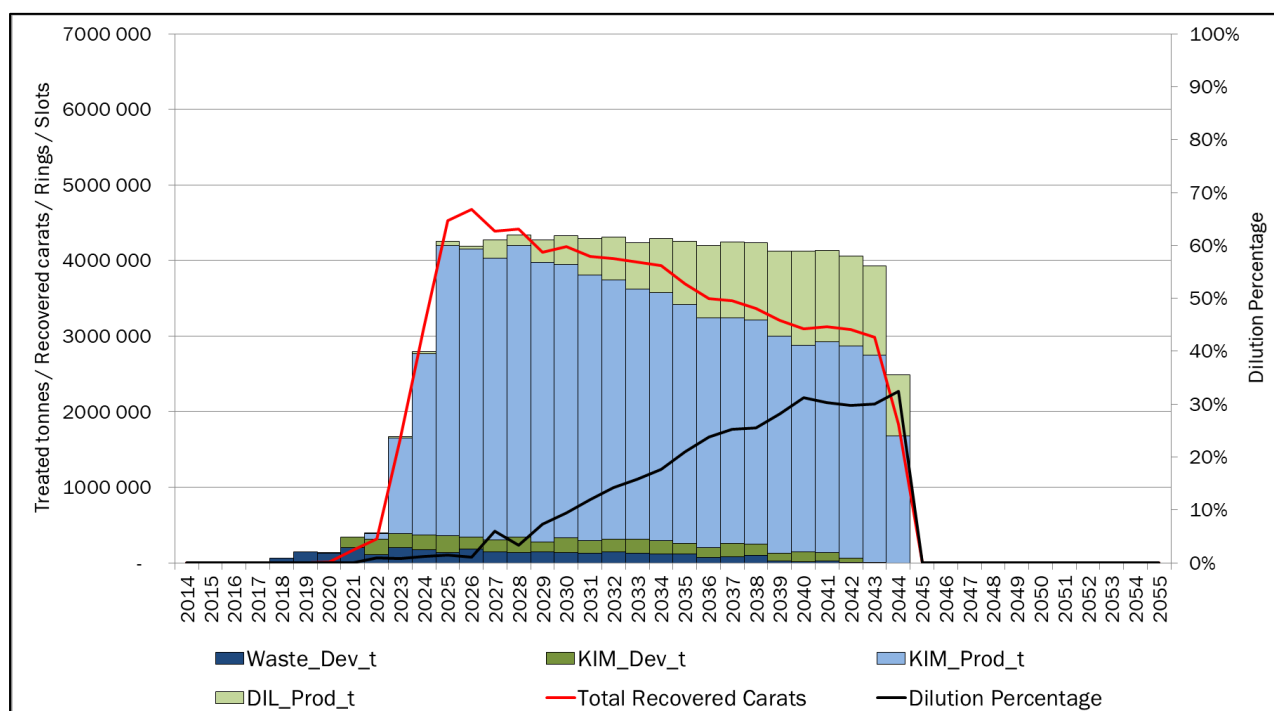


Figure 3.5 K01 annual production profile (Source: Breed, 2016)

The grades in Figure 3.5 were derived from the template mixing model. Table 3.2 indicates the mining parameters used for each of the production levels on K01.

Table 3.2 K01 mining production parameters (Source: Breed & Dabula, 2015)

Area	Description	Unit	Value
Layout	Mining Method		Sub-level Cave
	Production rate	Mt/year	4
	Cave height	m	35 (below pit bottom)
	Cave area	Ave ha	6.7Ha (120m wide x 550m long)
	Tunnel spacing	m	15
	Ave tunnels per level		35 (15 active draw points)
	Level spacing	m	25
	Production levels		17
	Tunnel vertical orientation		Staggered
	Tunnel azimuth	°	0
	Waste tunnels	m(W) x m(H)	5 x 5
	Contact tunnels	m(W) x m(H) x m(L)	4.5 x 4.5 x 10
	Kimberlite tunnels	m(W) x m(H)	4.5 x 4.2

Area	Description	Unit	Value
	Rim tunnel to contact distance	m	22.5 (Skin to skin)
	Footwall construction		Crushed aggregate and dust suppression
Schedule	Waste tunnels	m/month	40
	Contact tunnels	m/month	10
	Kimberlite tunnels	m/month	25
Long Hole	Face shape		Chevron
	Min lead / lag - vertical	°	45.0
	Max lead / lag - adjacent tunnels	Rings m	1 – 4 2.5 - 10
	Operational levels	level	3 - 4
	Slot cut raisebore hole diameter	m	1.1
	Rings per tunnel per month	No.	4
	Ring spacing	m	2.5
	Holes per ring	No.	10
	Hole diameter	mm	102
	Maximum hole length	m	31.81
	Tonnes per ring	t	2237
	Fragmentation		90% < 900mm
	Tonnes per draw point per day	t	500
	Max allowable waste ingress	%	30
	Sink rate per year	m/year	23
Production	Extraction strategy		Maximise initial grade then maximise total carat recovery
	Extraction Percentage: 54L	%	60
	Extraction Percentage: 56L	%	102
	Extraction Percentage: 59L	%	109
	Extraction Percentage: 61L	%	110
	Extraction Percentage: 64L	%	110
	Extraction Percentage: 66L	%	112
	Extraction Percentage: 69L	%	115
	Extraction Percentage: 71L	%	115
	Extraction Percentage: 74L	%	118
	Extraction Percentage: 76L	%	120
	Extraction Percentage: 79L	%	125
	Extraction Percentage: 81L	%	130
	Extraction Percentage: 84L	%	135
	Extraction Percentage: 86L	%	138
	Extraction Percentage: 89L	%	140
	Extraction Percentage: 91L	%	146
	Extraction Percentage: 94L	%	150
General	Blasting system		Centralised blasting at end of shift
	Material handling		Pallets with telehandlers and flatbeds

3.4. K01 infrastructure design

The infrastructure design dictated where the orepasses for K01 were located. This infrastructure was designed in Mine2-4D ®. The design was then scheduled in EPS ® to determine the timing of the development for top and bottom access to these orepasses. For the purposes of this study it was assumed that the design of all orepasses and necessary development was completed, and the focus of the study would be the subsequent location of all orepasses in such a manner that the tramming distance in the truckloop is minimised and the load and haul distance for LHDs on each level is also minimised. Once optimisation was completed and the suitable orepass positions determined, the design was then changed to account for these new positions. The design criteria for infrastructure (Table 3.3) were assigned to K01.

Table 3.3: K01 infrastructure parameters

Description	Value
Production kimberlite development tunnel Dimension	4.2m (H) x 4.5m (W)
Production waste development tunnel dimension	5.0m (H) x 5.0m (W)
Total production levels	17
Total K01 orepasses	8
Total orepass tips per level	4
Truckloop maximum tramming distance	1319m

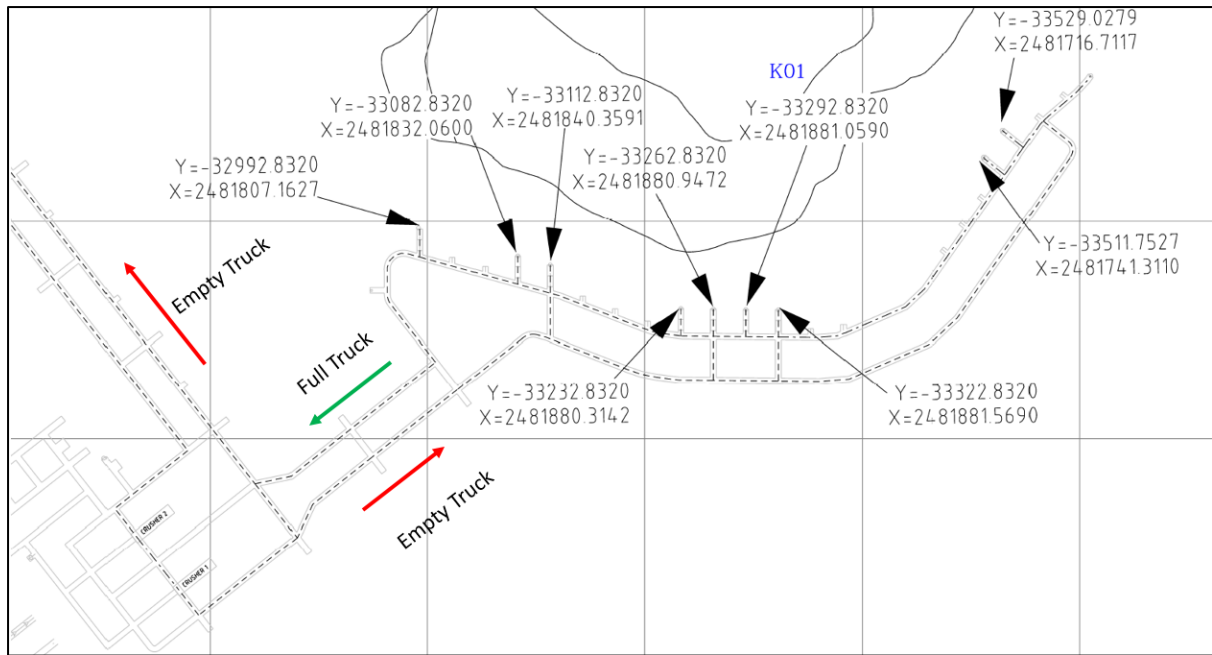


Figure 3.7 K01 infrastructure layout, level not stipulated (Source: De Beers Consolidated Mines, 2015)

Since there are only four tips on each of the levels as shown in Figure 3.8 leading to one of the eight orepasses on each of the 17 levels, K01 will have the same layout where a ring is loaded above the kimberlite production tunnel, then trammed along the rim tunnel to the closest tip.

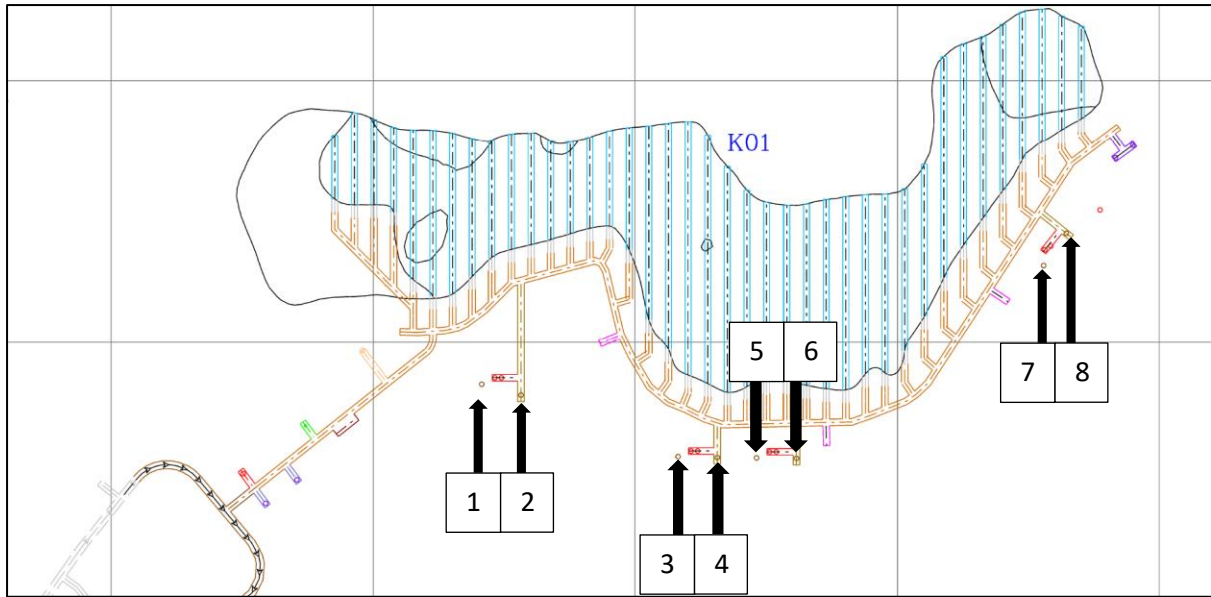


Figure 3.8 K01 level orepass layout, level not stipulated (Source: De Beers Consolidated Mines, 2015)

From Figure 3.8 the even numbered orepasses are connected to one level and the odd numbered orepasses are connected to the next level below. On each of the levels the tramming distance was calculated by taking the dX and dY distance to each of the orepasses from the loading point. The location of the orepasses was then optimised to minimise the tramming distance from the loading point to the tips and the hauling distance from the orepass on the truckloop to the crushers.

3.5. Proposed model for simulating loading and hauling

A model was developed to simulate loading and hauling within the K01 orebody. This model was able to calculate the closest orepass from a particular loading point. Distances from the loading point to the orepass were calculated using Microsoft Excel and the following information was used as inputs into the model:

- The X and Y coordinates of each loading point within the production tunnel;
- The X and Y coordinates of the orepass that the LHD is tipping into;
- The total tonnes to be loaded at each loading point;
- The X and Y coordinates or tramming distances on the truckloop from the orepass to the crusher.

Figure 3.9 illustrates the calculation for dX and dY used to calculate the indicative distance from the loading point to the tip.

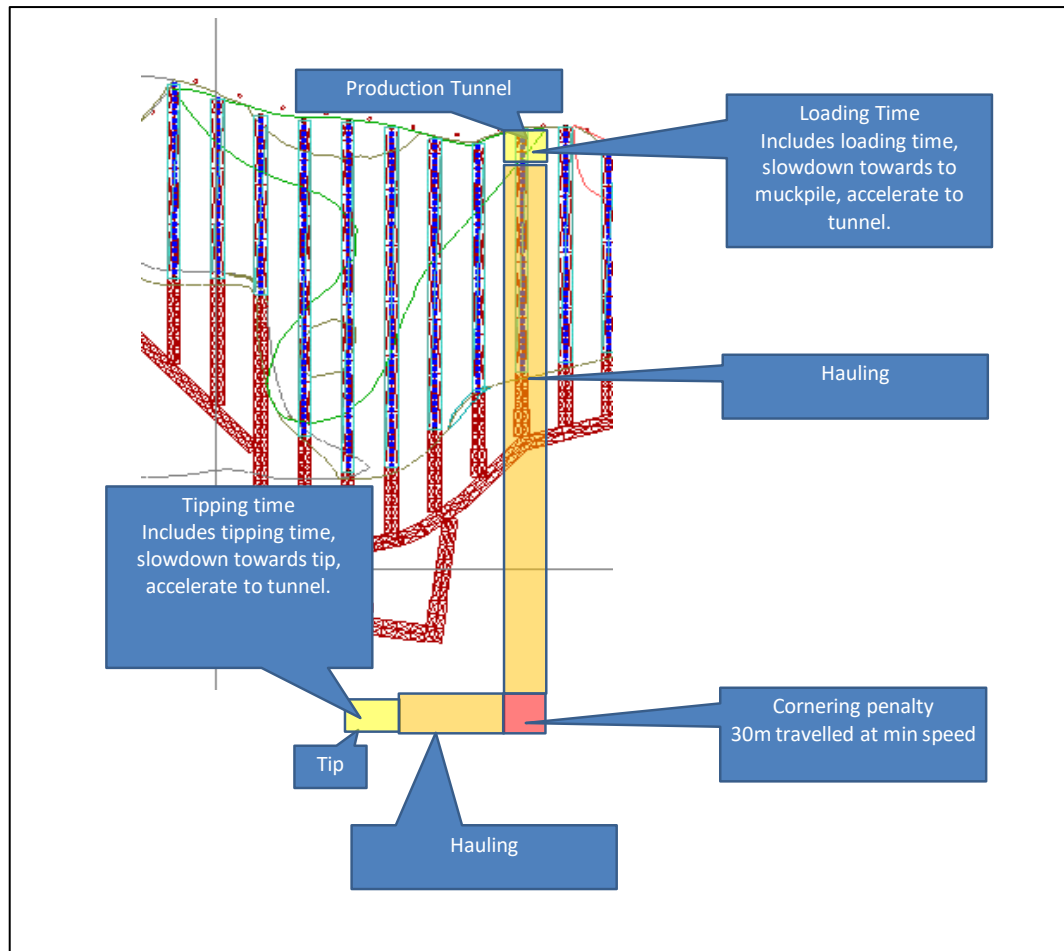


Figure 3.9 Proposed logic in model for loading

In Figure 3.9 the traveling distance was determined by calculating the difference in the distance along the X-axis between the orepass and the loading point. Similarly, the difference in the distance along the Y-axis between the orepass and the loading point was also calculated. From each loading point these differences in distances were then summed up to determine the tramming distance to the orepass.

3.5.1. Model inputs for loading and hauling

The model also determined the hauling costs and loading costs per metre. This was based on average input costs in the Venetia financial model (Smit, 2017). These inputs were then used to determine the metres per hour, the cost per metre and the cost per tonne metre. The tonne metre measure is not the same as the unit measure for torque. This metric was used to determine the cost of loading and hauling for each of the orepasses in the design and the optimisation aimed at minimising tonne metres. In Table 3.4 the model inputs are tabulated and a cost per tonne metre was calculated. Cost per tonne metre was used as the measure to optimise because with each iteration

of the model when optimised the total hauling and tramming distance would change due to the orepass location changing.

Table 3.4: Model inputs for LHD – Sandvik LH514

Parameter	Unit	Value
Loading Bucket Capacity	m ³	7
Relative Density	kg/m ³	2.68
Bulking Factor	%	0.5
Moisture content	%	0
Relative Density After Blast	kg/m ³	1.79
Fill Factor	%	0.9
Full_Speed	km/h	9.2
Empty_speed	km/h	11.0
Efficiency on speed	%	0.85
Applied_speed	km/h	7.82
Loading	h	0.017
Tipping	h	0.008
Cornering penalty per cycle	h	0.0033
Total Fixed Cycle time	h	0.03
Bucket_load	t	11.26
Cost per hours	R/h	651.00
Metres per hours	m/h	7 820.00
Tonne Metres per hour	tm/h	88 021.92
Cost per tonne Metre	R/tm	0.00740

Table 3.4 indicates that the average cost per tonne metre for LHD loading is R0.00740/tonne metre for a Sandvik LH514. Table 3.5 discusses the model inputs for the haul truck in the model.

Table 3.5: Model inputs for haul truck – Sandvik TH550

Parameter	Unit	Value
*Loading Bucket Capacity	m ³	28
*Relative Density	kg/m ³	2.68
*Bulking Factor	%	0.5
*Moisture content	%	0
*Relative Density After Blast	kg/m ³	1.79
*Fill Factor	%	0.92
*Travel Speed full (km/h)	km/h	16
*Travel Speed empty (km/h)	km/h	18
*Efficiency on speed	%	1

Parameter	Unit	Value
Applied speed	km/h	16
Loading	h	0.045
Tipping	h	0.033
Cornering penalty per cycle	h	0.0019
Total Fixed Cycle time	h	0.08
Bucket load	t	46.02
Cost per hour	R/h	290.00
Metres per hours	m/h	16 000.00
TonneMetres per hour	tm/h	736 392.53
Cost per TonneMetre	R/tm	0.00039
LHD to Truck cost ratio		18.78

Table 3.5 indicates that the average cost per tonne metre for LHD loading is R0.00039/tonne metre for a Sandvik TH550 and the LHD to truck cost ratio is 18.87. This is understandable as the truck has a lower cost per hour and it has a bigger load size compared to the LHD and it travels at a faster speed than the LHD. This ratio was used as an input in the model for determining the total tonne metre cost for each orepass. It should also be noted that the metres per hour are calculated from the tramming speed for the truck (16 km per hour). The bucket load for the truck is taken as 46.02 t when loading the Sandvik TH550 at the fill factors and bucket capacities stated in Table 3.5. The LHDs are not tipping directly into the haul trucks so they do not need to be matched

3.5.2. Model structure

The model was structured such that seven worksheets were used to generate the solution. The model allowed for the user to manually input the changes to co-ordinates for the positioning of orepasses. The combination of all these worksheets produced an output that showed the average cost per orepass as shown in Figure 3.10.

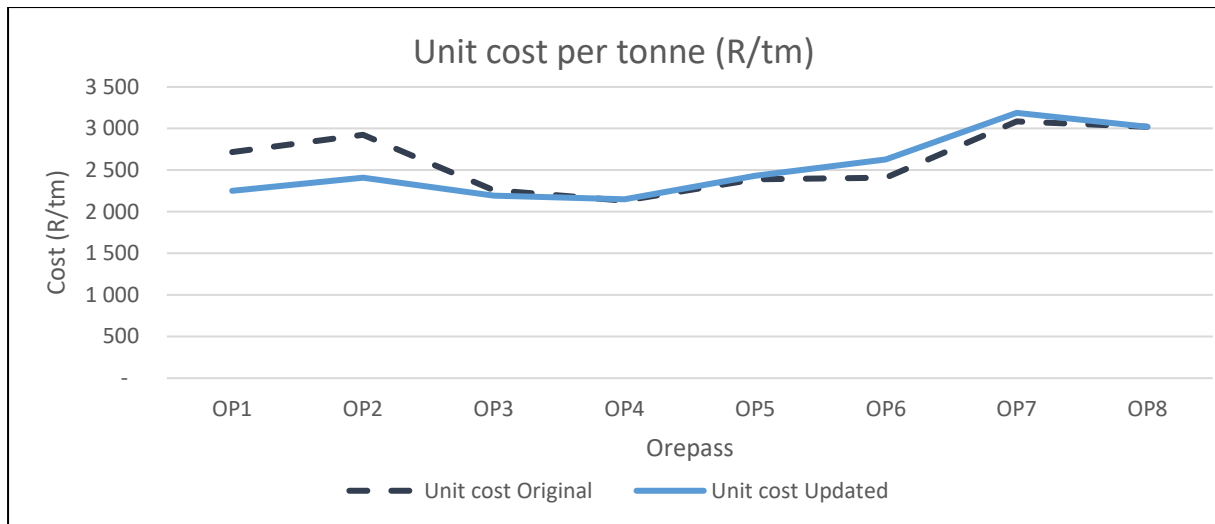


Figure 3.10 Example of a Unit cost per tonne metre comparison

From Figure 3.10 the solid line in the graph was the updated unit cost for each orepass compared to the original design (dashed line). The aim of the model was to minimise the total unit cost per orepass and also to ensure that the unit cost was spread out as much as possible. The model optimisation would aim at minimising the total unit cost for all orepasses combined. A spreadsheet analysis was done on the Microsoft Excel model and Table 3.6 shows how all the worksheets work together to produce the result.

