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MANDELA MINING PRECINCT

Rocker Shovel Improvements

Research findings

Dr S Uludag, 9 Nov 2023

Introduction

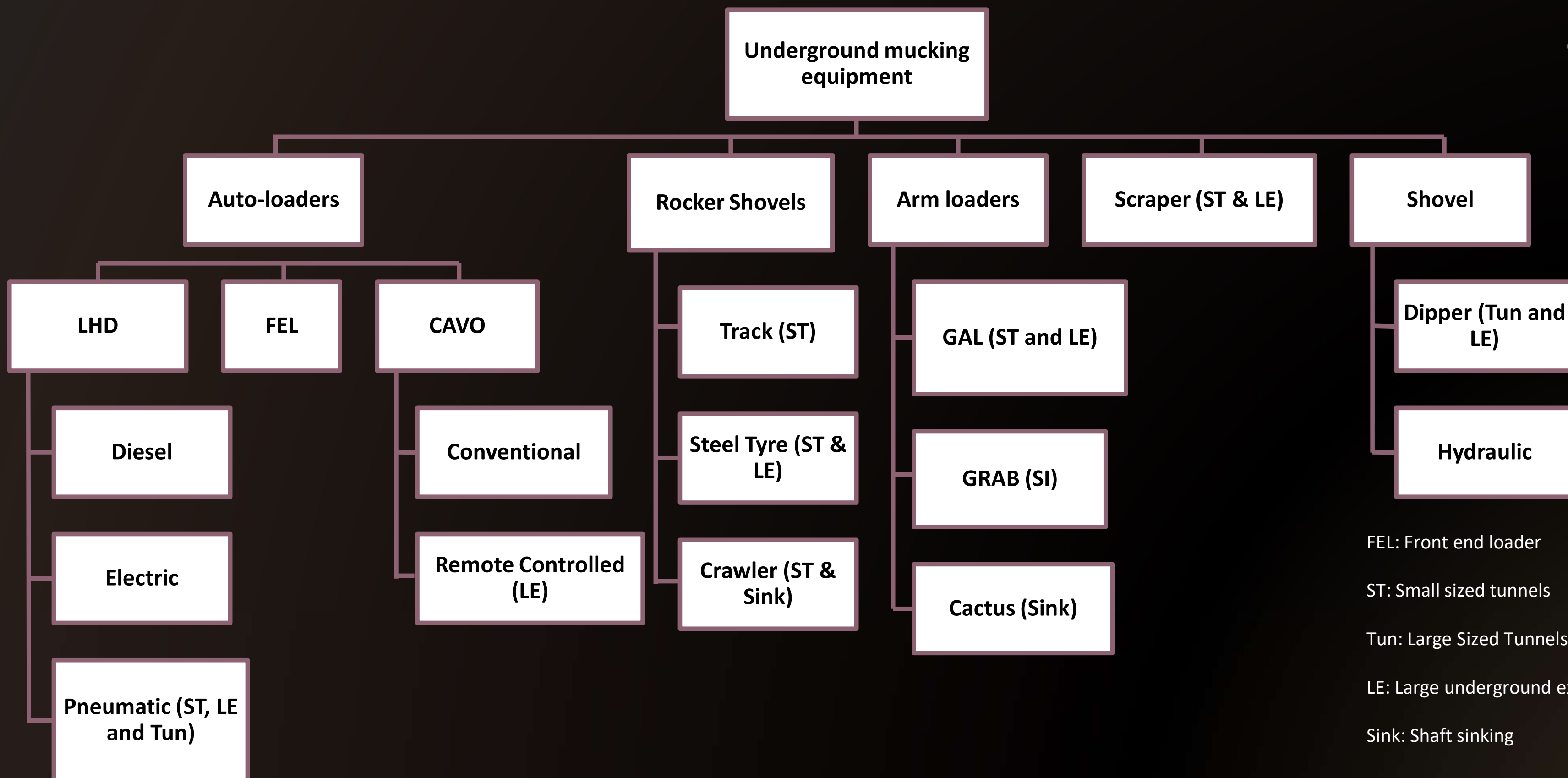
- Dr. S Uludag, University of Pretoria, Mining Engineering Department
- 30 years of mining engineering research and consultancy
- Lead Researcher on WP 6 amd WP5 as part of the LOCM
- PHD in System Dynamics field

