AN ALTERNATIVE STRATEGIC OPTION IN MANAGING MINE MOBILE ASSET REPLACEMENT

by

Nicholas J. Frenks

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Approval

Name: **Nicholas J. Frenks**

Degree: **Master of Business Administration**

Title of Project: **An Alternative Strategic Option in Managing Mine Mobile Asset Replacement**

Supervisory Committee:

Dr. Michael Parent
First Reader
Professor of Management Information Systems and Marketing
Faculty of Business Administration

Dr. Leyland Pitt
Second Reader
Professor, Marketing and Dennis F. Culver EMBA Alumni Chair of Business
Faculty of Business Administration

Date Approved:

Abstract

Teck Highland Valley Copper is the largest copper mine in Canada. The operation requires annual sustaining capital funding in order to replace equipment and maintain capacity. The asset replacement strategy is to replace mine mobile equipment once it achieves a pre-determined asset life. The problem arises during a low commodity-pricing environment when sustaining capital funds are not readily available. The capacity loss in subsequent years can adversely affect the operating capacity and operating margin of the mine.

This paper will look at two alternative options that can be utilised during low commodity pricing environments. The first option will be to procure a single asset to maintain capacity in the short term. The second will be to execute a targeted precision rebuild of the asset to maintain capacity going forward in the longer term and provide a cost effective alternative to asset replacement.

Dedication

I would like to thank my wife Yvette and my children, Meaghan and Brandon. Their patience, love and understanding throughout the last nine years ensured that this journey could come to fruition. All of you gave up many outings and time spent together in order to allow me the opportunity to pursue this higher learning. I will be forever grateful.

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Glossary

HVC	Highland Valley Copper
Re & Re	Remove and replace or repair and replace
EOC	Equivalent Annual Cost
LOM	Life of Mine
CBAM	Condition Based Asset Management
RTD	Rubber Tired Dozer
CMO	Coal Mountain Operations
GHO	Greenhills Operations
EVO	Elkview Operations
CRO	Cardinal River Operations
FRO	Fording River Operations
TPR	Targeted Precision Rebuild
Bad Actor	The problem or issue that affects capacity in mobile equipment
MTBF	Mean time between failure
MTTR	Mean time to repair
CBCC	Condition based component change

1: Introduction

1.1 Introduction to Teck Highland Valley Copper Partnership

Teck Highland Valley Copper Partnership is the largest copper mining operation in Canada. The site consists of two vastly different operating areas; the metallurgical concentrator complex and the open pit mining areas. The concentrator covered stockpiles receive ore from the three gyratory crushers.

Figure 1 **-** *View of Teck Highland Valley Concentrator Complex and Ore Storage Covers*

Source – Teck Highland Valley Copper 2012

Once in the concentrator, crushing, grinding and flotation lines separate the copper and moly concentrate from the waste rock.

Figure 2 - View Inside Teck Highland Valley Concentrator

Source – Teck Highland Valley Copper

The copper and moly concentrate are liberated from the waste rock and transported to market. The process waste slurry remains in the Highland Tailings Pond.

Figure 3 - Highland Tailings Pond

Source – Teck Highland Valley Copper 2013

The open pit mining area consists of three operating open pits. The pits are Valley, Lornex and Highmont. The mining area also has a mine shop complex where both heavy and light equipment repairs are completed.

Figure 4 **-** *Teck Highland Valley Copper – Picture of Highmont and Valley Pits*

Source – Teck Highland Valley Copper

Figure 5 **-** Teck Highland Valley Copper Mine Equipment Shop

Source – Teck Highland Valley Copper 2015

Figure 6 **-** Inside View of Teck Highland Valley Mine Shop

Source – Teck Highland Valley 2015

1.2 Project Overview

In the mechanized open pit mines of today, the equipment is complex and very expensive to procure and repair over the life of the mine resource. In this project, I will investigate to understand if an alternate asset management strategy exists concerning the end of life asset replacement at Highland Valley Copper. Many of our mine mobile assets are fast approaching their replacement operating hours and it would be beneficial to Teck Highland Valley Copper to understand if there is a more cost effective alternative to straight-out asset replacement at predetermined asset lives.

In chapter two, I will introduce the fleets at Teck Highland Valley Copper. I will include many illustrations and tables in order to help gauge the size and the number of mine mobile assets required to operate a resource the size of Highland Valley Copper. In chapter three, I will discuss the problem as it occurs to us today. Chapter 4 will review the existing strategy for equipment replacement. In chapter five, I will discuss the 793 haul truck fleet that presently exists at Teck Highland Valley Copper as well as the strategy we use to maintain such a fleet. In chapter six I will look at what a new mine mobile asset replacement strategy would look like at Teck Highland Valley Copper. Chapter 7 will draw my conclusions.