Table 3.6: Model spread sheet analysis

	Sheet	Stored Rows	Stored Cols	Used Rows	Used Cols	# Unique Formulae	Sheet							Total
							1	2	3	4	5	6	7	
1	Haul_Dist	14	10	14	10	3	-	-	-	-	-	-	-	-
2	K01Tun_Co	137	77	137	77	69	-	-	-	-	-	-	-	-
3	LHD_Input	43	33	43	9	23	-	-	-	-	-	-	-	-
4	Infra_Co	69	15	69	12	19	-	-	-	-	-	-	1	1
5	K01Rings_export	29392	28	29392	28	11	-	1	-	2	-	1	-	4
6	K01LHD_Tonnes	792	512	792	512	15	-	1	-	-	2	-	-	3
7	CO-ORD_change	29393	41	81	40	22	2	-	1	-	2	-	-	5
Total						162	2	2	1	2	4	1	1	13

Table 3.6 indicates that Sheets 4 to 7 interact with each other. Each worksheet in the Microsoft Excel model had a function that was required to build up the final answer for

the total cost of loading and hauling for all the orepasses combined. Table 3.7 better explains how each of the worksheets in the model interacted to produce a final answer based on the coordinates of the orepass and Figure 3.11 graphically depicts the flow of data between the different Microsoft Excel sheets.

Table 3.7: Operations done in each worksheet in the model

	Sheet	Operations Done
1	Haul_Dist	Calculates the haulage distance on the truckloop for the base case and provides the base start position for orepass 1 for the adjusted orepass positioning in the model
2	K01Tun_Co	Series of pivot tables that are used to determine the total length and start of each of the individual tunnels on K01. This was used to determine the length of tramming from the ring to the start of the tunnel.
3	LHD_Input	Input sheet used to determine the cost of tramming for the LHD and the trucks. This derives the calculated Cost per TonneMetre (from Table 3.4 and Table 3.5)
4	Infra_Co	Sheet that receives updated orepass positions from "CO-ORD change" sheet and provides the input X and Y co-ordinates that were used to calculate the minimum tramming distance from each ring to each orepass. This sheet also indicates the levels that have tips, since each orepass has a tip on every second level.
5	K01Rings_export	Receives the X-and Y coordinates from the Infra_Co sheet and calculates the distance to each orepass based on the updated co-ordinates from each optimisation. This sheet then takes the minimum distance to select the orepass where the mined tonnes from a ring are trammed.
6	K01LHD_Tons	This combines the schedule from PCSLC with the allocated orepass positions so that the scheduled tonnes to be mined from each tunnel can then be applied to the TonneMetre cost for the LHD's and for the trucks on the truckloop.
7	CO-ORD_change	This is the sheet where the following is done: * The orepass position is input into the sheet * The total TonneMetres for the LHD and truck are used to calculate the total cost of all the orepasses which would be directly proportional to the tramming distance calculated in sheet "K01LHD_Tonnes" * The following constraints are tested as a simple "TRUE" or "FALSE" statement: - Proximity between orepasses should be more than 25m, this is from centre to centre; - The orepasses should not be closer than 40m from the orebody. This is a mine design constraint since the main access tunnels should be located outside the area of high geotechnical stresses; - The orepasses should all be located to the south of the orebody because the crushers, intake ventilation, return ventilation, and other services are all located to the south of the orebody.

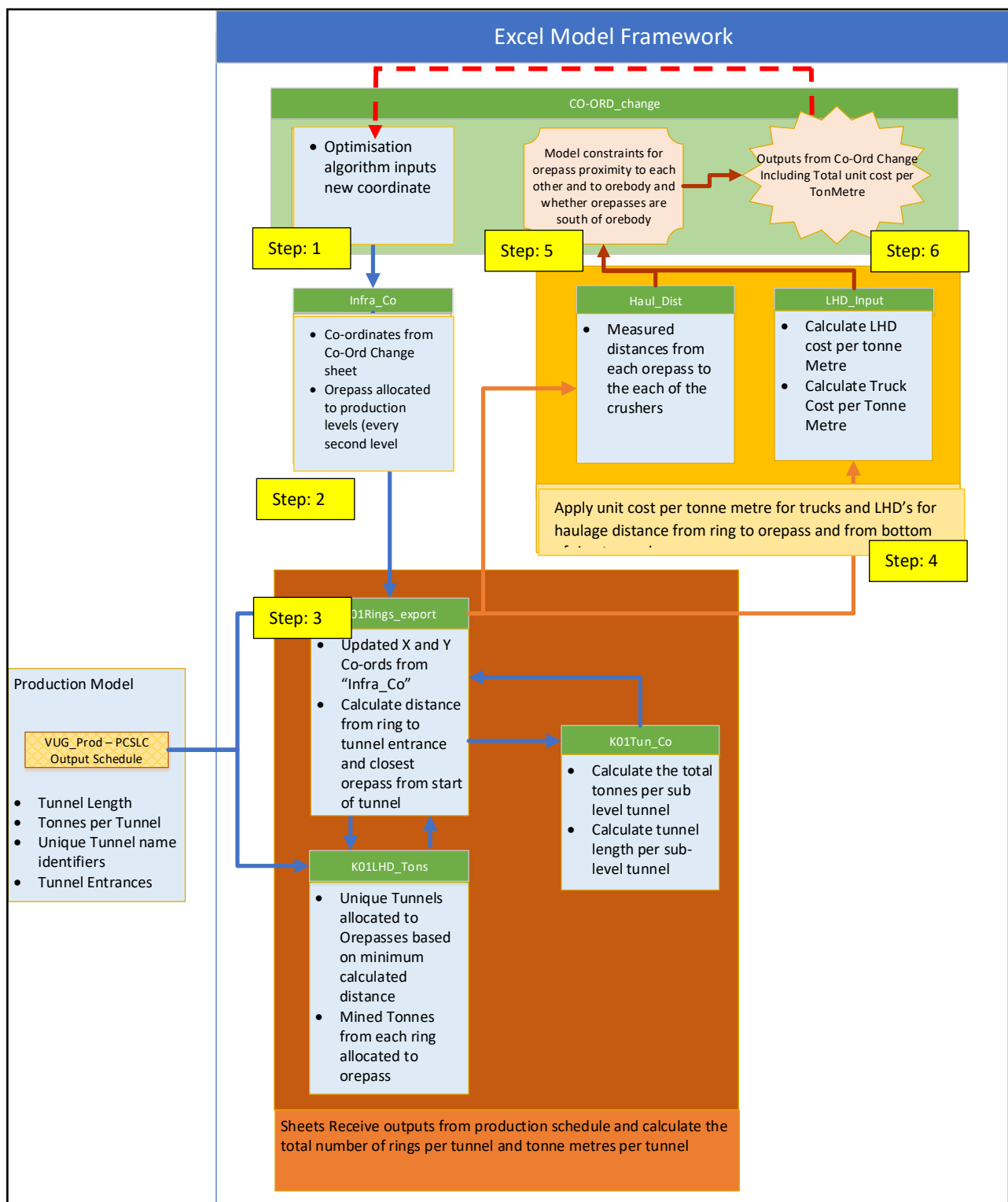


Figure 3.11 Microsoft Excel model framework

In Figure 3.11, the process of making an adjustment in the optimisation process follows the following steps:

Step 1 – a co-ordinate adjustment is made on the X and Y coordinates for all 8 orepasses in the mine design.

Step 2 – the new coordinates are then transferred to the **Infra_Co** worksheet and each orepass is allocated to the relevant level, as discussed in Table 3.3. There are 4 tips per level.

Step 3 – In the **K01Rings_export**, **K01LHD_Tons** and **K01Tun_Co** sheets the inputs from **Infra_Co** are received, and this is combined with the production schedule to determine how many tonnes will be flowing out of each orepass based on its updated **X** and **Y** Coordinates. The tonnes extracted from each ring are taken as inputs from the PCLSC production schedule.

Step 4 – Based on the tonnages running through each orepass and the tonnages hauled from each orepass to each crusher the total tonne metres cost for each orepass is calculated in the **LHD_input** and **Haul_Dist** sheets

Step 5 – The total tonne metre cost for each orepass is aggregated and costed and the constraints are applied to verify whether these inputs are valid, as discussed in Section 3.7.2 and Section 3.7.3.

Step 6 – Valid outputs from the model run are stored and then Step 1 is repeated.

The steps listed above are followed when running both the genetic and linear programming optimisations

3.6. Base case results from model

The initial approved design was used as a base case for the model. This is the model with the orepasses positioned as shown in Figure 3.7 and Figure 3.8. Table 3.8 shows the important parameters in the base case.

Table 3.8: Orepass Coordinate base inputs into the model

Orepass No.	X-Coord	Y-Coord
OP1	33082.83	-81832
OP2	33112.83	-81840.3
OP3	33232.83	-81880.3
OP4	33262.83	-81880.9
OP5	33292.83	-81881.2
OP6	33322.83	-81881.5
OP7	33511.75	-81741.3
OP8	33529.02	-81716.7
Unit Cost Per Tonne Metre (R/tm)		20 941

The model base case had a total cost of R20 941 per tonne metre when combining all the orepasses. This cost is based on the entire life of mine schedule and combines both loading and hauling costs. The optimisation focussed on minimising the cost per tonne metre as shown in Figure 3.12 and this was done by adjusting the X and Y coordinates in the model. The tonne metre was discussed in Section 3.5.1.

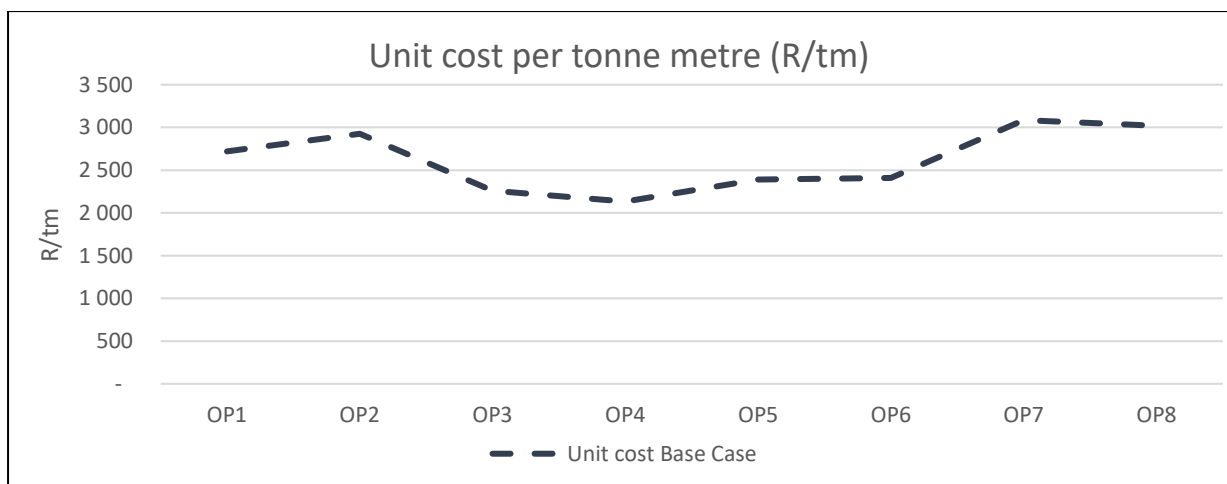


Figure 3.12 Unit cost for orepasses in the base case

Figure 3.12 indicates that the total unit costs for the base case when looking at loading and hauling costs combined could be improved in orepasses 2 ,7 and 8 since too many

tonnes were being loaded and hauled through those orepasses. The optimisation addressed those issues and adjusted the X and Y coordinates to minimise the unit cost per tonne metre.

3.7. Optimisation

As discussed in Section 3.1, two optimisation techniques were used to minimise the unit cost per tonne metre for loading and hauling for all orepasses on K01. The Microsoft Excel sheet was taken through the Evolver ® tool in Palisade's Decision Suite. There is both linear programming and genetic algorithm optimisation modules in the tool. Evolver® has the OptQuest optimisation engine that performs linear programming optimisations and handles problems that are non-linear. OptQuest performs trials on the Microsoft Excel model until the most suitable answer is reached or the objective function is not improving anymore after a predetermined number of iterations on the model.

3.7.1. Model linearity

The model was run in Solver® and when running a simple simplex optimisation for a linear programming optimisation the optimisation could not be completed. Figure 3.13 shows that the outputs from the Solver® optimisation were not valid because one of the constraints in the model was not linear.

Solver Results

×

The linearity conditions required by this LP Solver are not satisfied.

☒ Keep Solver Solution

☐ Restore Original Values

☐ Return to Solver Parameters Dialog

Reports

Linearity

☒ Outline Reports

OK

Cancel

Save Scenario...



The linearity conditions required by this LP Solver are not satisfied.
Create a linearity report to see where the problem is, or switch to the GRG engine.

Figure 3.13 LP Solver results

Table 3.9 shows the constraints for keeping the orepasses at more than the allowable tolerance from each other and ensuring that the orepasses are at least 40 metres away from the orebody. These constraints are not linear functions because they need to be tested with each iteration and will always be changing since the orepass positions will also be changing with each trial. The “Cell” and “Formula” columns refer to the cell in the excel model referenced in Section 7.1 of the appendix.

Table 3.9: LP Solver inputs into the model

Cell	Name	Cell Value	Formula	Linear Function
\$AD\$24	Test 1 (Orepass Proximity) NEW	1	\$AD\$24=1	No
\$AD\$25	Test 2 (All Orepasses are South of Orebody) NEW	1	\$AD\$25=1	Yes
\$AD\$26	Test 3 (Proximity of Orepasses to Orebody) NEW	1	\$AD\$26=1	No

The objective function was not a linear function and thus, it was necessary to look at an optimisation technique that can handle non-linear functions. For this reason, the OptQuest® optimisation engine was used as it can optimise non-linear functions.

3.7.2. Linear programming

For the linear programming the following constraints were used:

- Orepasses cannot be closer than 25m from each other;
- All orepasses are to be to the south of the K01 orebody;
- The orepasses are not to be positioned closer than 40m from the orebody.

The **Objective function** was to minimise the total unit cost per tonne metre for all eight orepasses.

The adjustable parameters in the model were the X and Y coordinates in the model. These two parameters were allowed in the model to move by between 150m and negative 150m. This distance was chosen because there are eight planned orepasses for K01. The total maximum width of the K01 orebody is about 600m so this would mean a spacing of 75m if all the orepasses were spaced out evenly. Currently orepasses are placed in groups of two. The 150m envelope for potential positioning of orepasses ensures that there will be no potential gaps and all possible areas for an orepass to be positioned will be available for optimisation.

The Optimisation Engine generated a random number to do the adjustment on the X and Y coordinates for the all the orepasses. The best answer was stored if all constraints were met and the number was less than the previous best answer obtained. The optimisation was run until there was a change of less than 0.1% from the optimal answer after 10 000 iterations.

3.7.3. Genetic algorithm

The GA optimisation used the same constraints as the linear programming optimisation:

- Orepasses cannot be closer than 25m from each other;
- All orepasses are to be to the south of the K01 orebody;
- The orepasses are not to be positioned closer than 40m from the orebody.

The objective function was to minimise the total unit cost per tonne metre for all eight orepasses.

The adjustable parameters in the model were the X and Y coordinates in the model. These two parameters were allowed in the model to move by between 150m and negative 150m in increments of 0.5m in the X and Y direction.

The population size in the GA optimisation was 60 with a mutation rate of 0.25 and a crossover rate of 0.5 as shown in Table 3.10. Although there is literature that involves the use of the GA, there is not much that indicates what the ideal population size should be; it is recommended that this be done through trial and error. The population size influences the computational time and whether the optimisation will converge to an optimal solution after enough generations (Abukhamsin, 2009).

The only changes that were applied were the X and Y position of each of the orepasses. Thus, there were 16 total variables for the 8 orepass positions that were optimised, this is less than the population size of 60. The optimisation results show that the GA optimisation stabilised and converged to a result.

Table 3.10: Genetic algorithm inputs

Parameter	Value
Population Size	60
Mutation Rate	0.25
Parameter	Value
Crossover Rate	0.5

The genetic algorithm optimisation was also run until the change in the objective function was less than 0.1% after 10 000 iterations and mutations. The principles described in Chapter 2.6 were applied in the optimisation.

3.8. Chapter summary

In this chapter the research methodology was discussed. The methods used to deplete the orebody were discussed including the way that ore is mixed in the cave through template mixing to ensure that the correct grades are predicted at the loading points

(drawpoints). The infrastructure design was reviewed and the layout of orepasses around the K01 orebody and on the production levels were also discussed.

The Microsoft Excel model that was used to simulate production and provide the metrics for cost per tonne metre hauled was also introduced and Palisade Evolver® was used to do linear programming and genetic algorithm optimisation because only the constraint for ensuring that the orepasses were not placed to the south of the orebody was linear. The base or the sum of all the unit costs for the eight orepasses in the design was R20 900 R/tm. The following chapter will discuss the results of the LP and GA optimisation on the Microsoft Excel model.

4. RESULTS AND DISCUSSION

4.1. Introduction

The results from the optimisations on the base model are presented and discussed in this chapter. The appendix contains all the results from both the genetic algorithm optimisation and the base model inputs.

There was improvement on the objective function compared to the base model where the positions of orepasses were manually determined based on the surrounding geology and the general layout of the orebody.

4.2. Linear programming results

As stated in Chapter 3 the OptQuest engine in Palisade's Evolver® was used to determine the optimal solution to minimise the total cost per tonne metre for all the orepasses. The results of the optimisation are shown in Table 4.1, the "Cell to Optimise" row refers to the cell in the excel model referenced in Section 7.1 of the appendix.

Table 4.1: Linear programming outputs

Goal	Action
Cell to Optimise	'CO-ORD_change'!BK13
Type of Goal	Minimum

Results	Value
Valid trials	642
Total trials	16 906
Original value	20 941
Best value found	18 746

The final minimised figure after 16 906 trials was R 18 746 per tonne metre and of the 16 906 trials performed 642 were valid. The total time taken for the optimisation exercise was about 54 hours. This indicates a reduction in the total tonne metres by 10.5%.

Table 4.2: Linear programming orepass position results

	Linear Programming (Orepass positions after optimisation)		Adjustments recommended from Optimisation compared to base case (Orepass positions)	
Orepass Number	X Coord	Y Coord	Δ in X Coord from Base Case	Δ in Y Coord from Base Case
OP1	33106.83	-81802	24	30
OP2	33133.83	-81822.3	21	18
OP3	33214.83	-81868.3	-18	12
OP4	33268.83	-81877.9	6	3
OP5	33301.83	-81875.2	9	6
OP6	33331.83	-81875.5	9	6
OP7	33508.75	-81714.3	-3	27
OP8	33529.02	-81683.7	0	33
Unit Cost Per Tonne (Tonne Metre)	Optimised – 18 746		Base Case- 20941	

Figure 4.1 indicates that the model ran the optimisation and started to stabilise and took long to reach an optimal result.

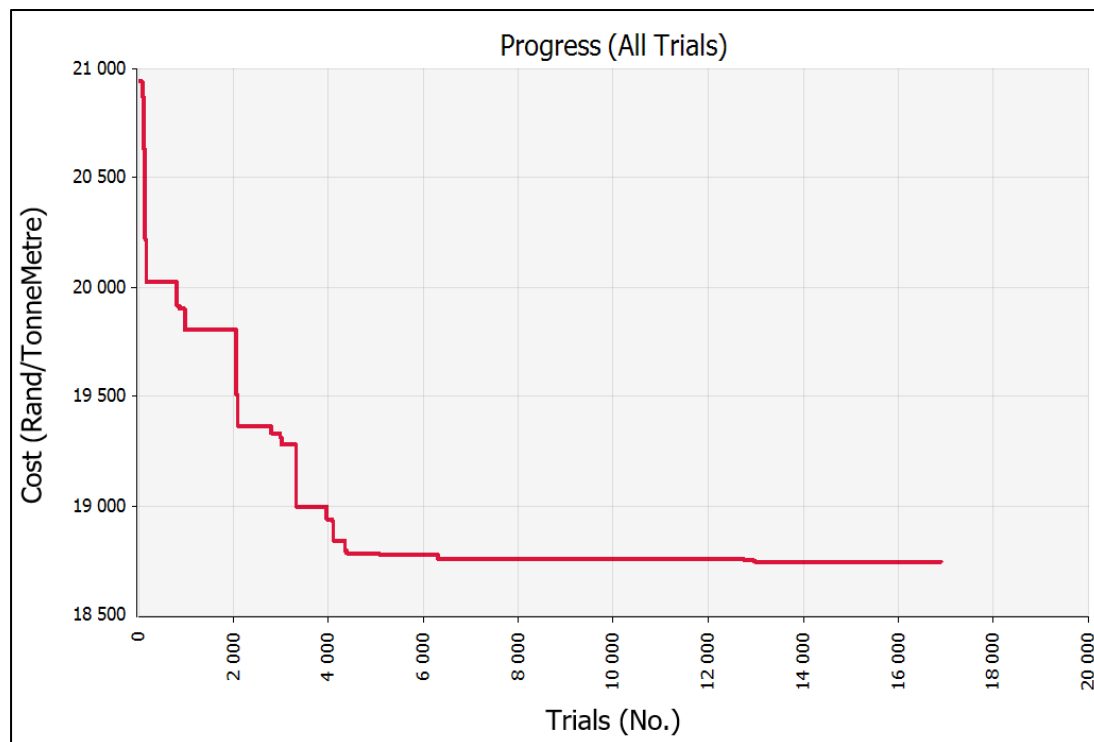


Figure 4.1 Progress of LP optimisation results

From the base case the total tonne metre cost improved from R 20 941 to R18 746. This is an improvement of 10.5% from the original cost for the orepasses. The proposed lay out is shown in Figure 4.2, the orange circles represent the original positions of the orepasses.