Objective of the study

Establish the industry and requirements for the rocker shovel system optimization with potential proximity detection capability

- Cost effective and low maintenance
- Easy to operate and robust
- Sustainable

Types of Underground Mucking Equipment



FEL: Front end loader

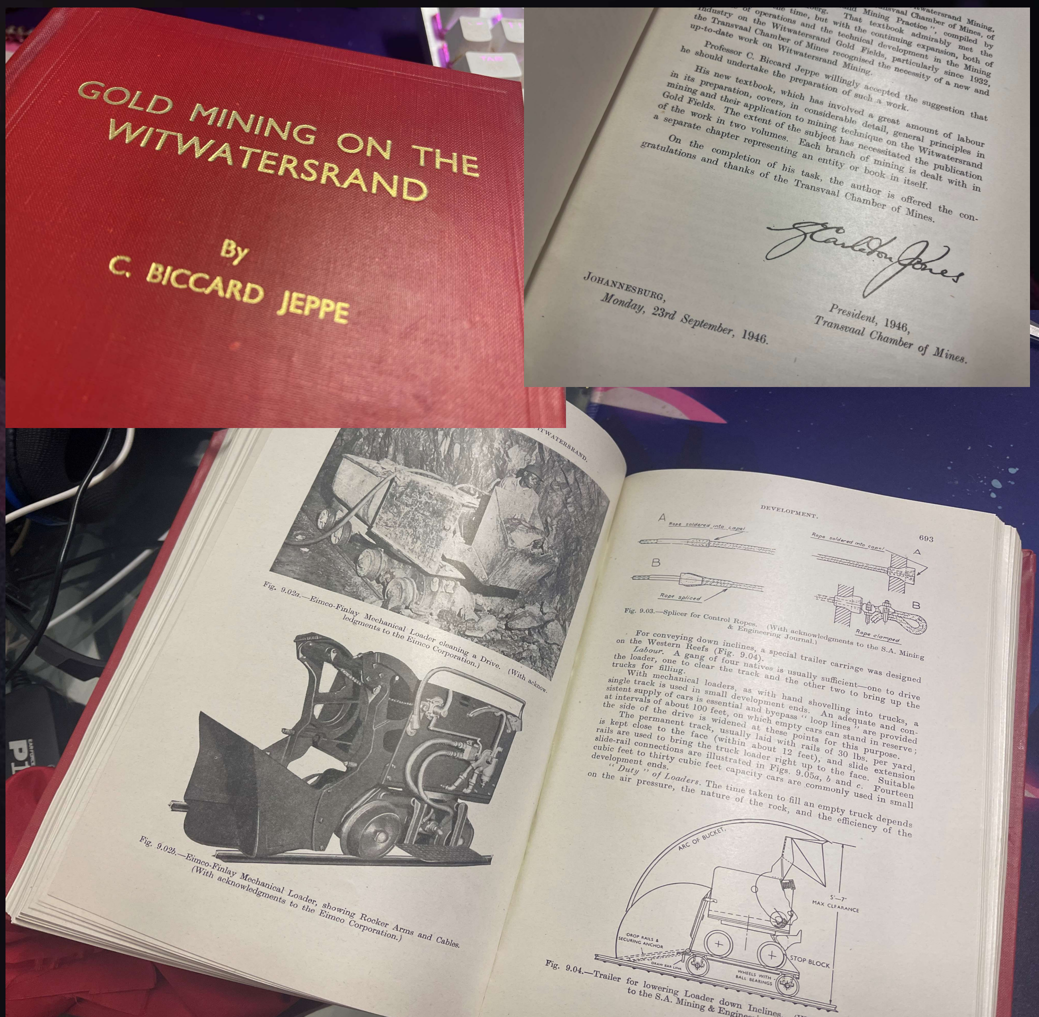
ST: Small sized tunnels

Tun: Large Sized Tunnels