2: Teck Highland Valley Copper's Mobile Fleets

2.1 Production Excavators

Teck Highland Valley Copper has a shovel fleet that consists of the following:

6 – 2800 P&H Electric rope shovels with 41 yd. buckets

2 – 495HR Bucyrus-Erie Electric rope shovels with 56 yd. buckets

Figure 7 **-** Teck Highland Valley Copper P&H 2800 Class Electric Shovel

Source – Teck Highland Valley 2013

Figure 8 **-** Teck Highland Valley Copper 495HR Shovel Loading Cat 793 Caterpillar Haul Trucks

Source – Teck Highland Valley 2015

Teck Highland Valley Copper also has two production loaders that are used when one of the shovels are under repair or to work the stockpile in order to tram ore to the crushers. They are both LeTourneau L1850 Diesel Electric loaders.

Figure 9 **-** Teck Highland Valley Copper L1850 Loader loading a 793 Caterpillar Haul Truck

SOURCE – Teck Highland Valley Copper 2015

Figure 10 **-** Teck L1800 Loader **-** 50yd Bucket

Source – Teck Resources 2001

2.2 Production Drills

Teck Highland Valley Copper must separate the waste and ore prior to processing in the concentrator and utilizes a fleet of electric blast-hole drills to drill the waste and ore patterns in the respective pits. Teck Highland Valley Copper has six of these 49R Bucyrus-Erie class drills.

Figure 11 **-** Teck Highland Valley 49HR Production Drill on Drill Pattern

Source – Teck Highland Valley 2015

2.3 Production Haul Trucks

Teck Highland Valley utilizes a fleet of 52 haul trucks to move its ore and waste rock from the respective pits. The fleet consists of Caterpillar 793 mechanical drive 240- ton haul trucks. They vary in age from 1999 (793C models) through 2013 (793F models).

Figure 12 - Teck Highland Valley Copper -793C 240-ton Caterpillar Haul Truck

Source – Teck Highland Valley Copper 2015

2.4 Auxiliary Fleets

Teck Highland Valley Copper has the following auxiliary fleets to enable production to occur as efficiently and safely as possible:

Table 1: Teck Highland Valley Copper Auxiliary Equipment Fleets

	Teck Highland Valley Copper - Auxiliary Equipment Fleets		
12	D10 Caterpillar Dozers	9	Caterpillar hydraulic tracked excavators
2	D8T Caterpillar Dozers	3	789 Caterpillar Water Trucks
2	844H Caterpillar Rubber Tired Dozers	2	793 Caterpillar Water Trucks
3	14 series Caterpillar Graders	9	Komatsu Loaders
6	16 series Caterpillar Graders	7	Slurry/Stemming and Blasting Trucks
4	24 series Caterpillar Graders	4	Caterpillar Loaders
9	Bobcat Loaders		

Source – drawn by author

Figure 13 **-** D10 Caterpillar Dozer

Source – Teck Highland Valley Copper 2015

Figure 14 **-** RTD Clean**-**up Machine

Source – Teck Highland Valley Copper 2015

Figure 15 **-** Caterpillar Grader With 24' Blade for Haul Road Maintenance

Source – Teck Resources 2008

2.5 Service Fleets

Teck Highland Valley Copper has an extensive service fleet that is used to assist the auxiliary and production fleet to ensure mine capacity is kept at targeted levels. The service fleets consist of the following:

Table 2: Teck Highland Valley Copper Service Equipment Fleets

	Teck Highland Valley Copper - Service Equipment Fleets		
16	Trailers-5 ton to 250 ton.	10	Dump/Water/Sand & garbage trucks
10	boat trailers (environmental group)	20	Lube/Fuel/Service trucks
10	fusion machines - 6" - 36" dia. Pipe	2	Fire Trucks
5	5th wheel tractor units	28	Fork lifts/Lift trucks
2	Ambulance	9	Scissor Lifts/Man-lifts
2	Rubber tired backhoes	15	diesel welders
1	ball truck	19	diesel generators
11	20 passenger busses	2	tow trucks
16	mobile cranes -2 ton through 245 ton		

Source – drawn by author 2015

Figure 16 - Service Truck

Source – Teck Highland Valley Copper 2015

3: The Problem

3.1 Low & High Commodity Pricing Environments

Margin protection along with productivity improvement and capital preservation are all on top of mind today as we are progressing towards the bottom portion of the commodity cycle. Once through the bottom part of the cycle, we will again prioritize growth, removing production & capacity constraints and re-capitalizing in order to maintain capacity and take advantage of technology.