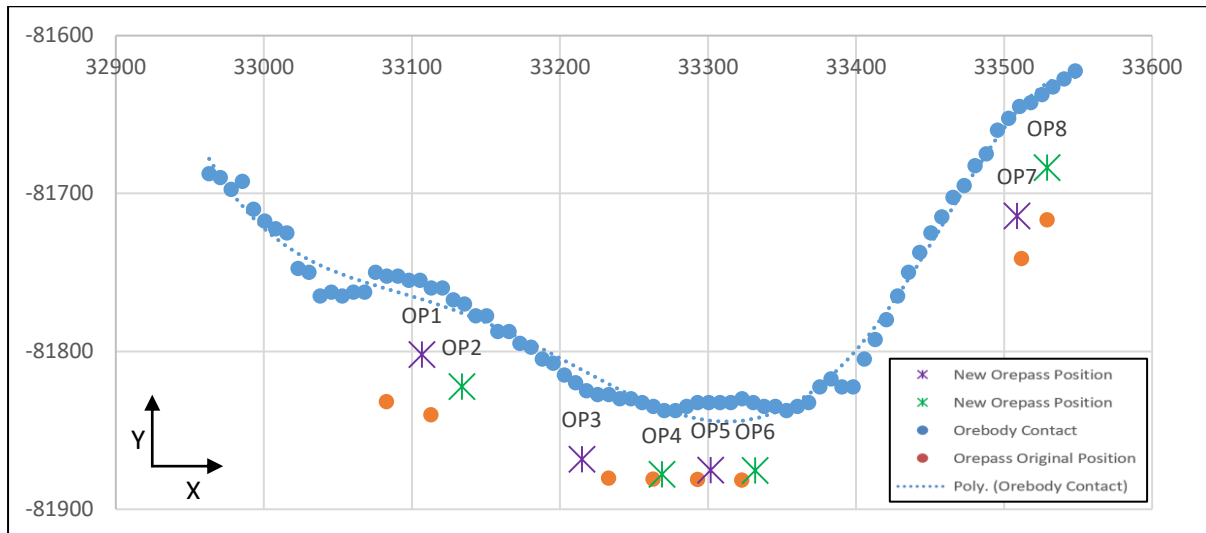


Figure 4.2 Proposed orepass positions

The optimisation brought the layout of the orepasses closer to the orebody and the positions of orepasses were adjusted to give the best tonne metre value. The histogram in Figure 4.3 indicates that a large proportion of valid results were within the range of the optimised solution. The ">20 941" bin was large, but this bin is not considered because this result is not better than the base case which is R20 941 R/tm.

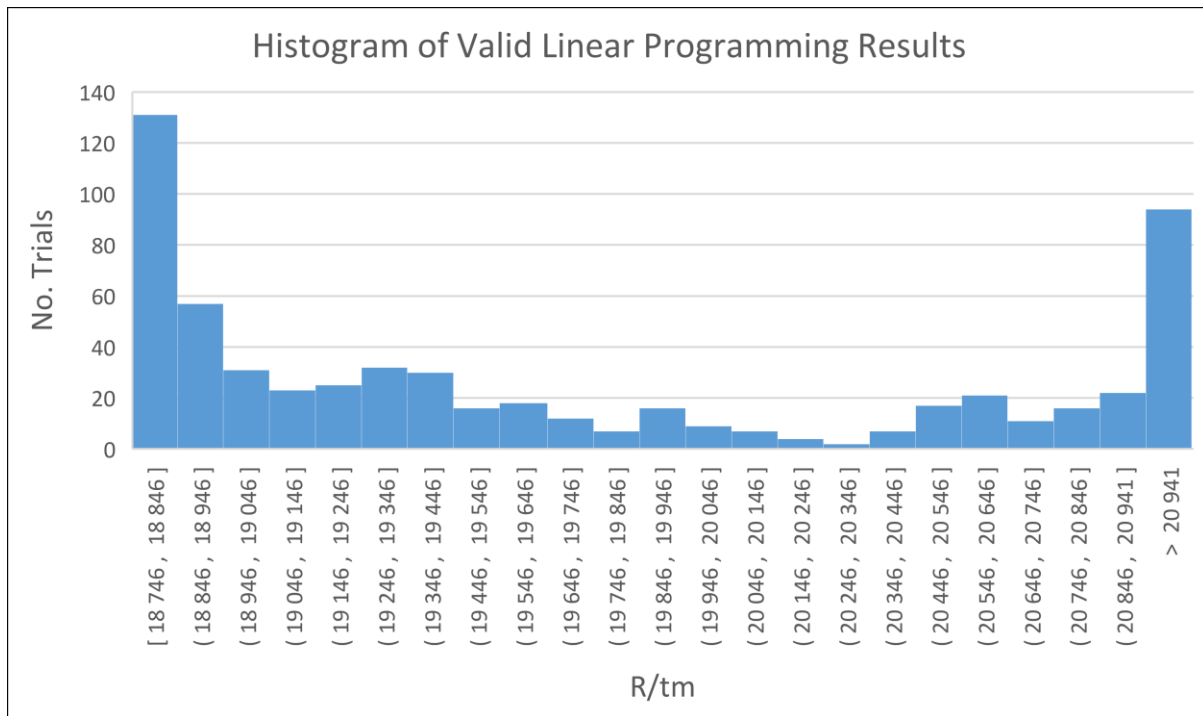


Figure 4.3 Histogram of Valid Linear Programming results

4.3. Genetic algorithm results

As stated in Chapter 3 the genetic algorithm engine in Palisade's Evolver® was used to determine the optimal solution to minimise the total cost per tonne metre for all the orepasses. The results of the optimisation are shown in Table 4.3, the "Cell to Optimise" row refers to the cell in the excel model referenced in Section 7.2 of the appendix.

Table 4.3: Genetic algorithm outputs

Goal	
Cell to Optimise	'CO-ORD_change'!BK13
Type of Goal	Minimum
Results	
Valid Trials	2 425
Total Trials	13 463
Original Value	20 941
Best Value Found	18 390

The final minimised figure after 13 463 trials was R 18 390 per tonne metre and of the 13 463 trials performed 2 425 were valid. The total time taken for the optimisation exercise was about 69 hours.

The GA optimisation outputs are summarised in Table 4.4.

Table 4.4: Summarised genetic algorithm outputs

	Genetic Algorithm (Orepass positions after optimisation)		Adjustments recommended from Optimisation compared to base case (Orepass positions)	
Orepass Number	X Coord	Y Coord	Δ in X Coord from Base Case	Δ in Y Coord from Base Case
OP1	33120.66	-81810.68	37.83	21.32
OP2	33143.13	-81824.63	30.30	15.67
OP3	33231.16	-81868.89	-1.67	11.41
OP4	33261.71	-81876.52	-1.12	4.38
OP5	33297.54	-81873.15	4.71	8.05
OP6	33322.51	-81871.88	-0.32	9.62
OP7	33494.14	-81732.15	-17.61	9.15
OP8	33512.24	-81706.85	-16.78	9.85
Unit Cost Per Tonne Metre	Optimised - 18 389		Base Case - 20 941	

Figure 4.3 indicates that the model ran the optimisation and started to stabilise and took long to reach an optimal result.

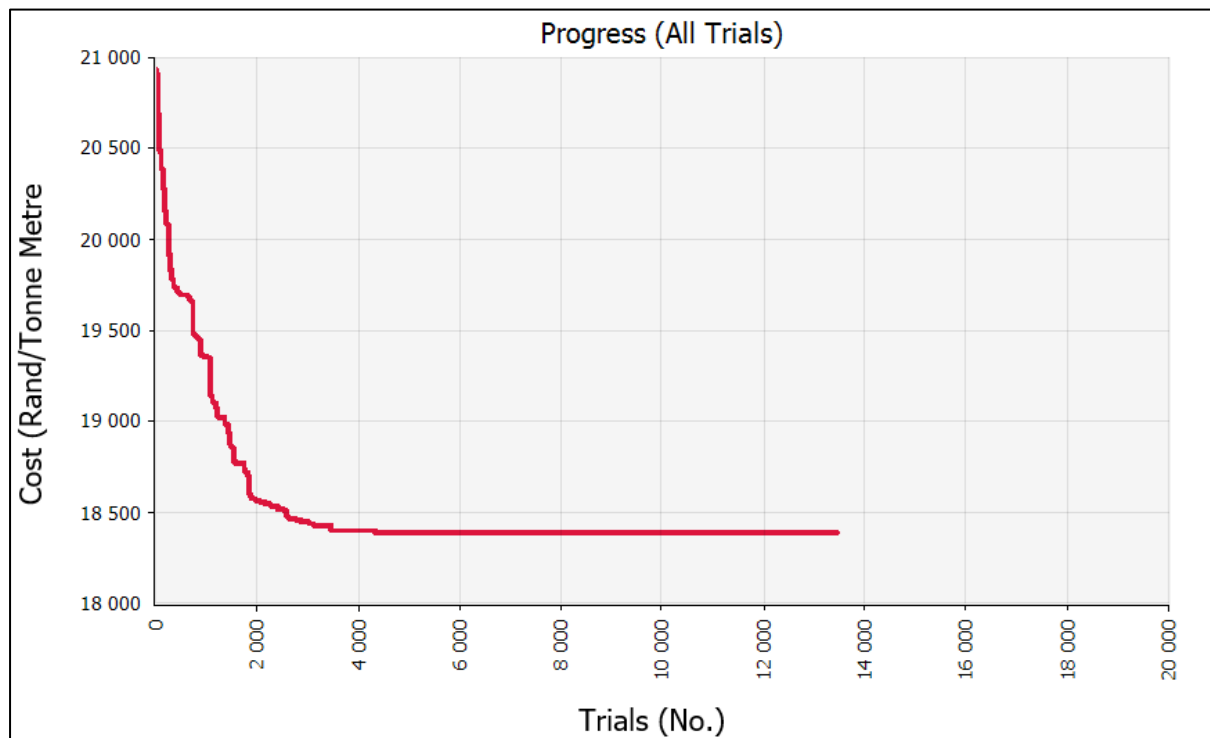


Figure 4.4 Progress of GA optimisation results

From the base case the total tonne metre cost improved from R 20 941 to R18 389. This is an improvement of 12% from the original cost for the orepasses. The proposed layout is shown in Figure 4.4, the orange circles represent the original positions of the orepasses.

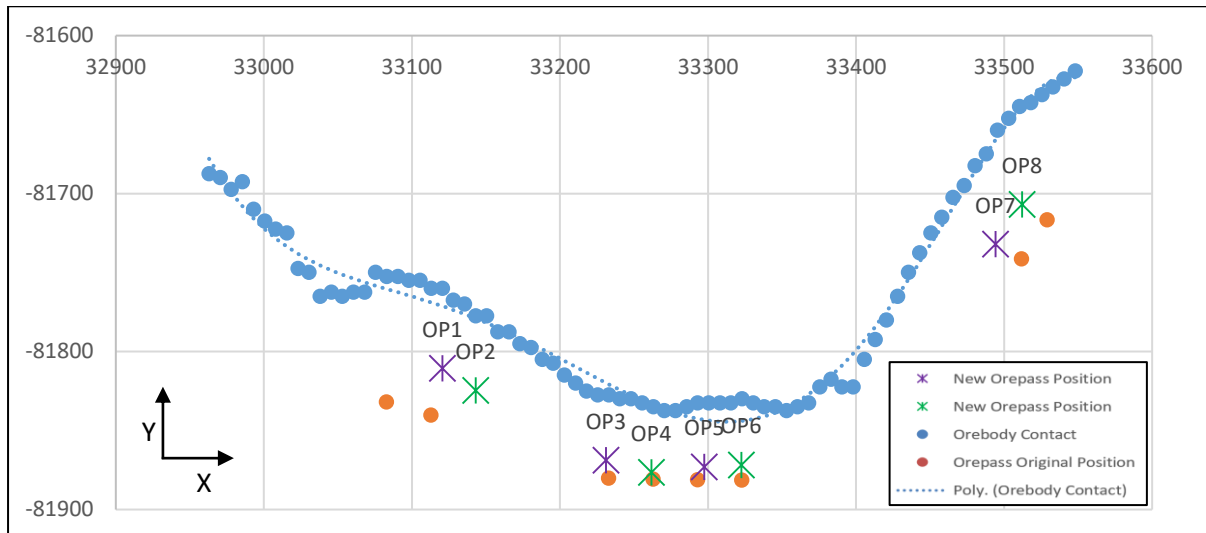


Figure 4.5 Proposed orepass positions

The optimisation brought the layout of the orepasses closer to the orebody and the positions of orepasses have also been adjusted to give the best tonne metre value. The relative positions of orepass 1 and 2, and orepass 7 and 8 changed noticeably. All three constraints were met in the optimal solution. The histogram in Figure 4.6 below indicates that a large proportion of valid results were within the range of the optimised solution.

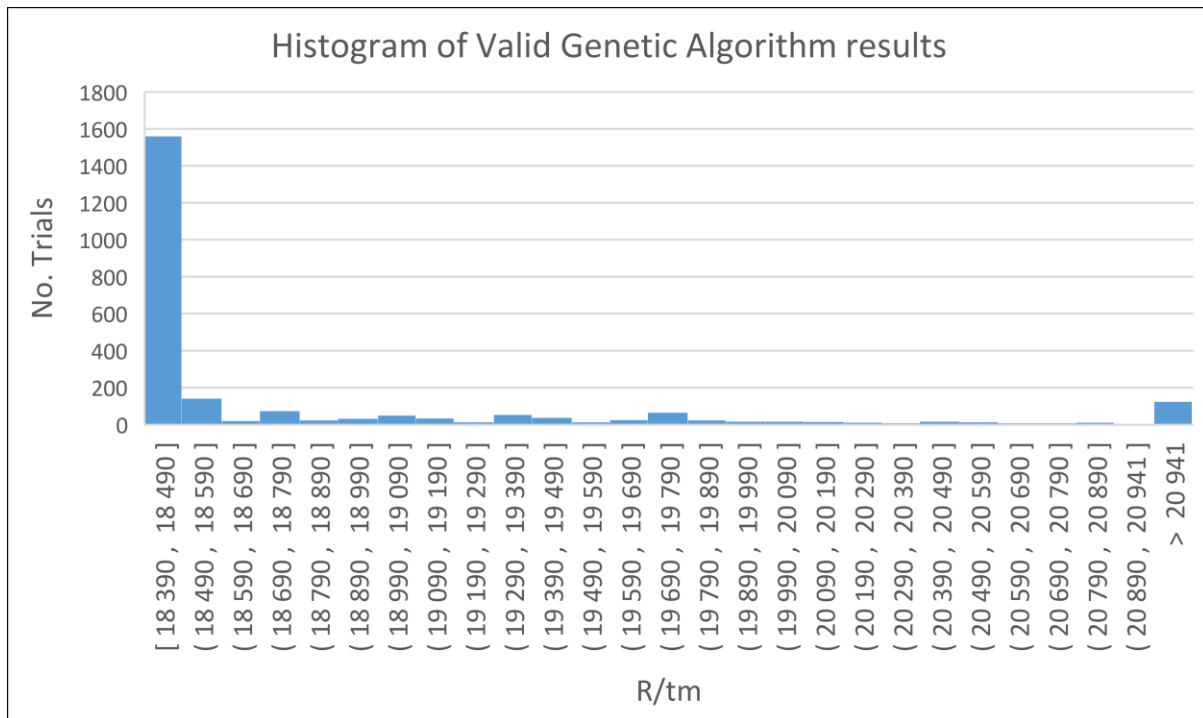


Figure 4.6 Histogram of valid Genetic Algorithm Results

4.4. Analysis of results

Both the genetic algorithm optimisation and the linear programming optimisation brought an improvement in the total tonne metre cost for all eight orepasses in K01. The improvements in results were up to 12%. The major changes in orepass position were in orepasses 1, 2, 7 and 8. Orepasses 3 to 6 did not have any significant change to their position because the orebody is thickest in that area when looking at it in its vertical extent.

With linear programming optimisation the constraint that states that the orepasses are not to be within 40m of the orebody was satisfied in 9.97% of the trials, for the genetic algorithm optimisation the same constraint was satisfied in 28.63% of the trials. This indicated that this constraint (orepass proximity to orebody) was satisfied the least out of all the trials. The LP optimisation had a total Rand per tonne metre value of 18 746 and the GA optimisation had a total tonne metre value of 18 390 which results in a variance of 356 Rand per tonne metre which is 1.7% of the original base case Rand per tonne metre of R20 941 per tonne metre.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

This chapter considers the results and proposes a way forward. Section 5.2 considers the results of the optimisations with reference being made to the objectives of the study as stated in Chapter 1. The limitations of the research and the recommendations for possible future work are also made.

5.2. Findings

Loading and hauling costs have a significant impact on the operating cost of a mining operation. The more these costs are reduced the more positive an impact that can be made on the overall operating cost. The savings that can be made from reducing the distance for tramming for an LHD from the loading point to the tip will reduce loading costs. The benefit of minimising the distance for hauling for a truck in the truckloop from the loading chute at the bottom of the orepass to the crusher will reduce hauling costs. These savings can potentially increase the effective life of machinery because they will be hauling less and thus, will reduce costs of diesel.

The problem statement raised the following research question:

“Can genetic algorithm and linear programming approaches be used to determine the location of orepasses at Venetia Mine to derive a benefit in costs?”

If an orepass is positioned in such a manner that the tramming (loading and hauling) distance is minimised there is a direct **cost benefit** as diesel costs will be directly reduced. This positioning will reduce the tramming portion of a loading or hauling cycle. As seen with the positioning of the optimised orepass positions in Figures 4.2 and 4.5

The genetic algorithm and linear programming optimisations done on the orepasses at Venetia Mine resulted in a reduced combined tonne metre cost for all orepasses in K01 as shown in Chapter 4. The reduction in total cost per tonne metre for the GA was 12% and 10.5% for the LP optimisation.

The optimisation work in Evolver® with the Microsoft Excel model could also be used as a tool in the same way to what is done with a Whittle shell when optimising for the best open pit design given a certain set of economic parameters. Once the optimal

shell has been determined a realistic and plausible mine design can be applied to that Whittle shell. This optimisation for locating orepasses can give the mine designer the best location for orepasses for a specific layout in level spacing and tunnel spacing in a sub-level cave. This optimised design can then be adjusted to account for geology and other geotechnical constraints around the orebody that may prevent the locating of those orepasses. These constraints can also be included in the model so that the optimal location of orepasses given a set of geotechnical and geological constraints can be determined without the input from the mine designer.

5.3. Limitations of the research

As stated previously the optimisations did not take into consideration geotechnical constraints, e.g. faults, dykes and satellite kimberlite pipes that surround the K01 orebody. The other issue is that the optimisation is based on a specific schedule and the schedule cannot be changed for the optimisation. Such a change would result in a different draw order from the rings which could result in different tonnages being drawn from each tunnel.

The study focussed only on Venetia Underground Mine. The optimisations and results may not be a true representation for other sub-level caving mining operations and as such these optimisations need to be tested on other operations.

The calculation uses the tunnel length and the spacing between tunnels to determine the optimal orepass position. If the mine design were to change i.e. if the spacing between tunnels on each level or the spacing between levels was to change, the optimisation would give different results. That is, the optimisation is applicable only for the design on which it is applied.

5.4. Recommendations

This research was based on one mine design on one orebody with only one specific production profile and schedule applied to it. The results obtained in this report need to be verified on a different design, orebody and schedule so that the hypothesis is further validated. A more accurate and realistic optimised objective function will be achieved if geotechnical and geological limitations are considered as constraints in the optimisation. This would provide a realistic and implementable orepass layout on the design. The recommended orepass layouts should be implemented on the design and the required supporting infrastructure i.e. ventilation raises, tip development, accesses

from the rim tunnel can also be provided for in these new orepass positions and should be observed in relation to the new orepass positions.