LE: Large underground excavations

Sink: Shaft sinking

Before 1946

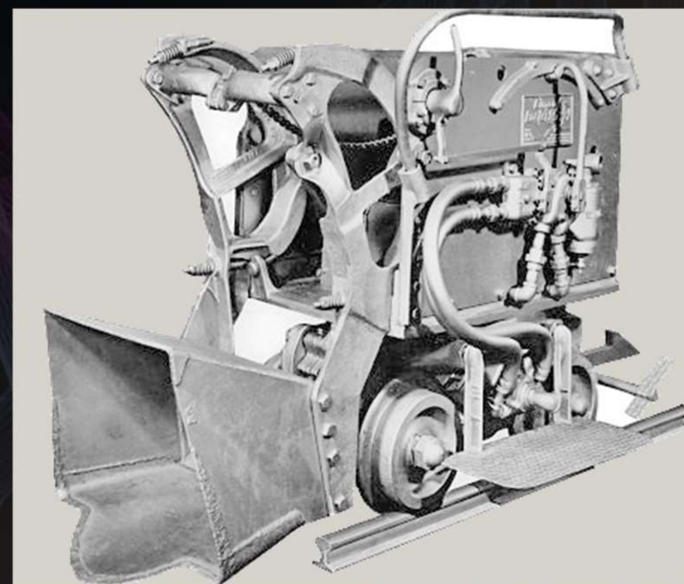


Now: 2022

- Rail Bound: Pneumatic (Boesman)

Machine Human Interaction: Pneumatic Rocker Shovel

- Requires Pneumatic power
- Manual
- Limited ergonomics for the user
- Violent and noisy
- High risk of derailments



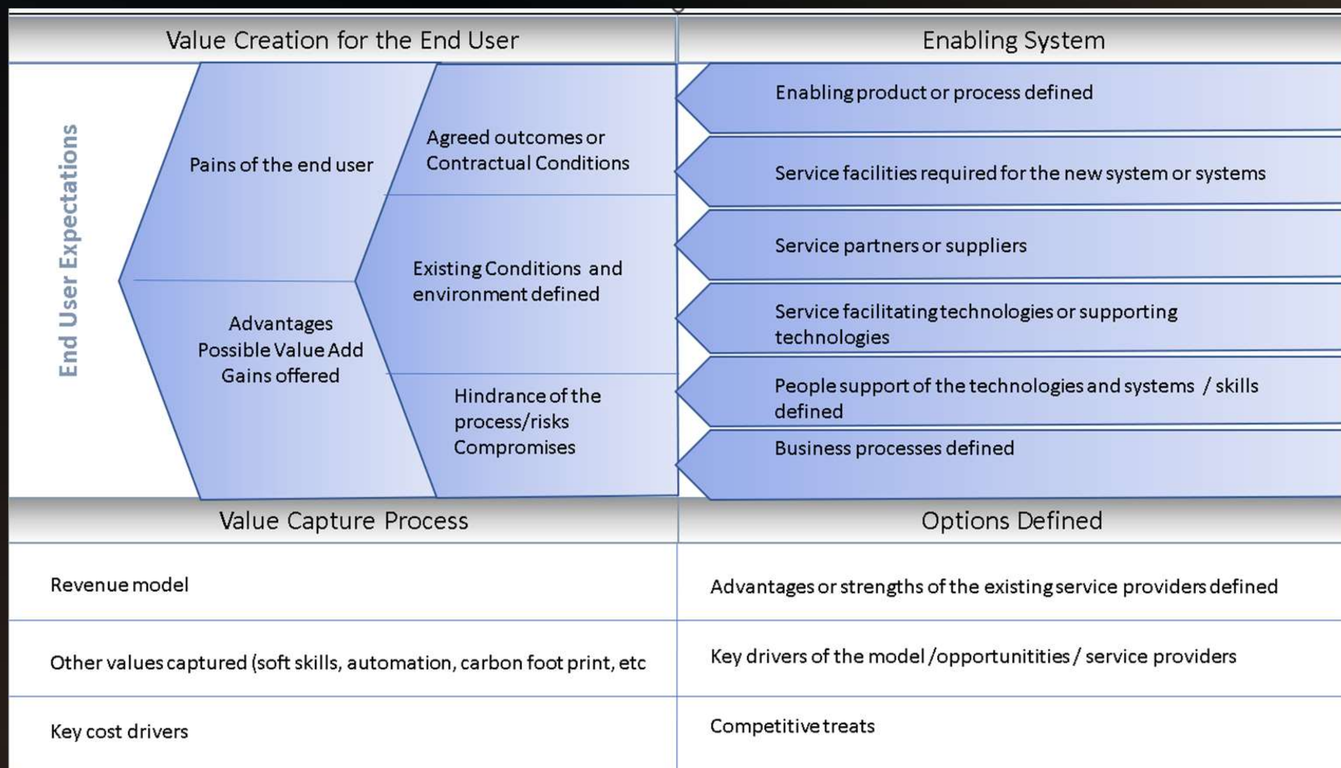
Rail Bound: Hydro-powered (HPE)


Never went into production due to lack of infrastructure or commitment by the mines to have a new infrastructure

Narrow Reef Development End Challenges

- Cycle time
- Machine human interaction
- Coupling decoupling challenges
- Rail extension challenges
- Operational challenges
- Limitations with remote controllability
- Battery power challenges
- Hopper/Material car swopping challenges

Framework towards blueprint



Framework to create a blueprint model for an improved rocker shovel-based development-end cleaning system

Objectives of a Blueprint Model

- A blueprint model can aim to demonstrate a combination of conditions such as:
- Bench marking to identify internal opportunities for improvement:
  - Performance benchmarking
  - Practice benchmarking
  - Internal benchmarking
  - External benchmarking
- Cost Constraints
- Cost Reduction

Mine Parameters for the Blueprint

- All unit processes are to be captured per
- Tunnel specifications
- Machine specifications

Performance Area	Units	ACTUAL	OPTIMAL
Advance per blast	m	2	2.5
Advance Rate	m/month	42	58
Average Density	t/m^3	2.78	2.78
Tons per blast	t/blast	79	91
Tons per month	t/month	1663	2192
ORD FACE CYCLE		Actual	Optimal
Travelling time (return)	min	43.3	34.3
Cleaning time	min	114.6	142.6
Primary support time	min	13.5	28.0
Face preparation time	min	55.0	50.0
Drilling time	min	101.4	105.0
Charging & Blasting time	min	199.2	55.2
Face Cycle time required/blast	hrs	8.1	6.3

- Unit Processes are:
- Drilling
- Blasting
- Support
- Cleaning or mucking

BluePrint: Summary Specs per Machine Type

	Unit	Trident														Salzgitter Mzansi	HPE		Epiroc Haggloader				GST	Brokk
Machine model		12B	12E	12AC	21AC	21B	215	26S	26B	26H	632H	630	LM 57	LM 71	CAVO 320	HL380U	RLD 700	Rhino Loade	Haggloader 7H	Haggloader 7HR-	Haggloader 10H	Haggloader 10HR	SQL Loader	Brokk 110
Operating mass	kg	1950	1950	1950	3275	3275	3275	4840	4840	4840	5680	4695	3150	4900	4100	0	4900	5500	15300	15300	21900	21900	7968.4	990
Machine length	mm	1910	1910	1910	2280	2280	2280	2820	2820	2820	3735	2845	2340	2720	2670	2670	2600	5100	9983	10136	12328	12803	8725	1847
Machine width	mm	670	670	670	970	970	970	1005	1005	1005	1400	1490	1050	1340	1570	1410	1350	1450	2195	2195	3807	3807	1934	1583
Machine height	mm	1240	1240	1240	1490	1490	1490	1635	1635	1635	1525	1510	1482	1550	1900	1850	1630	1700	2555	2602	4184	4184	2447	1147
Discharge height	mm	1240	1240	1240	1390	1390	1390	1820	1820	1820	1575	1900	1465	1550	1680	2750	2850	2350	3245	3288	4184	4184	0	0
Minimum roof height	mm	1970	1970	1970	2350	2350	2350	2855	2855	2855	3215	3225	2440	2855	2670	2750	2950	2800	3245	3288	4184	4184	2447	1290
Clean-up width	mm	1880	1880	1880	2360	2360	2360	3160	3160	3160	0	0	2850	3160	0	3000	1600	1500	4000	3363	2088	3844	1934	0
Bucket capacity	m^3	0.13	0.13	0.13	0.3	0.3	0.3	0.35	0.35	0.35	0.6	0.39	0.26	0.4	0.3	0.28	0.36	0.24	3	3.5	4	5	0.38	0.6
In-situ density	t/m^3	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
No. of hours per shift	hours	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
No. of working days per month	days	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
No. of actual working hours per shift	hours	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69
Total allocated cleaning shift hours per month	**hours**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**	**176**
Total actual cleaning hours per month	**hours**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**	**59**
Average maintenance hours per shift	hours	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total shift maintenance hours per month	**hours**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**
Average breakdown downtime per shift	hours	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total shift breakdown downtime per shift	**hours**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**
Total downtime per month	**hours**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**	**22**
Machine availability	%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%
Machine utilisation	%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%
No. of machines per panel		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No. of back-up machines per panel		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total number of drill rigs		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fleet availability	**%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**	**88%**
Fleet utilisation	**%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**	**34%**