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7. APPENDICES

7.1. Linear programming optimisation results

Evolver: Optimization Summary

Performed By: Dabula, Gangatha

Date: 06 August 2018 09:49:31 AM

Model: VUP_TMM_K01Prod_orepass_positioning_LP_01.xlsx

Goal	Value
Cell to Optimize	'CO-ORD_change'!BK13
Type of Goal	Minimum

Results	Value
Valid Trials	642
Total Trials	16906
Original Value	20 941
+ soft constraint penalties	0.00
= result	20 941
Best Value Found	18 746
+ soft constraint penalties	0.00
= result	18 746
Best Trial Number	12966
Time to Find Best Value	54:07:57
Reason Optimization Stopped	Progress condition
Time Optimization Started	2018/07/30 15:03
Time Optimization Finished	2018/08/06 09:48
Total Optimization Time	70:30:00
Adjustable Cell Values	'CO-ORD_change'!AB3
Original	0
Best	24
Adjustable Cell Values	'CO-ORD_change'!AC3
Original	0
Best	30
Adjustable Cell Values	'CO-ORD_change'!AB4
Original	0
Best	21
Adjustable Cell Values	'CO-ORD_change'!AC4
Original	0
Best	18
Adjustable Cell Values	'CO-ORD_change'!AB5
Original	0
Best	-18
Adjustable Cell Values	'CO-ORD_change'!AC5
Original	0

Results	Value
Best	12
Adjustable Cell Values	'CO-ORD_change'!AB6
Original	0
Best	6
Adjustable Cell Values	'CO-ORD_change'!AC6
Original	0
Best	3
Adjustable Cell Values	'CO-ORD_change'!AB7
Original	0
Best	9
Adjustable Cell Values	'CO-ORD_change'!AC7
Original	0
Best	6
Adjustable Cell Values	'CO-ORD_change'!AB8
Original	0
Best	9
Adjustable Cell Values	'CO-ORD_change'!AC8
Original	0
Best	6
Adjustable Cell Values	'CO-ORD_change'!AB9
Original	0
Best	-3
Adjustable Cell Values	'CO-ORD_change'!AC9
Original	0
Best	27
Adjustable Cell Values	'CO-ORD_change'!AB10
Original	0
Best	0
Adjustable Cell Values	'CO-ORD_change'!AC10
Original	0
Best	33

Constraints	Value
Description	AD24 = 1
Definition	AD24 = 1
Constraint Type	Hard
Precision	0
Satisfied for % of Trials	51.32%
Description	AD25 = 1
Definition	AD25 = 1
Constraint Type	Hard
Precision	0
Satisfied for % of Trials	23.52%
Description	AD26 = 1

Results	Value
Definition	AD26 = 1
Constraint Type	Hard
Precision	0
Satisfied for % of Trials	9.97%

Adjustable Cells	Value
Description	
Solving Method	Recipe
Cell Range	-150 <= 'CO-ORD_change'!AB3:AC10 <= 150

Optimization Settings	Value
Runtime	
Trials	FALSE
Time	FALSE
Progress	TRUE
Maximum Change	0.10%
Number of Trials	10000
Formula	FALSE
Stop on Error	FALSE
Engine	
Random # Generator Seed	336385152 (Chosen Randomly)
Optimization Engine	OptQuest
Macros	
At Start of Optimization	N/A
Before Recalculation	N/A
After Recalculation	N/A
After Storing Output	N/A
At End of Optimization	N/A

Evolver: Log of Progress Steps

Performed By: Dabula, Gangatha

Date: 06 August 2018 09:50:12

AM

Model:

VUP_TMM_K01Prod_orepass_positioning_LP_01.

xlsx

Trial	Elapsed Time	Result	Adjustable Cells																Hard Constraints		
			AB 3	AC 3	AB 4	AC 4	AB 5	AC 5	AB 6	AC 6	AB 7	AC 7	AB 8	AC 8	AB 9	AC 9	AB1 0	AC1 0	AD2 4 = 1	AD2 5 = 1	AD2 6 = 1
1	00:07:47	20 941	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
74	00:27:05	20 901	0	0	0	0	0	0	0	0	3	3	0	0	0	0	3	3	1	1	1
76	00:27:37	20 868	6	0	0	0	0	0	0	0	0	0	0	3	3	3	3	6	1	1	1
100	00:33:57	20 824	6	0	0	0	0	0	0	0	0	0	0	6	6	6	3	9	1	1	1
107	00:35:48	20 801	6	0	0	0	0	0	0	0	0	0	0	6	6	9	3	9	1	1	1
108	00:36:04	20 779	6	0	0	0	0	0	0	0	0	0	0	6	6	12	3	9	1	1	1
117	00:38:26	20 741	3	0	0	0	0	3	0	0	0	0	0	6	6	12	3	9	1	1	1
118	00:38:42	20 685	3	0	0	0	0	6	0	0	0	0	0	6	6	12	3	9	1	1	1
119	00:38:57	20 630	3	0	0	0	0	9	0	0	0	0	0	6	6	12	3	9	1	1	1
133	00:42:39	20 473	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	3	1	1	1
137	00:43:43	20 449	3	3	3	3	3	3	3	3	3	3	3	3	3	6	0	3	1	1	1
142	00:45:02	20 398	3	0	3	3	0	9	0	3	0	3	0	6	3	12	0	9	1	1	1
153	00:47:55	20 218	3	0	6	6	0	9	0	3	0	3	0	6	3	12	0	9	1	1	1
154	00:48:11	20 182	3	0	9	9	0	9	0	3	0	3	0	6	3	12	0	9	1	1	1
155	00:48:26	20 150	3	0	12	12	0	9	0	3	0	3	0	6	3	12	0	9	1	1	1
156	00:48:42	20 123	3	0	15	15	0	9	0	3	0	3	0	6	3	12	0	9	1	1	1
157	00:48:58	20 099	3	0	18	18	0	9	0	3	0	3	0	6	3	12	0	9	1	1	1
173	00:53:06	20 024	3	0	21	18	0	9	0	3	0	3	0	6	3	12	0	9	1	1	1
815	03:36:06	19 915	3	0	21	18	6	9	3	3	3	6	0	6	0	21	3	12	1	1	1

857	03:46:35	19 905	3	0	21	18	3	9	3	3	3	6	0	6	0	21	3	12	1	1	1
974	04:15:40	19 804	-6	6	21	18	-6	9	3	3	3	6	6	6	0	21	3	21	1	1	1
2066	08:47:15	19 615	-6	12	21	18	-18	9	3	3	3	6	6	6	0	24	3	21	1	1	1
2067	08:47:30	19 562	-6	15	21	18	-24	9	3	3	3	6	6	6	0	27	3	21	1	1	1
2068	08:47:45	19 506	-6	18	21	18	-27	9	3	3	3	6	6	6	0	30	3	21	1	1	1
2081	08:50:59	19 497	-6	18	21	18	-24	9	3	3	3	6	6	6	0	30	3	21	1	1	1
2082	08:51:14	19 491	-6	18	21	18	-21	9	3	3	3	6	6	6	0	30	3	21	1	1	1
2083	08:51:29	19 394	-6	18	21	18	-18	9	3	3	3	6	6	6	0	30	3	21	1	1	1
2084	08:51:44	19 388	-6	18	21	18	-15	9	3	3	3	6	6	6	0	30	3	21	1	1	1
2085	08:51:59	19 385	-6	18	21	18	-12	9	3	3	3	6	6	6	0	30	3	21	1	1	1
2099	08:55:28	19 375	-6	18	21	18	-15	9	3	3	6	6	6	6	0	30	3	21	1	1	1
2100	08:55:43	19 364	-6	18	21	18	-15	9	3	3	9	6	6	6	0	30	3	21	1	1	1
2786	11:46:40	19 336	-3	18	21	18	-12	9	6	3	9	6	6	6	0	30	3	21	1	1	1
2982	12:35:33	19 312	-3	18	21	18	-12	9	6	3	9	6	6	6	0	33	3	24	1	1	1
3002	12:40:32	19 302	-3	18	21	18	-12	9	6	3	9	6	6	6	0	33	3	27	1	1	1
3003	12:40:47	19 294	-3	18	21	18	-12	9	6	3	9	6	6	6	0	33	3	30	1	1	1
3004	12:41:02	19 287	-3	18	21	18	-12	9	6	3	9	6	6	6	0	33	3	33	1	1	1
3005	12:41:17	19 282	-3	18	21	18	-12	9	6	3	9	6	6	6	0	33	3	36	1	1	1
3321	14:00:02	19 226	3	18	21	18	-12	9	6	3	9	6	6	6	-3	27	3	36	1	1	1
3322	14:00:17	19 223	6	18	21	18	-12	9	6	3	9	6	6	6	-3	24	3	36	1	1	1
3323	14:00:32	19 203	9	18	21	18	-12	9	6	3	9	6	6	6	-3	24	3	36	1	1	1
3324	14:00:47	19 184	12	18	21	18	-12	9	6	3	9	6	6	6	-3	24	3	36	1	1	1
3325	14:01:02	19 166	15	18	21	18	-12	9	6	3	9	6	6	6	-3	24	3	36	1	1	1
3326	14:01:17	19 047	18	18	21	18	-12	9	6	3	9	6	6	6	-3	24	3	36	1	1	1
3327	14:01:32	19 028	21	18	21	18	-12	9	6	3	9	6	6	6	-3	24	3	36	1	1	1
3328	14:01:47	19 011	24	18	21	18	-12	9	6	3	9	6	6	6	-3	24	3	36	1	1	1
3329	14:02:02	18 995	27	18	21	18	-12	9	6	3	9	6	6	6	-3	24	3	36	1	1	1
3968	16:41:20	18 939	27	18	21	18	-12	12	6	3	9	6	6	6	-3	24	3	36	1	1	1
4077	17:08:28	18 935	24	21	21	18	-12	12	6	0	9	6	6	6	-3	24	0	33	1	1	1
4093	17:12:26	18 901	24	24	21	18	-12	12	6	0	9	6	6	6	-3	24	0	33	1	1	1

4094	17:12:41	18 869	24	27	21	18	-12	12	6	0	9	6	6	6	-3	24	0	33	1	1	1
4095	17:12:56	18 839	24	30	21	18	-12	12	6	0	9	6	6	6	-3	24	0	33	1	1	1
4362	18:19:26	18 798	24	30	21	18	-12	12	6	3	9	6	6	6	-3	21	0	33	1	1	1
4376	18:22:56	18 782	24	30	21	18	-12	12	6	3	9	6	6	6	-3	24	0	33	1	1	1
5082	21:19:28	18 776	24	30	21	18	-18	12	6	3	9	6	6	6	-3	24	0	33	1	1	1
6304	26:25:06	18 756	24	30	21	18	-18	12	6	3	9	6	6	6	-3	27	0	33	1	1	1
12761	53:17:01	18 751	24	30	24	18	-18	12	6	3	9	6	9	6	-3	27	0	33	1	1	1
12966	54:07:56	18 746	24	30	21	18	-18	12	6	3	9	6	9	6	-3	27	0	33	1	1	1

7.2. Linear programming Microsoft Excel model - spreadsheet and formulae

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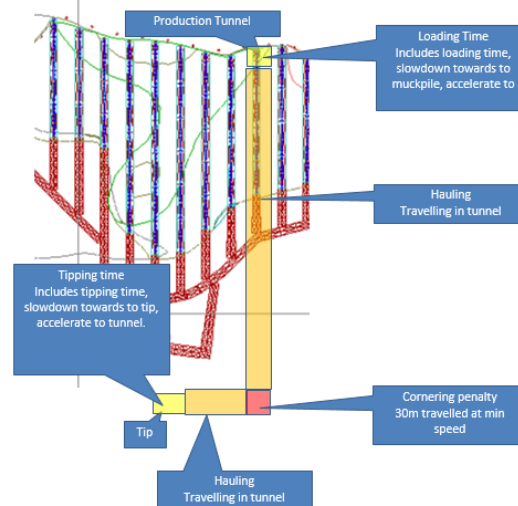
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
1		Opazsz	X	Y		K01Opazsz	Level	Typ			Level																		
2	K01	OP1	~CO-ORD_change\AD3	~CO-ORD_change\AE3		OP1	L196	-F28G2			L196	A																	
3	K01	OP2	~CO-ORD_change\AD4	~CO-ORD_change\AE4		OP2	-G2	-F28G3			L171	B																	
4	K01	OP3	~CO-ORD_change\AD5	~CO-ORD_change\AE5		OP5	-G3	-F48G4			L166	A																	
5	K01	OP4	~CO-ORD_change\AD6	~CO-ORD_change\AE6		OP7	-G4	-F58G5			L121	B																	
6	K01	OP5	~CO-ORD_change\AD7	~CO-ORD_change\AE7		OP2	L171	-F48G6			L96	A																	
7	K01	OP4	~CO-ORD_change\AD8	~CO-ORD_change\AE8		OP4	-G6	-F78G7			L71	B																	
8	K01	OP7	~CO-ORD_change\AD9	~CO-ORD_change\AE9		OP6	-G7	-F88G8			L46	A																	
9	K01	OP3	~CO-ORD_change\AD10	~CO-ORD_change\AE10		OP3	-G8	-F98G9			L21	B																	
10	K01	Warto	32491.54	-81981.2		OP1	L166	-F98G10			L-4	A																	
11						OP3	-G9	-F118G11			L-29	B																	
12	K02	OP1	32596.36	-81636.19		OP5	-G11	-F128G12			L-54	A																	
13	K02	OP2	32525.91	-81544.02		OP7	-G12	-F138G13			L-79	B																	
14	K02	OP3	32496.56	-81487.56		OP2	L121	-F148G14			L-104	A																	
15	K02	OP4	32472.25	-81371.81		OP4	-G14	-F158G15			L-129	B																	
16	K02	OP5	32486.17	-81316.88		OP6	-G15	-F168G16			L-154	A																	
17	K02	Warto	32676.65	-81925.22		OP3	-G16	-F178G17			L-179	B																	
18						OP1	L96	-F188G18			L-204	A																	
19		CR1	32775.59	-8206.91		OP3	-G18	-F198G19																					
20		CR2	32690.27	-81956.6		OP5	-G19	-F208G20																					
21						OP7	-G20	-F218G21																					
22						OP2	L71	-F228G22																					
23						OP4	-G22	-F238G23																					
24						OP6	-G23	-F248G24																					
25						OP3	-G24	-F258G25																					
26						OP1	L46	-F268G26																					
27						OP3	-G26	-F278G27																					
28						OP5	-G27	-F288G28																					
29						OP7	-G28	-F298G29																					
30						OP2	L21	-F308G30																					
31						OP4	-G30	-F318G31																					
32						OP6	-G31	-F328G32																					
33						OP3	-G32	-F338G33																					
34						OP1	L-4	-F348G34																					
35						OP3	-G34	-F358G35																					
36						OP5	-G35	-F368G36																					
37						OP7	-G36	-F378G37																					
38						OP2	L-29	-F388G38																					
39						OP4	-G38	-F398G39																					
40						OP6	-G39	-F408G40																					
41						OP3	-G40	-F418G41																					
42						OP1	L-54	-F428G42																					
43						OP3	-G42	-F438G43																					
44						OP5	-G43	-F448G44																					
45						OP7	-G44	-F458G45																					
46						OP2	L-79	-F468G46																					
47						OP4	-G46	-F478G47																					
48						OP6	-G47	-F488G48																					
49						OP3	-G48	-F498G49																					
50						OP1	L-104	-F508G50																					
51						OP3	-G50	-F518G51																					
52						OP5	-G51	-F528G52																					
53						OP7	-G52	-F538G53																					
54						OP2	L-129	-F548G54																					
55						OP4	-G54	-F558G55																					
56						OP6	-G55	-F568G56																					
57						OP3	-G56	-F578G57																					
58						OP1	L-154	-F588G58																					
59						OP3	-G58	-F598G59																					
60						OP5	-G59	-F608G60																					
61						OP7	-G60	-F618G61																					
62						OP2	L-179	-F628G62																					
63						OP4	-G62	-F638G63																					
64						OP6	-G63	-F648G64																					
65						OP3	-G64	-F658G65																					
66						OP1	L-204	-F668G66																					
67						OP3	-G66	-F678G67																					
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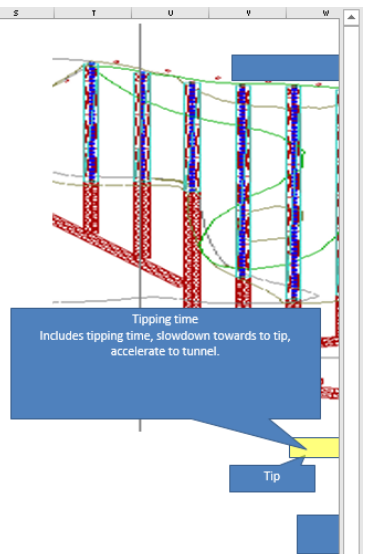
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A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
	Level	Tunnel	Tunnel Number	Ring	Ring number	Ring ID	Ring Name	Ring Name Alias	Tunnel Name	Tunnel Name Alias	Shape	X	Y	Z	OP1
1	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	1	L-20407R001	RINGR25	33008	-16602.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
2	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	2	L-20407R002	RINGR25	33008	-16605	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
3	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	3	L-20407R003	RINGR25	33008	-16607.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
4	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	4	L-20407R004	RINGR25	33008	-16610	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
5	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	5	L-20407R005	RINGR25	33008	-16612.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
6	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	6	L-20407R006	RINGR25	33008	-16615	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
7	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	7	L-20407R007	RINGR25	33008	-16617.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
8	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	8	L-20407R008	RINGR25	33008	-16620	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
9	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	9	L-20407R009	RINGR25	33008	-16622.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
10	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	10	L-20407R010	RINGR25	33008	-16625	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
11	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	11	L-20407R011	RINGR25	33008	-16627.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
12	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	12	L-20407R012	RINGR25	33008	-16630	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
13	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	13	L-20407R013	RINGR25	33008	-16632.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
14	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	14	L-20407R014	RINGR25	33008	-16635	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
15	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	15	L-20407R015	RINGR25	33008	-16637.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
16	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	16	L-20407R016	RINGR25	33008	-16640	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
17	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	17	L-20407R017	RINGR25	33008	-16642.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
18	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	18	L-20407R018	RINGR25	33008	-16645	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
19	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	19	L-20407R019	RINGR25	33008	-16647.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
20	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	20	L-20407R020	RINGR25	33008	-16650	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
21	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	21	L-20407R021	RINGR25	33008	-16652.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
22	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	22	L-20407R022	RINGR25	33008	-16655	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
23	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	23	L-20407R023	RINGR25	33008	-16657.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
24	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	24	L-20407R024	RINGR25	33008	-16660	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
25	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	25	L-20407R025	RINGR25	33008	-16662.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
26	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	26	L-20407R026	RINGR25	33008	-16665	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
27	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	27	L-20407R027	RINGR25	33008	-16667.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
28	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	28	L-20407R028	RINGR25	33008	-16670	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
29	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	29	L-20407R029	RINGR25	33008	-16672.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
30	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	30	L-20407R030	RINGR25	33008	-16675	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
31	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	31	L-20407R031	RINGR25	33008	-16677.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
32	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	32	L-20407R032	RINGR25	33008	-16680	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
33	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	33	L-20407R033	RINGR25	33008	-16682.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
34	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	34	L-20407R034	RINGR25	33008	-16685	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
35	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	35	L-20407R035	RINGR25	33008	-16687.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
36	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	36	L-20407R036	RINGR25	33008	-16690	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
37	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	37	L-20407R037	RINGR25	33008	-16692.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
38	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	38	L-20407R038	RINGR25	33008	-16695	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
39	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	39	L-20407R039	RINGR25	33008	-16697.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
40	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	40	L-20407R040	RINGR25	33008	-16700	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
41	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	41	L-20407R041	RINGR25	33008	-16702.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
42	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	42	L-20407R042	RINGR25	33008	-16705	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
43	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	43	L-20407R043	RINGR25	33008	-16707.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
44	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	44	L-20407R044	RINGR25	33008	-16710	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
45	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	45	L-20407R045	RINGR25	33008	-16712.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
46	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	46	L-20407R046	RINGR25	33008	-16715	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
47	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	47	L-20407R047	RINGR25	33008	-16717.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
48	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	48	L-20407R048	RINGR25	33008	-16720	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
49	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	49	L-20407R049	RINGR25	33008	-16722.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
50	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	50	L-20407R050	RINGR25	33008	-16725	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
51	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	51	L-20407R051	RINGR25	33008	-16727.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
52	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	52	L-20407R052	RINGR25	33008	-16730	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
53	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	53	L-20407R053	RINGR25	33008	-16732.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
54	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	54	L-20407R054	RINGR25	33008	-16735	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
55	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	55	L-20407R055	RINGR25	33008	-16737.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
56	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	56	L-20407R056	RINGR25	33008	-16740	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
57	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	57	L-20407R057	RINGR25	33008	-16742.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
58	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	58	L-20407R058	RINGR25	33008	-16745	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
59	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	59	L-20407R059	RINGR25	33008	-16747.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
60	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	60	L-20407R060	RINGR25	33008	-16750	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
61	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	61	L-20407R061	RINGR25	33008	-16752.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
62	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	62	L-20407R062	RINGR25	33008	-16755	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
63	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2,3))	63	L-20407R063	RINGR25	33008	-16757.5	-204	#FERFORI(MATCH(P1#B2,Infra_Co#H2+M2#5.0)ABS(M2-INDEX(Infra_Co#B1#D3,MATCH(KO#RingR_expert1#Infra_Co#B1#E3,0.2))ABS(					
64	LEFT(N2,LEN LEFT(RIGHT(H2 +VALUE(RIGHT(C2,3))	RIGHT(H2,4)	+VALUE(RIGHT(E2												

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1		LHD																					
2							LH514	LH514E															
3		Loading Bucket Capacity	m3			11	7	7															
4		Relative Density	kg/m3			2.68	2.68	2.68															
5		Bulking Factor	%			0.5	0.5	0.5															
6		Moisture content	%			0	0	0															
7		Relative Density After Blast	kg/m3			=F4/(1+F5)	=G4/(1+G5)	=H4/(1+H5)															
8		Fill Factor	%			0.9	0.9	0.9															
9		Full Speed	km/hr			11.9	9.2	9.2															
10		Empty speed	%			3.5	10	3.2															
11		Efficiency on speed	%			0.8	0.85	0.8															
12		Applied speed	km/hr			=F11*F9	=G11*G9	=H11*H9															
13		Loading	s			=60/3600	=60/3600	=60/3600															
14		Tipping	s			=30/3600	=30/3600	=30/3600															
15		Cornering penalty				=30/1000/F9	=30/1000/G9	=30/1000/H9															
16		Total Fixed Cycle time	s			=SUM(F13:F15)	=SUM(G13:G15)	=SUM(H13:H15)															
17		Bucket load	t			=F5*F11*F8	=G5*G1*G8	=H5*H1*H8															
18		Cost per hour				651	651	412															
19		Meters per hour					=G12*1000																
20		TonMeters per hour					=G19*G17																
21		Cost per TonMeter					=G18/G20																
22		TRUCK					TH663	TH550	TH540														
23		*Loading Bucket Capacity	m3			32	28	22															
24		*Relative Density	kg/m3			2.68	2.68	2.68															
25		*Bulking Factor	%			0.5	0.5	0.5															
26		*Moisture content	%			0	0	0															
27		*Relative Density After Blast	kg/m3			=F24/(1+F25)	=G24/(1+G25)	=H24/(1+H25)															
28		*Fill Factor	%			0.92	0.92	0.92															
29		*Travel Speed full (km/hr)	%			30	16	22															
30		*Travel Speed empty (km/hr)	%			3.5	18	22															
31		*Efficiency on speed	%			0.8	1	0.8															
32		*Applied speed	km/hr			=F23*F31	=G23*G31	=H23*H31															
33		*Loading	hr			=180/3600	=180/3600	=180/3600															
34		*Tipping	hr			=120/3600	=120/3600	=120/3600															
35		*Cornering penalty				=30/1000/F29	=30/1000/G29	=30/1000/H29															
36		*Total Fixed Cycle time	hr			=SUM(F33:F35)	=SUM(G33:G35)	=SUM(H33:H35)															
37		*Bucket load	t			=F23*F21*F28	=G23*G21*G28	=H23*H21*H28															
38		*Cost per hour				280	280																
39		Meters per hour					=G32*1000																
40		TonMeters per hour					=G33*G37																
41		Cost per TonMeter					=G38/G40																
42																							
43		LHD to Truck cost ratio					=G21/G41		**LHD is 18.78 time														
44																							
45																							
46																							
47																							
48																							
49																							
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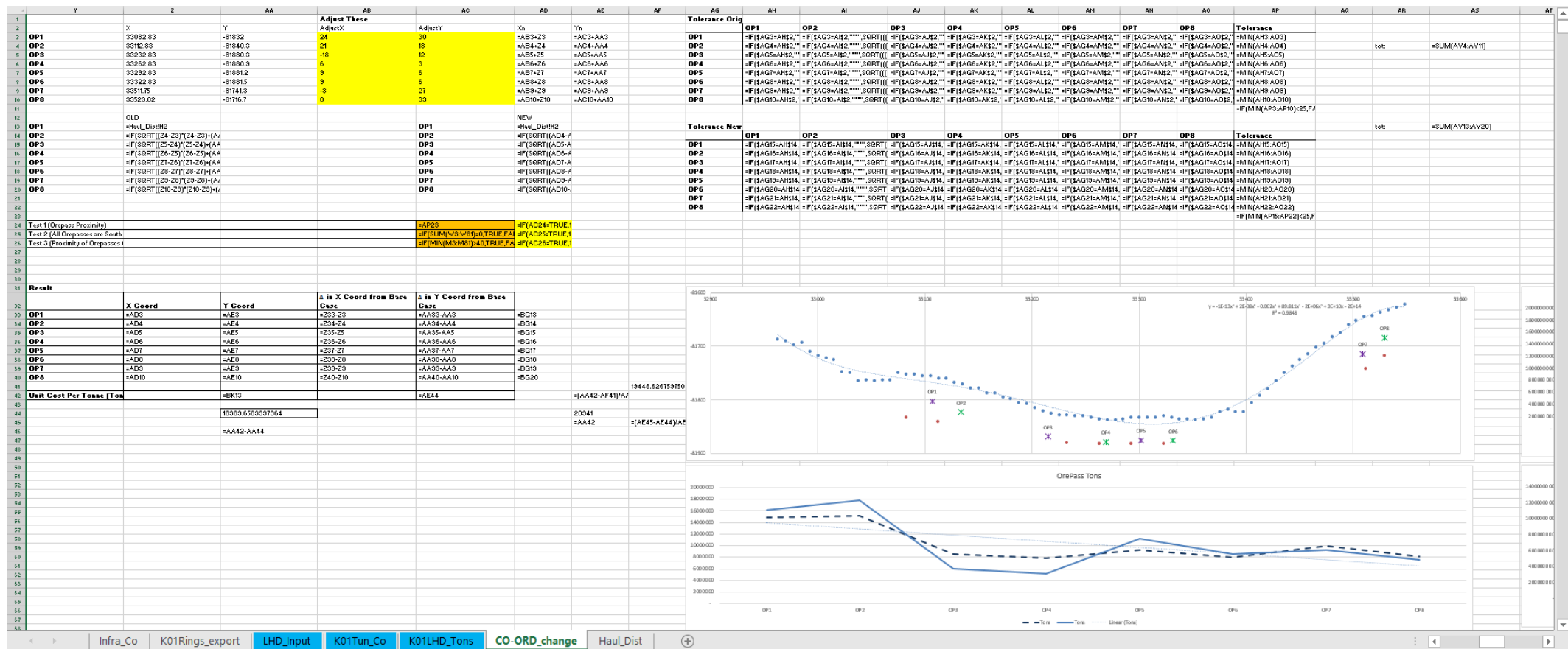
[illegible]

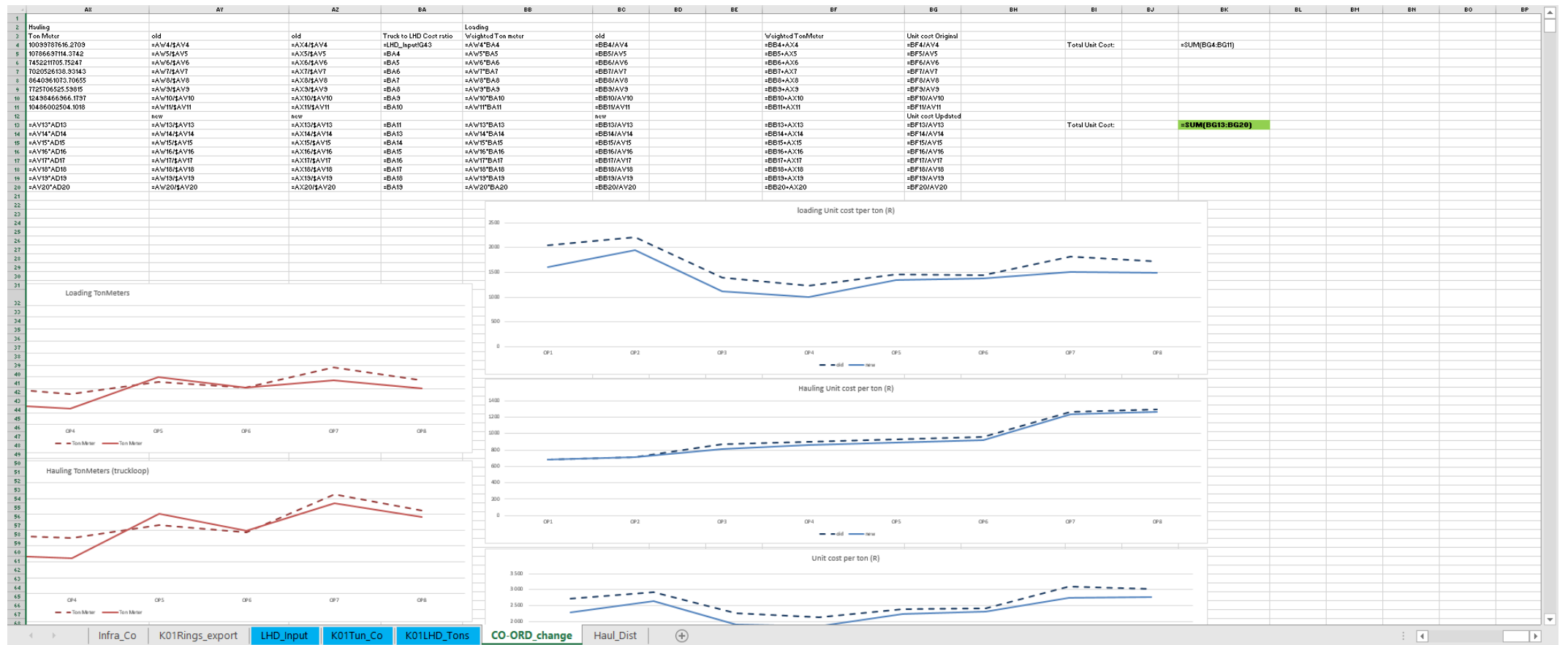
[illegible]

[illegible]

[illegible]

	B	C	D	E	F	G	H	I	J	K	L
1											
2	YOB	YOB									
3	30006	MINIF(KOIRings)									
4	30023	MINIF(KOIRings)									
5	30036	MINIF(KOIRings)									
6	30055	MINIF(KOIRings)									
7	30068	MINIF(KOIRings)									
8	30083	MINIF(KOIRings)									
9	30098	MINIF(KOIRings)									
10	30115	MINIF(KOIRings)									
11	30138	MINIF(KOIRings)									
12	30143	MINIF(KOIRings)									
13	30158	MINIF(KOIRings)									
14	30173	MINIF(KOIRings)									
15	30188	MINIF(KOIRings)									
16	30203	MINIF(KOIRings)									
17	30218	MINIF(KOIRings)									
18	30230	MINIF(KOIRings)									
19	30245	MINIF(KOIRings)									
20	30263	MINIF(KOIRings)									
21	30278	MINIF(KOIRings)									
22	30280	MINIF(KOIRings)									
23	30300	MINIF(KOIRings)									
24	30320	MINIF(KOIRings)									
25	30338	MINIF(KOIRings)									
26	30355	MINIF(KOIRings)									
27	30368	MINIF(KOIRings)									
28	30380	MINIF(KOIRings)									
29	30398	MINIF(KOIRings)									
30	30410	MINIF(KOIRings)									
31	30428	MINIF(KOIRings)									
32	30443	MINIF(KOIRings)									
33	30458	MINIF(KOIRings)									
34	30470	MINIF(KOIRings)									
35	30488	MINIF(KOIRings)									
36	30500	MINIF(KOIRings)									
37	30000.5	MINIF(KOIRings)									
38	30005.5	MINIF(KOIRings)									
39	30010.5	MINIF(KOIRings)									
40	30045.5	MINIF(KOIRings)									
41	30060.5	MINIF(KOIRings)									
42	30075.5	MINIF(KOIRings)									
43	30090.5	MINIF(KOIRings)									
44	30105.5	MINIF(KOIRings)									
45	30120.5	MINIF(KOIRings)									
46	30135.5	MINIF(KOIRings)									
47	30150.5	MINIF(KOIRings)									
48	30165.5	MINIF(KOIRings)									
49	30180.5	MINIF(KOIRings)									
50	30195.5	MINIF(KOIRings)									
51	30210.5	MINIF(KOIRings)									
52	30225.5	MINIF(KOIRings)									
53	30240.5	MINIF(KOIRings)									
54	30255.5	MINIF(KOIRings)									
55	30270.5	MINIF(KOIRings)									
56	30285.5	MINIF(KOIRings)									
57	30300.5	MINIF(KOIRings)									
58	30315.5	MINIF(KOIRings)									
59	30330.5	MINIF(KOIRings)									
60	30345.5	MINIF(KOIRings)									
61	30360.5	MINIF(KOIRings)									
62	30375.5	MINIF(KOIRings)									
63	30390.5	MINIF(KOIRings)									
64	30405.5	MINIF(KOIRings)									
65	30420.5	MINIF(KOIRings)									
66	30435.5	MINIF(KOIRings)									
67	30450.5	MINIF(KOIRings)									
68	30465.5	MINIF(KOIRings)									
69	30480.5	MINIF(KOIRings)									
70	30495.5	MINIF(KOIRings)									
71	30510.5	MINIF(KOIRings)									
72	30525.5	MINIF(KOIRings)									
73	30540.5	MINIF(KOIRings)									
74	30555.5	MINIF(KOIRings)									
75	30570.5	MINIF(KOIRings)									
76	30585.5	MINIF(KOIRings)									
77	30600.5	MINIF(KOIRings)									
78	30615.5	MINIF(KOIRings)									
79	30630.5	MINIF(KOIRings)									
80	30645.5	MINIF(KOIRings)									
81	30660.5	MINIF(KOIRings)									
82	30675.5	MINIF(KOIRings)									
83	30690.5	MINIF(KOIRings)									
84	30705.5	MINIF(KOIRings)									
85	30720.5	MINIF(KOIRings)									
86	30735.5	MINIF(KOIRings)									
87	30750.5	MINIF(KOIRings)									
88	30765.5	MINIF(KOIRings)									
89	30780.5	MINIF(KOIRings)									
90	30795.5	MINIF(KOIRings)									
91	30810.5	MINIF(KOIRings)									
92	30825.5	MINIF(KOIRings)									
93	30840.5	MINIF(KOIRings)									
94	30855.5	MINIF(KOIRings)									
95	30870.5	MINIF(KOIRings)									
96	30885.5	MINIF(KOIRings)									
97	30900.5	MINIF(KOIRings)									
98	30915.5	MINIF(KOIRings)									
99	30930.5	MINIF(KOIRings)									
100	30945.5	MINIF(KOIRings)									
101	30960.5	MINIF(KOIRings)									
102	30975.5	MINIF(KOIRings)									
103	30990.5	MINIF(KOIRings)									
104	31005.5	MINIF(KOIRings)									
105	31020.5	MINIF(KOIRings)									
106	31035.5	MINIF(KOIRings)									
107	31050.5	MINIF(KOIRings)									
108	31065.5	MINIF(KOIRings)									
109	31080.5	MINIF(KOIRings)									
110	31095.5	MINIF(KOIRings)									
111	31110.5	MINIF(KOIRings)									
112	31125.5	MINIF(KOIRings)									
113	31140.5	MINIF(KOIRings)									
114	31155.5	MINIF(KOIRings)									
115	31170.5	MINIF(KOIRings)									
116	31185.5	MINIF(KOIRings)									
117	31200.5	MINIF(KOIRings)									
118	31215.5	MINIF(KOIRings)									
119	31230.5	MINIF(KOIRings)									
120	31245.5	MINIF(KOIRings)									
121	31260.5	MINIF(KOIRings)									
122	31275.5	MINIF(KOIRings)									
123	31290.5	MINIF(KOIRings)									
124	31305.5	MINIF(KOIRings)									
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126	31335.5	MINIF(KOIRings)									
127	31350.5	MINIF(KOIRings)									
128	31365.5	MINIF(KOIRings)									
129	31380.5	MINIF(KOIRings)									
130	31395.5	MINIF(KOIRings)									
131	31410.5	MINIF(KOIRings)									
132	31425.5	MINIF(KOIRings)									
133	31440.5	MINIF(KOIRings)									
134	31455.5	MINIF(KOIRings)									
135	31470.5	MINIF(KOIRings)									
136	31485.5	MINIF(KOIRings)									
137	31500.5	MINIF(KOIRings)									
138	31515.5	MINIF(KOIRings)									
139	31530.5	MINIF(KOIRings)									
140	31545.5	MINIF(KOIRings)									
141	31560.5	MINIF(KOIRings)									
142	31575.5	MINIF(KOIRings)									
143	31590.5	MINIF(KOIRings)									
144	31605.5	MINIF(KOIRings)									
145	31620.5	MINIF(KOIRings)									
146	31635.5	MINIF(KOIRings)									
147	31650.5	MINIF(KOIRings)									
148	31665.5	MINIF(KOIRings)									
149	31680.5	MINIF(KOIRings)									
150	31695.5	MINIF(KOIRings)									
151	31710.5	MINIF(KOIRings)									
152	31725.5	MINIF(KOIRings)									
153	31740.5	MINIF(KOIRings)									
154	31755.5	MINIF(KOIRings)									
155	31770.5	MINIF(KOIRings)									
156	31785.5	MINIF(KOIRings)									
157	31800.5	MINIF(KOIRings)									
158	31815.5	MINIF(KOIRings)									
159	31830.5	MINIF(KOIRings)									
160	31845.5	MINIF(KOIRings)									
161	31860.5	MINIF(KOIRings)									
162	31875.5	MINIF(KOIRings)									
163	31890.5	MINIF(KOIRings)									
164	31905.5	MINIF(KOIRings)									
165	31920.5	MINIF(KOIRings)									
166	31935.5	MINIF(KOIRings)									
167	31950.5	MINIF(KOIRings)									
168	31965.5	MINIF(KOIRings)									
169	31980.5	MINIF(KOIRings)									
170	31995.5	MINIF(KOIRings)									
171	32010.5	MINIF(KOIRings)									
17											





	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1				CR1_Full	CR1_Empty	CR2_Full	CR2_Empty	CR_Full	CR_Empty																					
2	K01	OP1	K01OP1	710	550	648	612	679	581																					
3	K01	OP2	K01OP2	740	520	678	582	709	551	30																				
4	K01	OP3	K01OP3	899	704	837	766	868	735	159																				
5	K01	OP4	K01OP4	929	674	867	736	898	705	30																				
6	K01	OP5	K01OP5	959	704	897	766	928	735	30																				
7	K01	OP6	K01OP6	989	729	927	796	958	763	30																				
8	K01	OP7	K01OP7	1 289	1 161	1 227	1 223	1 258	1 192	300																				
9	K01	OP8	K01OP8	1 319	1 134	1 257	1 196	1 288	1 165	30																				
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36																														
37																														

Infra_Co

K01Rings_export

LHD_Input

K01Tun_Co

K01LHD_Tons

CO-ORD_change

Haul_Dist

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1				CR1_Full	CR1_Empty	CR2_Full	CR2_Empty	CR_Full	CR_Empty						
2	K01	OP1	=A2&B2	710	550	648	612	=(AVERAGE(D2,F2))	=(AVERAGE(E2,G2))						
3	K01	OP2	=A3&B3	740	520	678	582	=(AVERAGE(D3,F3))	=(AVERAGE(E3,G3))	=H3-H2					
4	K01	OP3	=A4&B4	899	704	837	766	=(AVERAGE(D4,F4))	=(AVERAGE(E4,G4))	=H4-H3					
5	K01	OP4	=A5&B5	929	674	867	736	=(AVERAGE(D5,F5))	=(AVERAGE(E5,G5))	=H5-H4					
6	K01	OP5	=A6&B6	959	704	897	766	=(AVERAGE(D6,F6))	=(AVERAGE(E6,G6))	=H6-H5					
7	K01	OP6	=A7&B7	989	729	927	796	=(AVERAGE(D7,F7))	=(AVERAGE(E7,G7))	=H7-H6					
8	K01	OP7	=A8&B8	1289	1161	1227	1223	=(AVERAGE(D8,F8))	=(AVERAGE(E8,G8))	=H8-H7					
9	K01	OP8	=A9&B9	1319	1134	1257	1196	=(AVERAGE(D9,F9))	=(AVERAGE(E9,G9))	=H9-H8					
10															
11															
12															
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37															

7.3. Genetic algorithm results

Evolver: Optimization Summary

Performed By: Dabula, Gangatha

Date: Friday, 24 November 2017 10:13:34

Model:

VUP_TMM_K01Prod_orepass_positioning_GA_03.xlsx

Goal	
Cell to Optimize	'CO-ORD_change'!BK13
Type of Goal	Minimum

Results	Value
Valid Trials	2425
Total Trials	13463
Original Value	20
+ soft constraint penalties	941
= result	0.00
Best Value Found	20
+ soft constraint penalties	941
= result	18
Best Trial Number	390
Time to Find Best Value	13448
Reason Optimization Stopped	68:34:02
Time Optimization Started	Progress condition
Time Optimization Finished	2017/11/21 10:36
Total Optimization Time	2017/11/24 10:05
Adjustable Cell Values	68:37:15
Original	'CO-ORD_change'!AB3
Best	0
Adjustable Cell Values	37.82610017
Original	'CO-ORD_change'!AC3
Best	0
Adjustable Cell Values	21.32116131
Original	'CO-ORD_change'!AB4
Best	0
Adjustable Cell Values	30.29991736
Original	'CO-ORD_change'!AC4
Best	0
Adjustable Cell Values	15.66648159
Original	'CO-ORD_change'!AB5
Best	0
Adjustable Cell Values	-1.673127429
Original	'CO-ORD_change'!AC5
Best	0
Adjustable Cell Values	11.40634955
Adjustable Cell Values	'CO-ORD_change'!AB6

Results	Value
Original	0
Best	-1.11627671
Adjustable Cell Values	'CO-ORD_change'!AC6
Original	0
Best	4.376889683
Adjustable Cell Values	'CO-ORD_change'!AB7
Original	0
Best	4.714062557
Adjustable Cell Values	'CO-ORD_change'!AC7
Original	0
Best	8.052916246
Adjustable Cell Values	'CO-ORD_change'!AB8
Original	0
Best	-0.316691766
Adjustable Cell Values	'CO-ORD_change'!AC8
Original	0
Best	9.61961244
Adjustable Cell Values	'CO-ORD_change'!AB9
Original	0
Best	-17.61245208
Adjustable Cell Values	'CO-ORD_change'!AC9
Original	0
Best	9.151308113
Adjustable Cell Values	'CO-ORD_change'!AB10
Original	0
Best	-16.78058285
Adjustable Cell Values	'CO-ORD_change'!AC10
Original	0
Best	9.853712483

Constraints	Value
Description	AD24 = 1
Definition	AD24 = 1
Constraint Type	Hard
Precision	0
Satisfied for % of Trials	78.64%
Description	AD25 = 1
Definition	AD25 = 1
Constraint Type	Hard
Precision	0
Satisfied for % of Trials	87.94%
Description	AD26 = 1
Definition	AD26 = 1
Constraint Type	Hard