Performance per Machine Type

Machine application performance	Unit																							
Tunnel width	m	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Tunnel height	m	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Lateral/horizontal clearance	%	63%	63%	63%	79%	79%	79%	105%	105%	105%	0%	0%	95%	105%	0%	100%	53%	50%	133%	112%	70%	128%	64%	0%
Vertical clearance	%	52%	52%	52%	62%	62%	62%	75%	75%	75%	85%	85%	64%	75%	70%	72%	78%	74%	85%	87%	110%	110%	64%	34%
Drilling efficiency	%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%
Length of hole drilled	m	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Average advance per development end per blast	m	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99
Development end tonnes per blast	t	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102	102
Hopper size (6t or 9t)	t	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Hopper fill factor	%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
No. of hoppers required	#	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
HLGE to X/Cut	m	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170
Tramming hopper to X/Cut	hours	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Total waiting for tramming	**hours**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Bucket fill factor	%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
Tonnes loaded per dig	t	0.234	0.23	0.234	0.54	0.54	0.54	0.63	0.63	0.63	1.08	0.702	0.468	0.72	0.54	0.504	0.648	0.432	0.09	0.105	0.12	0.15	0.792	1.08
No. of digs to load single hopper	#	26	26	26	12	12	12	10	10	10	6	9	13	9	12	12	10	14	67	58	50	40	8	6
Loading time per dig	min/dig	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Total digging time per development end per blast	**hours**	**2.6**	**2.6**	**2.6**	**1.2**	**1.2**	**1.2**	**1**	**1**	**1**	**0.6**	**0.9**	**1.3**	**0.9**	**1.2**	**1.2**	**1**	**1.4**	**6.7**	**5.8**	**5**	**4**	**0.8**	**0.6**
Total time digging and tramming per development end per blast	**hours**	**4.1**	**4.1**	**4.1**	**2.7**	**2.7**	**2.7**	**2.5**	**2.5**	**2.5**	**2.1**	**2.4**	**2.8**	**2.4**	**2.7**	**2.7**	**2.5**	**2.9**	**8.2**	**7.3**	**6.5**	**5.5**	**2.3**	**2.1**
No. of development ends cleaned per shift	#	0.89	0.89	0.89	1.35	1.35	1.35	1.46	1.46	1.46	1.74	1.52	1.3	1.52	1.35	1.35	1.46	1.26	0.45	0.5	0.56	0.66	1.59	1.74
No. of machines per development end	#	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Blasting efficiency	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
No. of actual blasts per month	#	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Tonnes cleaned by single machine per month	**t**	**1815.6**	**1816**	**1816**	**2754**	**2754**	**2754**	**2978**	**2978**	**2978**	**3549.6**	**3100.8**	**2652**	**3100.8**	**2754**	**2754**	**2978.4**	**2570.4**	**918**	**1020**	**1142.4**	**1346.4**	**3243.6**	**3549.6**

Numbers are not real but for model validation randomly generated within the common mining layouts experienced in narrow reef mines

Discussions

- The OEM industry seems to have less appetite for developing new equipment on already mature mines that are not interested in replacing the existing machinery with more expensive ones due to challenges of

- Limited flexibility in existing mine layouts
- Confined spaces
- Limited infrastructure
- Costly exercise to replace with modern equipment, small tunnels are more economical
- Not proven to work on several trial attempts of various loader options
- Little experience or training
- Production demand versus development rate matching it is not a bottleneck
- No measurable output in terms of how safe and practical are the alternative solutions

Phase 2 LOCM WP2

- Identify service providers involved in validation (for Level 9 legislation requirements) of equipment or products for South African mining applications in narrow reef hard rock mines.
- Establish a database of the validated equipment or products or equipment or products which require testing for technology readiness.
- Establish an information-sharing framework to create linkages between sponsors, OEMs, and research institutions to collaboratively partake in developing, testing and funding selective products.
- Establish at least three agreements from OEMs to conduct equipment or product testing at the MMP test mine.

Thank you

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