Results	Value
Precision	0
Satisfied for % of Trials	28.63%

Adjustable Cells	Value
Description	
Solving Method	Recipe
Cell Range	-150<= 'CO-ORD_change'!AB3:AC10 <= 150

Optimization Settings	Value
Runtime	
Trials	FALSE
Time	FALSE
Progress	TRUE
Maximum Change	0.10%
Number of Trials	10000
Formula	FALSE
Stop on Error	FALSE
Engine	
Random # Generator Seed	70926072 (Chosen Randomly)
Optimization Engine	Genetic Algorithm
Population Size	60
Mutation Rate	0.25
Crossover Rate	0.5
Operators (scores)	Default parent selection (0.2500)
	Default mutation (0.2500)
	Default crossover (0.2500)
	Default backtrack (0.2500)
Macros	
At Start of Optimization	N/A
Before Recalculation	N/A
After Recalculation	N/A
After Storing Output	N/A
At End of Optimization	N/A

Evolver: Log of Progress Steps

Performed By: Dabula, Gangatha

Date: Friday, 24 November 2017 10:13:50

Model: VUP_TMM_K01Prod_orepass_positioning_GA_03.xlsx

Trial	Elapsed Time	Result	Adjustable Cells																Hard Constraints		
			AB3	AC3	AB4	AC4	AB5	AC5	AB6	AC6	AB7	AC7	AB8	AC8	AB9	AC9	AB10	AC10	AD24 = 1	AD25 = 1	AD26 = 1
1	00:00:18	20 941	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
13	00:03:04	20 940	0	0	0	0	0	2	0	-1	1	-2	0	0	0	0	0	0	1	1	1
16	00:03:46	20 912	0	2	0	0	-2	2	3	-1	-1	-2	-1	0	-2	0	0	0	1	1	1
19	00:04:27	20 857	0	0	0	0	-2	2	3	-1	-1	0	-1	3	-2	0	0	0	1	1	1
23	00:05:22	20 855	0	0	0	0	-2	3	3	-1	-1	0	-1	3	-2	0	0	0	1	1	1
31	00:07:10	20 773	0	0	0	0	-2	3	0	-1	1	1	-1	3	-4	0	0	0	1	1	1
33	00:07:38	20 741	0	0	0	0	-2	2	0	-1	1	1	-1	5	-4	0	0	0	1	1	1
51	00:11:39	20 691	0	0	0	2	0	2	0	-1	1	1	-1	5	-6	0	0	0	1	1	1
60	00:13:32	20 642	-1	0	0	2	0	4	0	1	1	-1	-3	5	-9	0	0	0	1	1	1
63	00:14:08	20 609	0	0	0	2	1	4	-2	3	-1	-1	-3	5	-9	0	0	1	1	1	1
66	00:14:43	20 546	0	0	0	1	1	7	-2	3	-1	-1	-3	6	-8	0	0	1	1	1	1
69	00:15:19	20 523	0	0	0	2	1	7	-2	3	-4	1	-3	6	-8	0	0	1	1	1	1
76	00:16:41	20 522	-2	0	0	1	1	7	-2	3	-4	1	-3	6	-8	2	0	1	1	1	1
79	00:17:17	20 498	-2	0	0	1	1	7	-2	3	-3	1	-3	6	-9	2	0	1	1	1	1
83	00:18:04	20 494	-2	0	0	1	1	7	-2	3	-3	1	-3	6	-9	2	0	1	1	1	1
86	00:18:39	20 485	-2	1	0	1	1	6	-2	3	-3	1	-3	6	-9	5	0	1	1	1	1
96	00:20:37	20 449	-2	1	0	1	1	9	-3	3	-3	1	-3	5	-9	5	0	1	1	1	1
106	00:22:36	20 447	-2	1	0	1	1	9	-3	3	-2	1	-3	5	-9	5	0	1	1	1	1
112	00:23:49	20 400	-2	1	0	1	1	9	-3	3	-2	2	-2	8	-9	4	0	-1	1	1	1
118	00:25:00	20 389	-2	1	0	1	1	10	-3	1	-2	2	-2	8	-9	4	-1	-1	1	1	1
128	00:26:58	20 388	-2	1	0	1	1	10	-3	1	-2	2	-2	8	-9	4	-1	-1	1	1	1
135	00:28:22	20 382	-2	1	0	2	1	10	-3	1	-2	2	-2	8	-9	4	-1	-1	1	1	1
142	00:29:45	20 381	-2	1	0	1	1	10	-3	1	-2	2	-2	8	-9	4	-1	-1	1	1	1

150	00:31:20	20 286	-2	2	1	1	-1	10	-1	3	-2	5	-1	8	-10	4	-1	-1	1	1	1
153	00:31:55	20 277	-2	3	1	1	-1	10	-1	3	-2	5	-1	8	-8	6	-2	2	1	1	1
167	00:34:40	20 276	-2	2	1	2	-1	10	-1	3	-2	4	-1	8	-8	6	-2	2	1	1	1
171	00:35:27	20 276	-2	2	1	2	-1	10	-1	3	-2	4	-1	8	-8	6	-2	2	1	1	1
174	00:36:02	20 241	-2	2	1	2	-1	10	-1	3	-2	4	-1	8	-8	6	-5	2	1	1	1
179	00:37:05	20 195	-2	2	1	4	2	10	-1	3	-2	4	-1	8	-8	6	-5	2	1	1	1
183	00:37:59	20 191	-2	2	1	4	2	10	-1	3	-2	4	-1	8	-8	6	-5	2	1	1	1
187	00:38:53	20 188	-2	2	1	4	2	10	-1	4	-2	4	-1	8	-8	6	-5	2	1	1	1
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194	00:40:29	20 153	-2	2	1	4	0	10	-1	4	-2	5	-1	8	-8	6	-6	2	1	1	1
198	00:41:23	20 153	-2	2	1	4	0	10	-1	4	-2	5	-1	8	-8	6	-6	2	1	1	1
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209	00:43:50	20 110	-2	2	1	4	0	10	-1	3	-2	5	-1	8	-8	5	-5	18	1	1	1
215	00:45:11	20 087	-1	0	1	4	0	10	-1	3	-2	5	-1	8	-8	5	-8	17	1	1	1
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313	01:06:57	19 826	-1	-9	30	10	-1	10	-1	4	-2	6	1	8	-13	5	-7	17	1	1	1
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333	01:11:20	19 777	-1	-9	29	10	-1	10	-1	4	-2	6	1	8	-14	5	-9	17	1	1	1
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588	02:05:36	19 692	-1	-8	29	12	-1	11	-2	3	-2	6	0	8	-17	6	-10	17	1	1	1
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638	02:16:17	19 689	-1	-8	29	11	-1	11	-2	3	-2	6	0	8	-17	6	-10	17	1	1	1
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11655	47:51:59	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11665	47:54:37	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11674	47:56:59	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11692	48:01:33	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11699	48:03:17	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11708	48:05:32	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11717	48:08:02	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11732	48:11:29	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11740	48:13:22	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11757	48:17:43	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11774	48:21:54	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11791	48:25:55	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11797	48:27:19	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11820	48:32:48	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11830	48:35:09	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11845	48:38:47	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11863	48:43:17	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11915	48:56:10	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11931	49:00:05	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11939	49:01:59	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11957	49:06:30	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
11986	49:13:22	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12002	49:17:24	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12023	49:22:30	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12032	49:24:42	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12054	49:30:18	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12063	49:32:30	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1

12071	49:34:30	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12081	49:36:59	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12090	49:39:15	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12117	49:46:06	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12136	49:50:57	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12164	49:58:03	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12180	50:02:15	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12194	50:05:37	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12203	50:07:55	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12217	50:11:31	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12237	50:16:23	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12246	50:18:37	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12255	50:20:51	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12281	50:27:09	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12299	50:31:38	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12329	50:39:10	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12423	51:04:04	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12459	51:12:53	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12480	51:18:00	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12502	51:23:12	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12512	65:11:36	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12519	65:13:12	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12525	65:14:32	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12535	65:16:46	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12545	65:19:26	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12555	65:21:56	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12564	65:24:02	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12574	65:26:15	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12592	65:30:09	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12599	65:31:43	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1

12617	65:35:53	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12641	65:41:06	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12672	65:47:43	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12686	65:50:49	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12699	65:53:56	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12710	65:56:27	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12734	66:01:57	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12776	66:11:29	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12799	66:16:35	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12829	66:23:17	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12836	66:24:48	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12845	66:26:45	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12853	66:28:30	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12864	66:30:52	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12872	66:32:35	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12881	66:34:33	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12897	66:38:01	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12914	66:41:42	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12921	66:43:12	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12930	66:45:09	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12977	66:55:28	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12986	66:57:26	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
12993	66:59:00	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13004	67:01:27	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13027	67:06:13	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13036	67:08:05	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13053	67:11:36	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13058	67:12:38	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13121	67:25:30	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13162	67:33:49	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1

13178	67:37:05	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13212	67:43:59	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13220	67:45:37	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13265	67:55:01	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13275	67:57:07	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13285	67:59:18	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13300	68:02:37	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13307	68:04:08	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13315	68:05:52	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13343	68:11:51	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13352	68:13:46	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13361	68:15:39	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13373	68:18:07	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13383	68:20:12	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13392	68:22:04	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13415	68:26:51	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13423	68:28:37	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13432	68:30:31	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1
13448	68:34:02	18 390	38	21	30	16	-2	11	-1	4	5	8	0	10	-18	9	-17	10	1	1	1

7.4. Genetic algorithm Microsoft Excel model - spreadsheet and formulae

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
1		Orepass	X	Y		K01 Orepass	Level	Tips			Level																		
2	K01	OP1	33120.66	-81810.7		OP1	L196	OP1L196			L196	A																	
3	K01	OP2	33143.13	-81824.6		OP3	L196	OP3L196			L171	B																	
4	K01	OP3	33231.16	-81868.9		OP5	L196	OP5L196			L146	A																	
5	K01	OP4	33261.71	-81876.5		OP7	L196	OP7L196			L121	B																	
6	K01	OP5	33297.54	-81873.1		OP2	L171	OP2L171			L96	A																	
7	K01	OP6	33322.51	-81871.9		OP4	L171	OP4L171			L71	B																	
8	K01	OP7	33494.14	-81732.1		OP6	L171	OP6L171			L46	A																	
9	K01	OP8	33512.24	-81706.8		OP8	L171	OP8L171			L21	B																	
10	K01	Waste	32991.54	-81806.2		OP1	L146	OP1L146			L-4	A																	
11						OP3	L146	OP3L146			L-29	B																	
12	K02	OP1	32556.86	-81636.2		OP5	L146	OP5L146			L-54	A																	
13	K02	OP2	32525.91	-81544		OP7	L146	OP7L146			L-79	B																	
14	K02	OP3	32499.58	-81457.6		OP2	L121	OP2L121			L-104	A																	
15	K02	OP4	32473.25	-81371.8		OP4	L121	OP4L121			L-129	B																	
16	K02	OP5	32456.17	-81314.9		OP6	L121	OP6L121			L-154	A																	
17	K02	Waste	32676.65	-81825.2		OP8	L121	OP8L121			L-179	B																	
18						OP1	L96	OP1L96			L-204	A																	
19		CR1	32775.59	-82016.9		OP3	L96	OP3L96																					
20		CR2	32858.27	-81951.6		OP5	L96	OP5L96																					
21						OP7	L96	OP7L96																					
22						OP2	L71	OP2L71																					
23						OP4	L71	OP4L71																					
24						OP6	L71	OP6L71																					
25						OP8	L71	OP8L71																					
26						OP1	L46	OP1L46																					
27						OP3	L46	OP3L46																					
28						OP5	L46	OP5L46																					
29						OP7	L46	OP7L46																					
30						OP2	L21	OP2L21																					
31						OP4	L21	OP4L21																					
32						OP6	L21	OP6L21																					
33						OP8	L21	OP8L21																					
34						OP1	L-4	OP1L-4																					
35						OP3	L-4	OP3L-4																					
36						OP5	L-4	OP5L-4																					
37						OP7	L-4	OP7L-4																					

	A	B	C	D	E	F	G	H	I	J	K	L	M	
1		Orepass	X	Y		K01 Orepass	Level	Tips			Level			
2	K01	OP1	=CO-ORD_change!AD3	=CO-ORD_change!AE3		OP1	L196	=F2&G2			L196	A		
3	K01	OP2	=CO-ORD_change!AD4	=CO-ORD_change!AE4		OP3	=G2	=F3&G3			L171	B		
4	K01	OP3	=CO-ORD_change!AD5	=CO-ORD_change!AE5		OP5	=G3	=F4&G4			L146	A		
5	K01	OP4	=CO-ORD_change!AD6	=CO-ORD_change!AE6		OP7	=G4	=F5&G5			L121	B		
6	K01	OP5	=CO-ORD_change!AD7	=CO-ORD_change!AE7		OP2	L171	=F6&G6			L96	A		
7	K01	OP6	=CO-ORD_change!AD8	=CO-ORD_change!AE8		OP4	=G6	=F7&G7			L71	B		
8	K01	OP7	=CO-ORD_change!AD9	=CO-ORD_change!AE9		OP6	=G7	=F8&G8			L46	A		
9	K01	OP8	=CO-ORD_change!AD10	=CO-ORD_change!AE10		OP8	=G8	=F9&G9			L21	B		
10	K01	Waste	32991.54	-81806.2		OP1	L146	=F10&G10			L-4	A		
11						OP3	=G10	=F11&G11			L-29	B		
12	K02	OP1	32556.86	-81636.18		OP5	=G11	=F12&G12			L-54	A		
13	K02	OP2	32525.91	-81544.02		OP7	=G12	=F13&G13			L-79	B		
14	K02	OP3	32499.58	-81457.56		OP2	L121	=F14&G14			L-104	A		
15	K02	OP4	32473.25	-81371.81		OP4	=G14	=F15&G15			L-129	B		
16	K02	OP5	32456.17	-81314.88		OP6	=G15	=F16&G16			L-154	A		
17	K02	Waste	32676.65	-81825.22		OP8	=G16	=F17&G17			L-179	B		
18						OP1	L96	=F18&G18			L-204	A		
19		CR1	32775.59	-82016.91		OP3	=G18	=F19&G19						
20		CR2	32858.27	-81951.6		OP5	=G19	=F20&G20						
21						OP7	=G20	=F21&G21						
22						OP2	L71	=F22&G22						
23						OP4	=G22	=F23&G23						
24						OP6	=G23	=F24&G24						
25						OP8	=G24	=F25&G25						
26						OP1	L46	=F26&G26						
27						OP3	=G26	=F27&G27						
28						OP5	=G27	=F28&G28						
29						OP7	=G28	=F29&G29						
30						OP2	L21	=F30&G30						
31						OP4	=G30	=F31&G31						
32						OP6	=G31	=F32&G32						
33						OP8	=G32	=F33&G33						
34						OP1	L-4	=F34&G34						
35						OP3	=G34	=F35&G35						
36						OP5	=G35	=F36&G36						
37						OP7	=G36	=F37&G37						

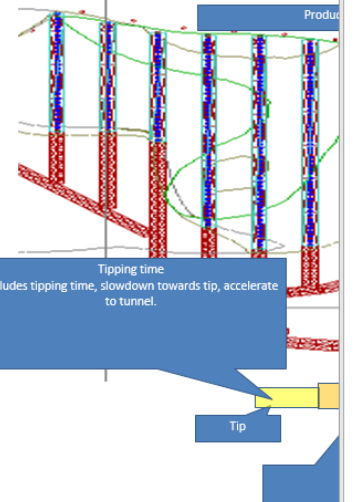
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G	H	I	J	L	M	N	O	P	Q	R
Ring ID	Ring Name	Ring Name Alias	Tuned Name	Tuned Name Alias	Shape	X	Y	Z	TOP	TOP2
1	L-240AT0SR001	L-240AT0S	RING125	33008	-816105	-204	#####	#####	#####	#####
2	L-240AT0SR002	L-240AT0S	RING125	33008	-816105	-204	#####	#####	#####	#####
3	L-240AT0SR003	L-240AT0S	RING125	33008	-816105	-204	#####	#####	#####	#####
4	L-240AT0SR004	L-240AT0S	RING125	33008	-81610	-204	#####	#####	#####	#####
5	L-240AT0SR005	L-240AT0S	RING125	33008	-816125	-204	#####	#####	#####	#####
6	L-240AT0SR006	L-240AT0S	RING125	33008	-81615	-204	#####	#####	#####	#####
7	L-240AT0SR007	L-240AT0S	RING125	33008	-816175	-204	#####	#####	#####	#####
8	L-240AT0SR008	L-240AT0S	RING125	33008	-81620	-204	#####	#####	#####	#####
9	L-240AT0SR009	L-240AT0S	RING125	33008	-816225	-204	#####	#####	#####	#####
10	L-240AT0SR010	L-240AT0S	RING125	33008	-81625	-204	#####	#####	#####	#####
11	L-240AT0SR011	L-240AT0S	RING125	33008	-816275	-204	#####	#####	#####	#####
12	L-240AT0SR012	L-240AT0S	RING125	33008	-81630	-204	#####	#####	#####	#####
13	L-240AT0SR013	L-240AT0S	RING125	33008	-816325	-204	#####	#####	#####	#####
14	L-240AT0SR014	L-240AT0S	RING125	33008	-81635	-204	#####	#####	#####	#####
15	L-240AT0SR015	L-240AT0S	RING125	33008	-816375	-204	#####	#####	#####	#####
16	L-240AT0SR016	L-240AT0S	RING125	33008	-81640	-204	#####	#####	#####	#####
17	L-240AT0SR017	L-240AT0S	RING125	33008	-816425	-204	#####	#####	#####	#####
18	L-240AT0SR018	L-240AT0S	RING125	33008	-81645	-204	#####	#####	#####	#####
19	L-240AT0SR019	L-240AT0S	RING125	33008	-816475	-204	#####	#####	#####	#####
20	L-240AT0SR020	L-240AT0S	RING125	33008	-81650	-204	#####	#####	#####	#####
21	L-240AT0SR021	L-240AT0S	RING125	33008	-816525	-204	#####	#####	#####	#####
22	L-240AT0SR022	L-240AT0S	RING125	33008	-81655	-204	#####	#####	#####	#####
23	L-240AT0SR023	L-240AT0S	RING125	33008	-816575	-204	#####	#####	#####	#####
24	L-240AT0SR024	L-240AT0S	RING125	33008	-81660	-204	#####	#####	#####	#####
25	L-240AT0SR025	L-240AT0S	RING125	33008	-816625	-204	#####	#####	#####	#####
26	L-240AT0SR026	L-240AT0S	RING125	33008	-81665	-204	#####	#####	#####	#####
27	L-240AT0SR027	L-240AT0S	RING125	33008	-816675	-204	#####	#####	#####	#####
28	L-240AT0SR028	L-240AT0S	RING125	33008	-81670	-204	#####	#####	#####	#####
29	L-240AT0SR029	L-240AT0S	RING125	33008	-816725	-204	#####	#####	#####	#####
30	L-240AT0SR030	L-240AT0S	RING125	33008	-81675	-204	#####	#####	#####	#####
31	L-240AT0SR031	L-240AT0S	RING125	33008	-816775	-204	#####	#####	#####	#####
32	L-240AT0SR032	L-240AT0S	RING125	33008	-81680	-204	#####	#####	#####	#####
33	L-240AT0SR033	L-240AT0S	RING125	33008	-816825	-204	#####	#####	#####	#####
34	L-240AT0SR034	L-240AT0S	RING125	33008	-81685	-204	#####	#####	#####	#####
35	L-240AT0SR035	L-240AT0S	RING125	33008	-816875	-204	#####	#####	#####	#####
36	L-240AT0SR036	L-240AT0S	RING125	33008	-81690	-204	#####	#####	#####	#####
37	L-240AT0SR037	L-240AT0S	RING125	33008	-816925	-204	#####	#####	#####	#####
38	L-240AT0SR038	L-240AT0S	RING125	33008	-81695	-204	#####	#####	#####	#####
39	L-240AT0SR039	L-240AT0S	RING125	33008	-816975	-204	#####	#####	#####	#####
40	L-240AT0SR040	L-240AT0S	RING125	33008	-81700	-204	#####	#####	#####	#####
41	L-240AT0SR001	L-240AT0S	RING125	33023	-8155	-204	#####	#####	#####	#####
42	L-240AT0SR002	L-240AT0S	RING125	33023	-81575	-204	#####	#####	#####	#####
43	L-240AT0SR003	L-240AT0S	RING125	33023	-81595	-204	#####	#####	#####	#####
44	L-240AT0SR004	L-240AT0S	RING125	33023	-81525	-204	#####	#####	#####	#####
45	L-240AT0SR005	L-240AT0S	RING125	33023	-8155	-204	#####	#####	#####	#####
46	L-240AT0SR006	L-240AT0S	RING125	33023	-81575	-204	#####	#####	#####	#####
47	L-240AT0SR007	L-240AT0S	RING125	33023	-81595	-204	#####	#####	#####	#####
48	L-240AT0SR008	L-240AT0S	RING125	33023	-81625	-204	#####	#####	#####	#####
49	L-240AT0SR009	L-240AT0S	RING125	33023	-81605	-204	#####	#####	#####	#####
50	L-240AT0SR010	L-240AT0S	RING125	33023	-816075	-204	#####	#####	#####	#####
51	L-240AT0SR011	L-240AT0S	RING125	33023	-81630	-204	#####	#####	#####	#####
52	L-240AT0SR012	L-240AT0S	RING125	33023	-816325	-204	#####	#####	#####	#####
53	L-240AT0SR013	L-240AT0S	RING125	33023	-81635	-204	#####	#####	#####	#####
54	L-240AT0SR014	L-240AT0S	RING125	33023	-816375	-204	#####	#####	#####	#####
55	L-240AT0SR015	L-240AT0S	RING125	33023	-81640	-204	#####	#####	#####	#####
56	L-240AT0SR016	L-240AT0S	RING125	33023	-816425	-204	#####	#####	#####	#####
57	L-240AT0SR017	L-240AT0S	RING125	33023	-81645	-204	#####	#####	#####	#####
58	L-240AT0SR018	L-240AT0S	RING125	33023	-816475	-204	#####	#####	#####	#####
59	L-240AT0SR019	L-240AT0S	RING125	33023	-81650	-204	#####	#####	#####	#####
60	L-240AT0SR020	L-240AT0S	RING125	33023	-816525	-204	#####	#####	#####	#####
61	L-240AT0SR021	L-240AT0S	RING125	33023	-81655	-204	#####	#####	#####	#####
62	L-240AT0SR022	L-240AT0S	RING125	33023	-816575	-204	#####	#####	#####	#####
63	L-240AT0SR023	L-240AT0S	RING125	33023	-81660	-204	#####	#####	#####	#####
64	L-240AT0SR024	L-240AT0S	RING125	33023	-816625	-204	#####	#####	#####	#####
65	L-240AT0SR025	L-240AT0S	RING125	33023	-81665	-204	#####	#####	#####	#####
66	L-240AT0SR026	L-240AT0S	RING125	33023	-816675	-204	#####	#####	#####	#####
67	L-240AT0SR027	L-240AT0S	RING125	33023	-81670	-204	#####	#####	#####	#####
68	L-240AT0SR028	L-240AT0S	RING125	33023	-816725	-204	#####	#####	#####	#####
69	L-240AT0SR029	L-240AT0S	RING125	33023	-81675	-204	#####	#####	#####	#####
70	L-240AT0SR030	L-240AT0S	RING125	33023	-816775	-204	#####	#####	#####	#####
71	L-240AT0SR031	L-240AT0S	RING125	33023	-81680	-204	#####	#####	#####	#####
72	L-240AT0SR032	L-240AT0S	RING125	33023	-816825	-204	#####	#####	#####	#####
73	L-240AT0SR033	L-240AT0S	RING125	33023	-81685	-204	#####	#####	#####	#####
74	L-240AT0SR034	L-240AT0S	RING125	33023	-816875	-204	#####	#####	#####	#####
75	L-240AT0SR035	L-240AT0S	RING125	33023	-81690	-204	#####	#####	#####	#####
76	L-240AT0SR036	L-240AT0S	RING125	33023	-816925	-204	#####	#####	#####	#####
77	L-240AT0SR037	L-240AT0S	RING125	33023	-81695	-204	#####	#####	#####	#####
78	L-240AT0SR038	L-240AT0S	RING125	33023	-816975	-204	#####	#####	#####	#####
79	L-240AT0SR039	L-240AT0S	RING125	33023	-81700	-204	#####	#####	#####	#####
80	L-240AT0SR040	L-240AT0S	RING125	33023	-817025	-204	#####	#####	#####	#####

[illegible]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1		LHD																					
2							LH514	LH514E															
3		Loading Bucket Capacity	m3			11	7	7															
4		Relative Density	kg/m3			2.68	2.68	2.68															
5		Bulking Factor	%			0.5	0.5	0.5															
6		Moisture content	%			0	0	0															
7		Relative Density After Blast	kg/m3			=F4/(1+F5)	=G4/(1+G5)	=H4/(1+H5)															
8		Fill Factor	%			0.9	0.9	0.9															
9		Full Speed	km/hr			11.9	9.2	9.2															
10		Empty speed	%			3.5	3.2	3.2															
11		Efficiency on speed	%			0.8	0.85	0.8															
12		Applied speed	km/hr			=F11*F9	=G11*G9	=H11*H9															
13		Loading	s			=60/3600	=60/3600	=60/3600															
14		Tipping	s			=30/3600	=30/3600	=30/3600															
15		Cornering penalty				=30/1000/F9	=30/1000/G9	=30/1000/H9															
16		Total Fixed Cycle time	s			=SUM(F13:F15)	=SUM(G13:G15)	=SUM(H13:H15)															
17		Bucket load	t			=F5*F7*F8	=G5*G7*G8	=H5*H7*H8															
18		Cost per hour					651	412															
19		Meters per hour					=G12*1000																
20		TonMeters per hour					=G19*G17																
21		Cost per TonMeter					=G18/G20																
22		TRUCK					TH663	TH550	TH540														
23		*Loading Bucket Capacity	m3			32	28	22															
24		*Relative Density	kg/m3			2.68	2.68	2.68															
25		*Bulking Factor	%			0.5	0.5	0.5															
26		*Moisture content	%			0	0	0															
27		*Relative Density After Blast	kg/m3			=F24/(1+F25)	=G24/(1+G25)	=H24/(1+H25)															
28		*Fill Factor	%			0.92	0.92	0.92															
29		*Travel Speed Full (km/hr)	%			30	16	22															
30		*Travel Speed empty (km/hr)	%			3.5	16	22															
31		*Efficiency on speed	%			0.8	1	0.8															
32		*Applied speed	km/hr			=F23*F31	=G23*G31	=H23*H31															
33		*Loading	hr			=180/3600	=180/3600	=180/3600															
34		*Tipping	hr			=120/3600	=120/3600	=120/3600															
35		*Cornering penalty				=30/1000/F29	=30/1000/G29	=30/1000/H29															
36		*Total Fixed Cycle time	hr			=SUM(F33:F35)	=SUM(G33:G35)	=SUM(H33:H35)															
37		*Bucket load	t			=F23*F27*F28	=G23*G27*G28	=H23*H27*H28															
38		*Cost per hour					280																
39		Meters per hour					=G32*1000																
40		TonMeters per hour					=G33*G37																
41		Cost per TonMeter					=G38/G40																
42																							
43		LHD to Truck cost ratio					=G21/G41		**LHD is 18.78 times														
44																							
45																							
46																							
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49																							
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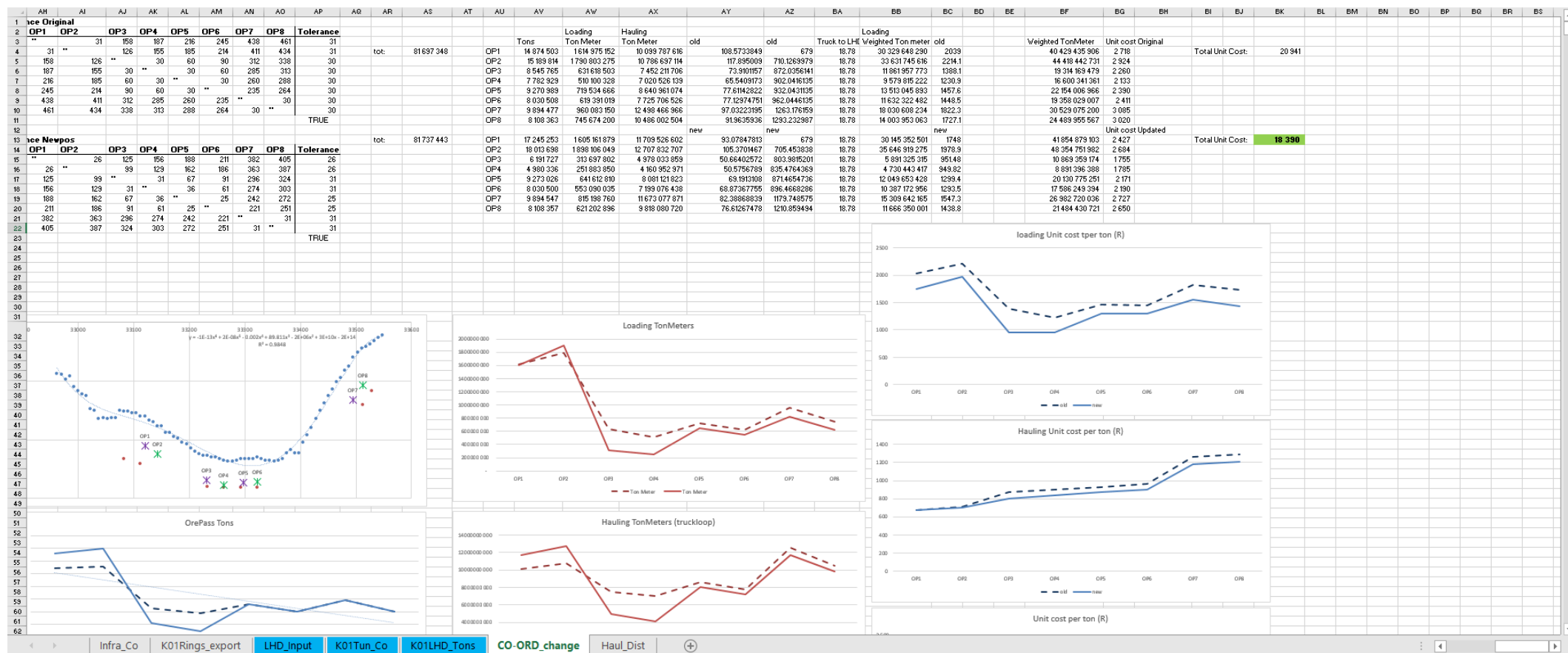
[illegible]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1																						
2																						
3																						
4		Coloma Labels																				
5		L-104																				
6	Row Labels	Mis of X	Mis of Y	Max of X	Max of Y	L121 Mis of X	Mis of Y	Max of X	Max of Y	L-129 Mis of X	Mis of Y	Max of X	Max of Y	L146 Mis of X	Mis of Y	Max of X	Max of Y	L-154 Mis of X	Mis of Y	Max of X	Max of Y	L171 Mis of X
7	T012																					
8	T013					32385.5	-81685	32390.5	-81627.5	33000.5	-81702.5	33000.5	-81622.5	32978	-81687.5	32978	-81635	33008	-81701.5	33008	-81630	33000.5
9	T014	32393	-81680	32393	-81627.5	33000.5	-81687.5	33000.5	-81620	33000.5	-81702.5	33000.5	-81622.5	32993	-81690	32993	-81635	33008	-81701.5	33008	-81630	33000.5
10	T015	33008	-81715	33008	-81671.5	33005.5	-81690	33005.5	-81625	33005.5	-81715	33005.5	-81615	33008	-81630	33008	-81635	33008	-81701.5	33008	-81630	33005.5
11	T016	33023	-81722.5	33023	-81610	33030.5	-81735	33030.5	-81627.5	33030.5	-81735	33030.5	-81612.5	33023	-81730	33023	-81635	33023	-81722.5	33023	-81615	33030.5
12	T017	33038	-81730	33038	-81607.5	33045.5	-81742.5	33045.5	-81630	33045.5	-81740	33045.5	-81607.5	33038	-81750	33038	-81612.5	33038	-81735	33038	-81612.5	33045.5
13	T018	33053	-81740	33053	-81605	33060.5	-81745	33060.5	-81630	33060.5	-81745	33060.5	-81605	33053	-81755	33053	-81637.5	33053	-81740	33053	-81607.5	33060.5
14	T019	33068	-81750	33068	-81605	33075.5	-81755	33075.5	-81632.5	33075.5	-81750	33075.5	-81607.5	33068	-81760	33068	-81640	33068	-81745	33068	-81605	33075.5
15	T020	33083	-81755	33083	-81607.5	33090.5	-81760	33090.5	-81637.5	33090.5	-81755	33090.5	-81610	33083	-81765	33083	-81645	33083	-81750	33083	-81607.5	33090.5
16	T021	33098	-81750	33098	-81612.5	33105.5	-81760	33105.5	-81640	33105.5	-81752.5	33105.5	-81612.5	33098	-81765	33098	-81642.5	33098	-81752.5	33098	-81612.5	33105.5
17	T022	33113	-81752.5	33113	-81617.5	33120.5	-81760	33120.5	-81640	33120.5	-81757.5	33120.5	-81617.5	33113	-81760	33113	-81640	33113	-81755	33113	-81615	33120.5
18	T023	33128	-81757.5	33128	-81620	33135.5	-81762.5	33135.5	-81642.5	33135.5	-81765	33135.5	-81642.5	33128	-81770	33128	-81642.5	33128	-81762.5	33128	-81620	33135.5
19	T024	33143	-81765	33143	-81627.5	33150.5	-81770	33150.5	-81645	33150.5	-81772.5	33150.5	-81652.5	33143	-81775	33143	-81647.5	33143	-81770	33143	-81630	33150.5
20	T025	33158	-81775	33158	-81635	33165.5	-81780	33165.5	-81642.5	33165.5	-81782.5	33165.5	-81640	33158	-81790	33158	-81645	33158	-81780	33158	-81640	33165.5
21	T026	33173	-81785	33173	-81640	33180.5	-81790	33180.5	-81640	33180.5	-81792.5	33180.5	-81645	33173	-81795	33173	-81642.5	33173	-81790	33173	-81647.5	33180.5
22	T027	33188	-81795	33188	-81645	33195.5	-81800	33195.5	-81640	33195.5	-81802.5	33195.5	-81652.5	33188	-81800	33188	-81640	33188	-81800	33188	-81647.5	33195.5
23	T028	33203	-81805	33203	-81655	33210.5	-81810	33210.5	-81640	33210.5	-81815	33210.5	-81665	33203	-81815	33203	-81640	33203	-81815	33203	-81642.5	33210.5
24	T029	33218	-81820	33218	-81667.5	33225.5	-81825	33225.5	-81630	33225.5	-81825	33225.5	-81635	33218	-81825	33218	-81637.5	33218	-81822.5	33218	-81627.5	33225.5
25	T030	33233	-81825	33233	-81677.5	33240.5	-81830	33240.5	-81635	33240.5	-81832.5	33240.5	-81640	33233	-81835	33233	-81645	33233	-81827.5	33233	-81642.5	33240.5
26	T031	33248	-81827.5	33248	-81685	33255.5	-81832.5	33255.5	-81640	33255.5	-81835	33255.5	-81645	33248	-81840	33248	-81690	33248	-81827.5	33248	-81697.5	33255.5
27	T032	33263	-81827.5	33263	-81695	33260.5	-81835	33260.5	-81645	33260.5	-81837.5	33260.5	-81650	33263	-81840	33263	-81695	33263	-81827.5	33263	-81722.5	33270.5
28	T033	33278	-81827.5	33278	-81705	33265.5	-81835	33265.5	-81650	33265.5	-81837.5	33265.5	-81655	33278	-81845	33278	-81705	33278	-81825	33278	-81725	33285.5
29	T034	33293	-81825	33293	-81722.5	33300.5	-81830	33300.5	-81710	33300.5	-81822.5	33300.5	-81720	33293	-81830	33293	-81700	33293	-81822.5	33293	-81722.5	33300.5
30	T035	33308	-81822.5	33308	-81737.5	33315.5	-81830	33315.5	-81725	33315.5	-81820	33315.5	-81725	33308	-81835	33308	-81705	33308	-81820	33308	-81737.5	33315.5
31	T036	33323	-81820	33323	-81747.5	33320.5	-81832.5	33320.5	-81735	33320.5	-81825	33320.5	-81735	33323	-81840	33323	-81715	33323	-81815	33323	-81747.5	33330.5
32	T037	33338	-81815.5	33338	-81655	33345.5	-81835	33345.5	-81745	33345.5	-81825	33345.5	-81655	33338	-81845	33338	-81725	33338	-81815.5	33338	-81655	33345.5
33	T038	33353	-81810	33353	-81675	33360.5	-81835	33360.5	-81655	33360.5	-81802.5	33360.5	-81655	33353	-81850	33353	-81695	33353	-81802.5	33353	-81675	33360.5
34	T039	33368	-81800	33368	-81685.5	33375.5	-81835	33375.5	-81665	33375.5	-81800	33375.5	-81660	33368	-81855	33368	-81690	33368	-81825.5	33368	-81685.5	33375.5
35	T040	33383	-81772.5	33383	-81642.5	33380.5	-81820	33380.5	-81680	33380.5	-81740	33380.5	-81637.5	33383	-81860	33383	-81687.5	33383	-81757.5	33383	-81642.5	33390.5
36	T041	33398	-81735	33398	-81655	33405.5	-81802.5	33405.5	-81685	33405.5	-81740	33405.5	-81627.5	33398	-81865	33398	-81707.5	33398	-81695	33398	-81655	33405.5
37	T042	33413	-81720	33413	-81675	33420.5	-81775	33420.5	-81660	33420.5	-81700	33420.5	-81582.5	33413	-81790	33413	-81675	33413	-81692.5	33413	-81602.5	33420.5
38	T043	33428	-81707.5	33428	-81575	33435.5	-81742.5	33435.5	-81562.5	33435.5	-81685	33435.5	-81567.5	33428	-81765	33428	-81595	33428	-81685	33428	-81570	33435.5
39	T044	33443	-81670	33443	-81567.5	33450.5	-81720	33450.5	-81575	33450.5	-81667.5	33450.5	-81565	33443	-81732.5	33443	-81575	33443	-81670	33443	-81565	33450.5
40	T045	33458	-81665	33458	-81585	33465.5	-81700	33465.5	-81570	33465.5	-81662.5	33465.5	-81560	33458	-81712.5	33458	-81570	33458	-81665	33458	-81585	33465.5
41	T046	33473	-81660	33473	-81562.5	33480.5	-81695	33480.5	-81560	33480.5	-81562.5	33480.5	-81560	33473	-81695	33473	-81565	33473	-81657.5	33473	-81562.5	33480.5
42	T047	33488	-81645	33488	-81560	33495.5	-81660	33495.5	-81550	33495.5	-81630	33495.5	-81560	33488	-81672.5	33488	-81552.5	33488	-81640	33488	-81560	33495.5
43	T048	33503	-81622.5	33503	-81562.5	33510.5	-81645	33510.5	-81547.5	33510.5	-81605	33510.5	-81572.5	33503	-81650	33503	-81547.5	33503	-81615	33503	-81565	33510.5
44	T049					33525.5	-81635	33525.5	-81592.5					33518	-81640	33518	-81547.5					33525.5
45	T050					33540.5	-81627.5	33540.5	-81597.5					33533	-81630	33533	-81555					33540.5
46	T051													33548	-81622.5	33548	-81575					
47	(blank)																					
48	Grand Total	32993	-81827.5	33503	-81560	32985.5	-81837.5	33540.5	-81547.5	33000.5	-81827.5	33510.5	-81560	32978	-81837.5	33548	-81547.5	33008	-81827.5	33503	-81560	32970.5
49		#B5				#F5								#J5				#N5				#S5
50	#A7	=SORT((D7-B7)*(D7-B7)*(C7-E7)*(C7-E7))				=SORT((H7-F7)*(H7-F7)*(G7-I7)*(G7-I7))								=SORT((L7-J7)*(L7-J7))				=SORT((P7-N7)*(P7-N7))				=SORT((T7-R7)*(T7-R7))
51	#A8	=SORT((D8-B8)*(D8-B8)*(C8-E8)*(C8-E8))				=SORT((H8-F8)*(H8-F8)*(G8-I8)*(G8-I8))								=SORT((L8-J8)*(L8-J8))				=SORT((P8-N8)*(P8-N8))				=SORT((T8-R8)*(T8-R8))
52	#A9	=SORT((D9-B9)*(D9-B9)*(C9-E9)*(C9-E9))				=SORT((H9-F9)*(H9-F9)*(G9-I9)*(G9-I9))								=SORT((L9-J9)*(L9-J9))				=SORT((P9-N9)*(P9-N9))				=SORT((T9-R9)*(T9-R9))
53	#A10	=SORT((D10-B10)*(D10-B10)*(C10-E10)*(C10-E10))				=SORT((H10-F10)*(H10-F10)*(G10-I10)*(G10-I10))								=SORT((L10-J10)*(L10-J10))				=SORT((P10-N10)*(P10-N10))				=SORT((T10-R10)*(T10-R10))
54	#A11	=SORT((D11-B11)*(D11-B11)*(C11-E11)*(C11-E11))				=SORT((H11-F11)*(H11-F11)*(G11-I11)*(G11-I11))								=SORT((L11-J11)*(L11-J11))				=SORT((P11-N11)*(P11-N11))				=SORT((T11-R11)*(T11-R11))
55	#A12	=SORT((D12-B12)*(D12-B12)*(C12-E12)*(C12-E12))				=SORT((H12-F12)*(H12-F12)*(G12-I12)*(G12-I12))								=SORT((L12-J12)*(L12-J12))				=SORT((P12-N12)*(P12-N12))				=SORT((T12-R12)*(T12-R12))
56	#A13	=SORT((D13-B13)*(D13-B13)*(C13-E13)*(C13-E13))				=SORT((H13-F13)*(H13-F13)*(G13-I13)*(G13-I13))								=SORT((L13-J13)*(L13-J13))				=SORT((P13-N13)*(P13-N13))				=SORT((T13-R13)*(T13-R13))
57	#A14	=SORT((D14-B14)*(D14-B14)*(C14-E14)*(C14-E14))				=SORT((H14-F14)*(H14-F14)*(G14-I14)*(G14-I14))								=SORT((L14-J14)*(L14-J14))				=SORT((P14-N14)*(P14-N14))				=SORT((T14-R14)*(T14-R14))
58	#A15	=SORT((D15-B15																				

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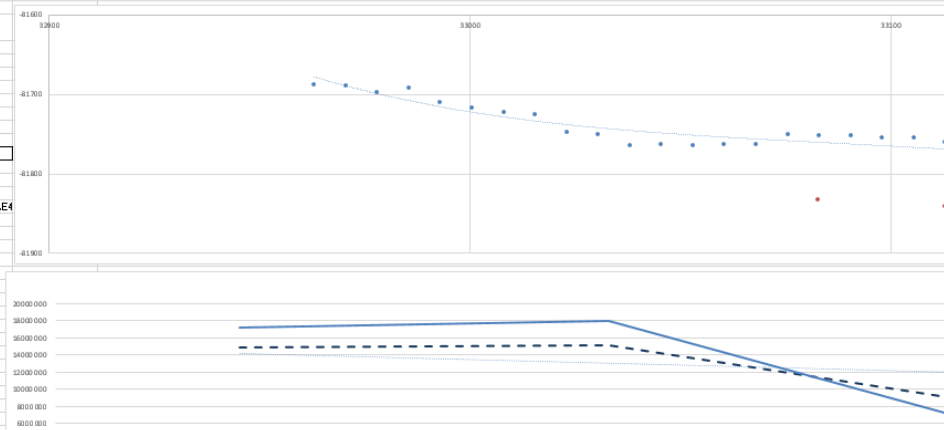


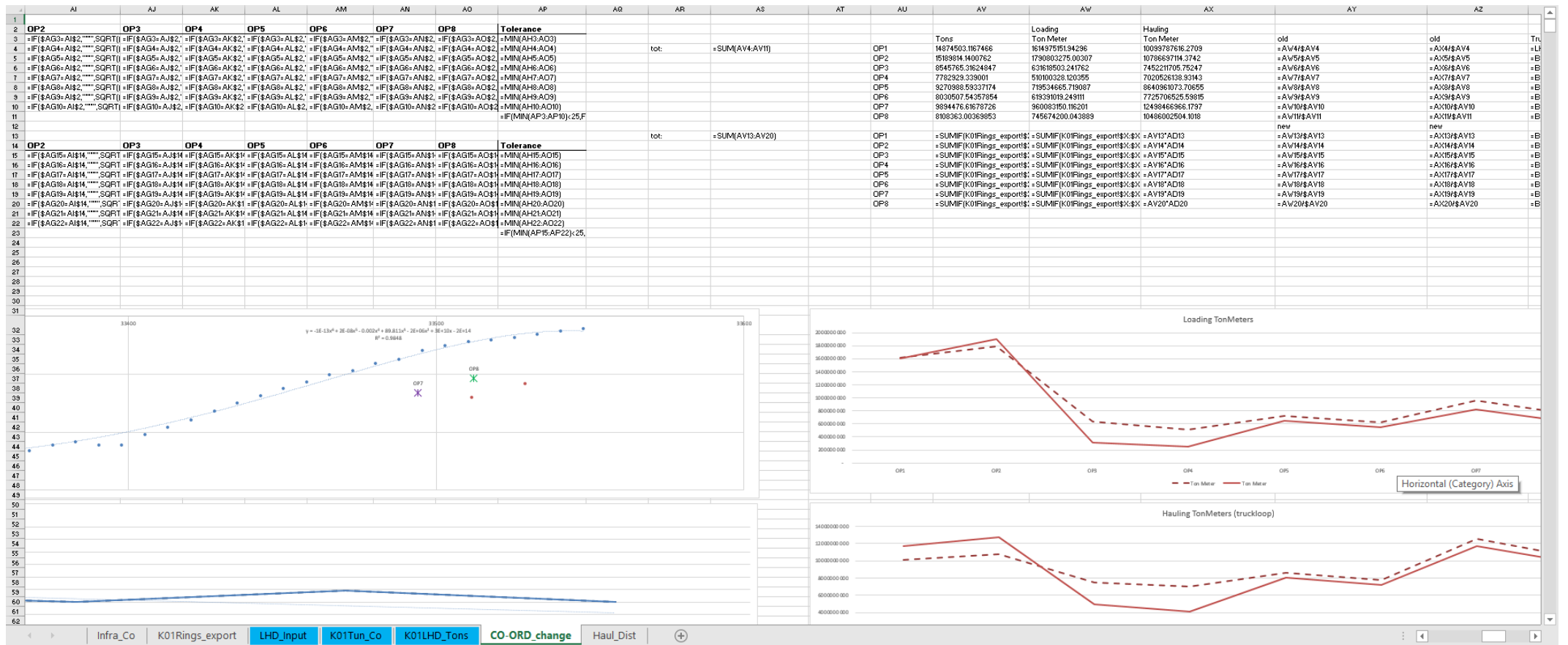
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		Infra_Co	K01Rings_export	LHD_input	K01Tun_Co	K01LHD_Tons	CO-ORD_change	Haul_Dist	

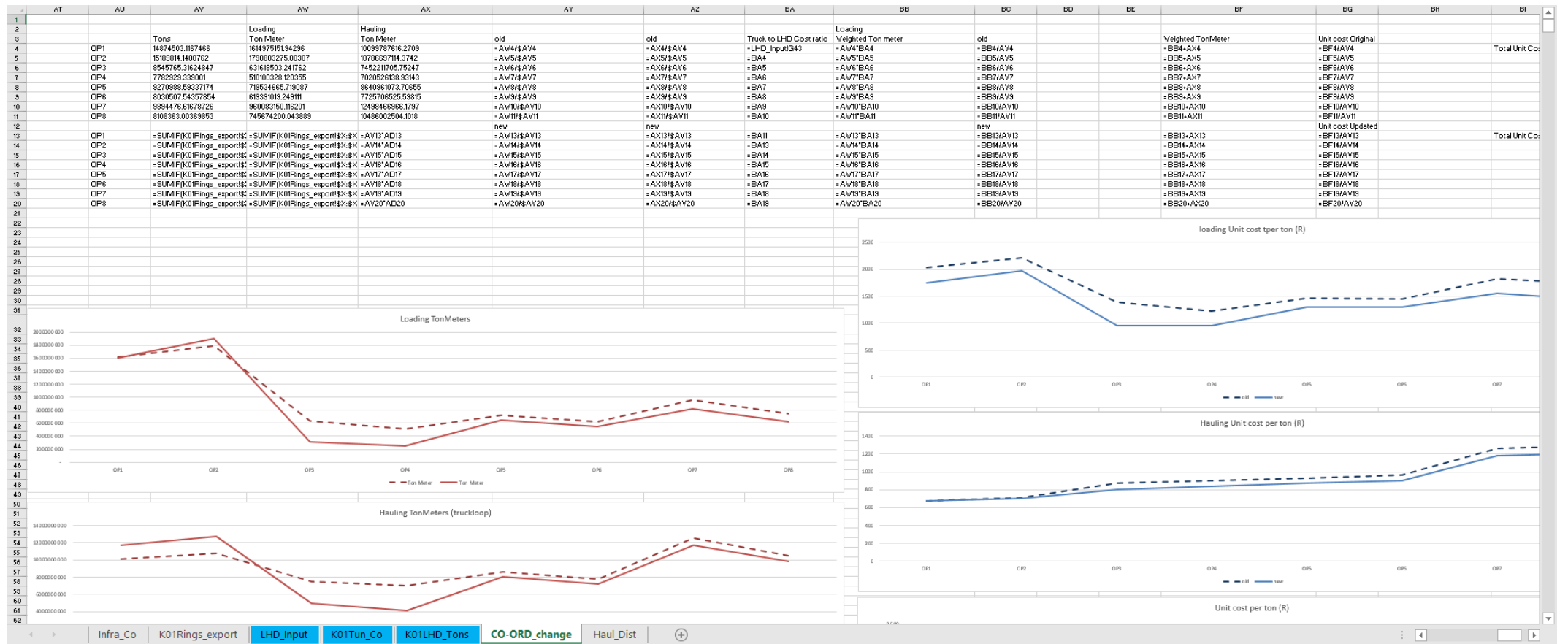
	N	O	P	Q
				Creepages North of Orebods
1	OP1		OP2	OP3
2				OP4
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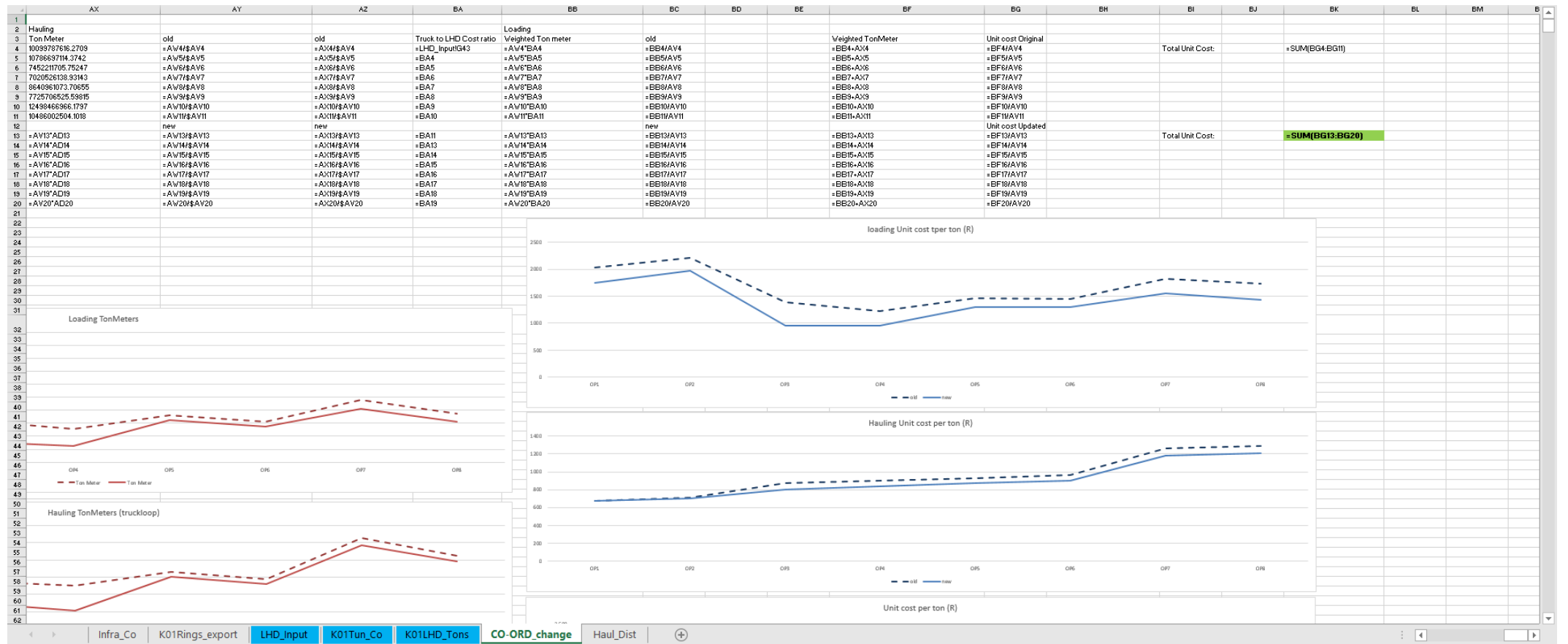
	U	V	W	X	Y	Z	AA	AB	AC	AD	
1	OP7	OP8			X	Y		Adjust These			Yn
2	=IF(AND(INDEX(\$2:\$2,SUM(C3:V3))	=IF(AND(INDEX(\$2:\$2,SUM(C3:V3))			OP1	30082.83	-01832	37.8261001742566	21.321813065569	=AB3-23	=A
3	=IF(AND(INDEX(\$2:\$2,SUM(C4:V4))	=IF(AND(INDEX(\$2:\$2,SUM(C4:V4))			OP2	3312.83	-01840.3	30.239917355502	15.664819319509	=AB4-24	=A
4	=IF(AND(INDEX(\$2:\$2,SUM(C5:V5))	=IF(AND(INDEX(\$2:\$2,SUM(C5:V5))			OP3	33232.83	-01880.3	-16731274285653	11.4063495489035	=AB5-25	=A
5	=IF(AND(INDEX(\$2:\$2,SUM(C6:V6))	=IF(AND(INDEX(\$2:\$2,SUM(C6:V6))			OP4	33262.83	-01880.9	-11627670398676	4.3768968317061	=AB6-26	=A
6	=IF(AND(INDEX(\$2:\$2,SUM(C7:V7))	=IF(AND(INDEX(\$2:\$2,SUM(C7:V7))			OP5	33282.83	-01881.2	4.77406285655552	0.05291824630903	=AB7-27	=A
7	=IF(AND(INDEX(\$2:\$2,SUM(C8:V8))	=IF(AND(INDEX(\$2:\$2,SUM(C8:V8))			OP6	33282.83	-01881.5	-0.36638755661146	9.61961243960759	=AB8-28	=A
8	=IF(AND(INDEX(\$2:\$2,SUM(C9:V9))	=IF(AND(INDEX(\$2:\$2,SUM(C9:V9))			OP7	33511.75	-01741.3	-17.6124520752449	3.15130811316879	=AB9-29	=A
9	=IF(AND(INDEX(\$2:\$2,SUM(C10:V10))	=IF(AND(INDEX(\$2:\$2,SUM(C10:V10))			OP8	33528.02	-01716.7	-16.7805828544241	9.85371248265039	=AB10-210	=A
10	=IF(AND(INDEX(\$2:\$2,SUM(C11:V11))	=IF(AND(INDEX(\$2:\$2,SUM(C11:V11))									
11	=IF(AND(INDEX(\$2:\$2,SUM(C12:V12))	=IF(AND(INDEX(\$2:\$2,SUM(C12:V12))				OLD				NEW	
12	=IF(AND(INDEX(\$2:\$2,SUM(C13:V13))	=IF(AND(INDEX(\$2:\$2,SUM(C13:V13))			OP1	=Haul_DistH2				=Haul_DistH2	
13	=IF(AND(INDEX(\$2:\$2,SUM(C14:V14))	=IF(AND(INDEX(\$2:\$2,SUM(C14:V14))			OP2	=IF(SQRT((Z24-Z3)*(Z4-Z3))				=IF(SQRT((AD4-AD3)*(AD4-AD3)*(AE4-AE3)*(AE4-AE3))	=IF(SQRT((AD4-AD3)*(AD4-AD3)*(AE4-AE3)*(AE4-AE3))
14	=IF(AND(INDEX(\$2:\$2,SUM(C15:V15))	=IF(AND(INDEX(\$2:\$2,SUM(C15:V15))			OP3	=IF(SQRT((Z5-Z4)*(Z5-Z4))				=IF(SQRT((AD5-AD4)*(AD5-AD4)*(AE5-AE4)*(AE5-AE4))	=IF(SQRT((AD5-AD4)*(AD5-AD4)*(AE5-AE4)*(AE5-AE4))
15	=IF(AND(INDEX(\$2:\$2,SUM(C16:V16))	=IF(AND(INDEX(\$2:\$2,SUM(C16:V16))			OP4	=IF(SQRT((Z6-Z5)*(Z6-Z5))				=IF(SQRT((AD6-AD5)*(AD6-AD5)*(AE6-AE5)*(AE6-AE5))	=IF(SQRT((AD6-AD5)*(AD6-AD5)*(AE6-AE5)*(AE6-AE5))
16	=IF(AND(INDEX(\$2:\$2,SUM(C17:V17))	=IF(AND(INDEX(\$2:\$2,SUM(C17:V17))			OP5	=IF(SQRT((Z7-Z6)*(Z7-Z6))				=IF(SQRT((AD7-AD6)*(AD7-AD6)*(AE7-AE6)*(AE7-AE6))	=IF(SQRT((AD7-AD6)*(AD7-AD6)*(AE7-AE6)*(AE7-AE6))
17	=IF(AND(INDEX(\$2:\$2,SUM(C18:V18))	=IF(AND(INDEX(\$2:\$2,SUM(C18:V18))			OP6	=IF(SQRT((Z8-Z7)*(Z8-Z7))				=IF(SQRT((AD8-AD7)*(AD8-AD7)*(AE8-AE7)*(AE8-AE7))	=IF(SQRT((AD8-AD7)*(AD8-AD7)*(AE8-AE7)*(AE8-AE7))
18	=IF(AND(INDEX(\$2:\$2,SUM(C19:V19))	=IF(AND(INDEX(\$2:\$2,SUM(C19:V19))			OP7	=IF(SQRT((Z9-Z8)*(Z9-Z8))				=IF(SQRT((AD9-AD8)*(AD9-AD8)*(AE9-AE8)*(AE9-AE8))	=IF(SQRT((AD9-AD8)*(AD9-AD8)*(AE9-AE8)*(AE9-AE8))
19	=IF(AND(INDEX(\$2:\$2,SUM(C20:V20))	=IF(AND(INDEX(\$2:\$2,SUM(C20:V20))			OP8	=IF(SQRT((Z10-Z9)*(Z10-Z9))				=IF(SQRT((AD10-AD9)*(AD10-AD9)*(AE10-AE9)*(AE10-AE9))	=IF(SQRT((AD10-AD9)*(AD10-AD9)*(AE10-AE9)*(AE10-AE9))
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1 Xn	Yn		Tolerance Orig
2 =AB3-Z3	=AC3-AA3		OP1
3 =AB4-Z4	=AC4-AA4		OP2
4 =AB5-Z5	=AC5-AA5		OP3
5 =AB6-Z6	=AC6-AA6		OP4
6 =AB7-Z7	=AC7-AA7		OP5
7 =AB8-Z8	=AC8-AA8		OP6
8 =AB9-Z9	=AC9-AA9		OP7
9 =AB10-Z10	=AC10-AA10		OP8
11			
12 NEV			Tolerance New
13 =Haul_DistH2			OP1
14 =IF(SQRT((AD4-AD3)*(AD4-AD3)+(AE4-AE3)*(AE4-AE3))>100,AD13-SQRT((AD4-AD3)*(AD4-AD3)+(AE4-AE3)*(AE4-AE3))*1.28)			OP2
15 =IF(SQRT((AD5-AD4)*(AD5-AD4)+(AE5-AE4)*(AE5-AE4))>100,AD14-SQRT((AD5-AD4)*(AD5-AD4)+(AE5-AE4)*(AE5-AE4))*1.28)			OP3
16 =IF(SQRT((AD6-AD5)*(AD6-AD5)+(AE6-AE5)*(AE6-AE5))>100,AD15-SQRT((AD6-AD5)*(AD6-AD5)+(AE6-AE5)*(AE6-AE5))*1.28)			OP4
17 =IF(SQRT((AD7-AD6)*(AD7-AD6)+(AE7-AE6)*(AE7-AE6))>100,AD16-SQRT((AD7-AD6)*(AD7-AD6)+(AE7-AE6)*(AE7-AE6))*1.28)			OP5
18 =IF(SQRT((AD8-AD7)*(AD8-AD7)+(AE8-AE7)*(AE8-AE7))>100,AD17-SQRT((AD8-AD7)*(AD8-AD7)+(AE8-AE7)*(AE8-AE7))*1.28)			OP6
19 =IF(SQRT((AD9-AD8)*(AD9-AD8)+(AE9-AE8)*(AE9-AE8))>100,AD18-SQRT((AD9-AD8)*(AD9-AD8)+(AE9-AE8)*(AE9-AE8))*1.28)			OP7
20 =IF(SQRT((AD10-AD9)*(AD10-AD9)+(AE10-AE9)*(AE10-AE9))>100,AD19-SQRT((AD10-AD9)*(AD10-AD9)+(AE10-AE9)*(AE10-AE9))*1.28)			OP8
21			
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23			
24 =IF(AC24=TRUE,1,0)			
25 =IF(AC25=TRUE,1,0)			
26 =IF(AC26=TRUE,1,0)			
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33 =BG13			
34 =BG14			
35 =BG15			
36 =BG16			
37 =BG17			
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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1				CR1_Full	CR1_Empty	CR2_Full	CR2_Empty	CR_Full	CR_Empty																					
2	K01	OP1	K01OP1	710	550	648	612	679	581																					
3	K01	OP2	K01OP2	740	520	678	582	709	551	30																				
4	K01	OP3	K01OP3	899	704	837	766	868	735	159																				
5	K01	OP4	K01OP4	929	674	867	736	898	705	30																				
6	K01	OP5	K01OP5	959	704	897	766	928	735	30																				
7	K01	OP6	K01OP6	989	729	927	796	958	763	30																				
8	K01	OP7	K01OP7	1 289	1 161	1 227	1 223	1 258	1 192	300																				
9	K01	OP8	K01OP8	1 319	1 134	1 257	1 196	1 288	1 165	30																				
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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1				CR1_Full	CR1_Empty	CR2_Full	CR2_Empty	CR_Full	CR_Empty						
2	K01	OP1	=A2&B2	710	550	648	612	=(AVERAGE(D2,F2))	=(AVERAGE(E2,G2))						
3	K01	OP2	=A3&B3	740	520	678	582	=(AVERAGE(D3,F3))	=(AVERAGE(E3,G3))	=H3-H2					
4	K01	OP3	=A4&B4	899	704	837	766	=(AVERAGE(D4,F4))	=(AVERAGE(E4,G4))	=H4-H3					
5	K01	OP4	=A5&B5	929	674	867	736	=(AVERAGE(D5,F5))	=(AVERAGE(E5,G5))	=H5-H4					
6	K01	OP5	=A6&B6	959	704	897	766	=(AVERAGE(D6,F6))	=(AVERAGE(E6,G6))	=H6-H5					
7	K01	OP6	=A7&B7	989	729	927	796	=(AVERAGE(D7,F7))	=(AVERAGE(E7,G7))	=H7-H6					
8	K01	OP7	=A8&B8	1289	1161	1227	1223	=(AVERAGE(D8,F8))	=(AVERAGE(E8,G8))	=H8-H7					
9	K01	OP8	=A9&B9	1319	1134	1257	1196	=(AVERAGE(D9,F9))	=(AVERAGE(E9,G9))	=H9-H8					
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Infra_Co

K01Rings_export

LHD_input

K01Tun_Co

K01LHD_Tons

CO-ORD_change

Haul_Dist