As the mining cycle takes us through a low and high pricing commodity environment, the mobile mine equipment maintenance strategy needs to allow us to execute optimally in both pricing environments and through the cycle.

3.2 Only one mobile mine maintenance replacement strategy

Today we have only one strategy for mobile mine equipment replacement. This strategy consists of mobile assets reaching a usage milestone and then sustaining capital funding is utilised to replace this asset. These asset life cycles are in our LOM (life of mine) plans as well as our five-year strategic and annual capital plans. These plans forecast the sustaining capital requirements in the coming years in order to maintain capacity at each or our mines.

Table 3: Highland Valley Copper Mobile Asset Replacement Life Cycles

HVC Replacement Life Cycles			
Description	Replacement Operating Hours	**Description**	Replacement Operating Hours
Bucyrus 495 Shovel	100000	Cat 24M Grader	40000
P&H 2800 Shovel	110000	Cat 16M Grader	50000
Bucyrus 49R Drill	100000	Cat 834 Loader	60000
Cat 793 Haul Truck	90000	Cat D10R Dozer	50000

Source – drawn by author, 2015

3.3 Unintended Consequences

When we are in a high pricing commodity environment, sustaining capital is available and we execute on our mobile mine equipment replacement strategy. When we enter a low commodity- pricing environment, our sustaining capital funding has to compete with all other sites for capital funding as well as the growth strategy of the corporation. Year to year we look at what equipment can be pushed in order to postpone replacement and curtail the sustaining capital requirement. This is not too difficult for a year or two but many low commodity pricing environments last for five to ten years. When we push equipment replacements in successive years without a strategy, we put our capacity at risk.

Capacity decreases as the equipment grows older and requires more repair. In a low commodity- pricing environment, increasing labour to maintain capacity is not an option as we are in a cost reduction mode due to the low commodity prices. The unintended consequence of pushing asset replacement is a reduction in capacity and an increase in repair costs. In this low commodity- pricing environment, downward margin pressure is a result of the increase in unit cost.

How could this occur? You first must understand that the mining industry has always attracted investor attention through its mergers and acquisitions and/or the growth strategy around greenfield or brownfield resource assets that it was developing. When the commodity cycle turns, the capital that funds these activities comes from the same pool of money that is available for sustaining capital. If you have already incurred buy-in obligations for a particular growth strategy, decisions must be made with the shrinking capital pool you have at your disposal. In some cases, the only lever left is the sustaining capital portion of this pool.

3.4 Could there be a solution to this problem?

In this paper, I will be looking to understand if an alternative strategy is an option as we transition from a high commodity-pricing environment to a low commodity-pricing environment. I will be using the haul truck fleet as the proxy for the other fleets. If we can create an alternative strategy that works for the haul truck fleet, the other fleets would likely be candidates for a similar strategy.

4: Existing Strategy for Equipment Replacement

4.1 Age

The age of an asset is not so much a concern when compared to usage or condition. The age tends to reflect the technology that was present when manufacturing took place. The health or condition of the asset places greater dependence on the operating hours that the asset has incurred which dictate where it is in its life cycle. Large earthmoving equipment such as the 793 Caterpillar haul trucks used at Teck Highland Valley copper are so large that we not only track the operating hours on the entire asset, but also the operating hours on all the components. We track the component operating hours so that we understand when the component is approaching its end of life. Optimally we would like to change the component prior to failure and on a planned basis in order to minimise the amount of downtime incurred as well as the cost to perform the change. Each of these components has a manufacturer's suggested operating life as well as an average rebuild cost.

These component re & re costs as well as regular preventive, predictive and running repairs make up the operating maintenance cost of the haul trucks.

4.2 Mobile Asset Replacement Guidelines

Most mobile asset replacement guidelines can be very controversial and difficult to garner agreement. Why does one operation run their equipment longer than another operation? Whose guidelines are optimum? These are questions that many site financial analysts find themselves asking.

Many things through the asset's life cycle influence the gradual degradation of a mobile asset. These factors not only increase cost, but also can often lead to the reduction in capacity. Some more common factors in the mining world are underfoot conditions or road maintenance, operating within the envelope of the equipment's design, and the preventive and predictive maintenance performed through its operating life.

Table 4: Teck Coal – Component Asset Lives

Component Asset Lives

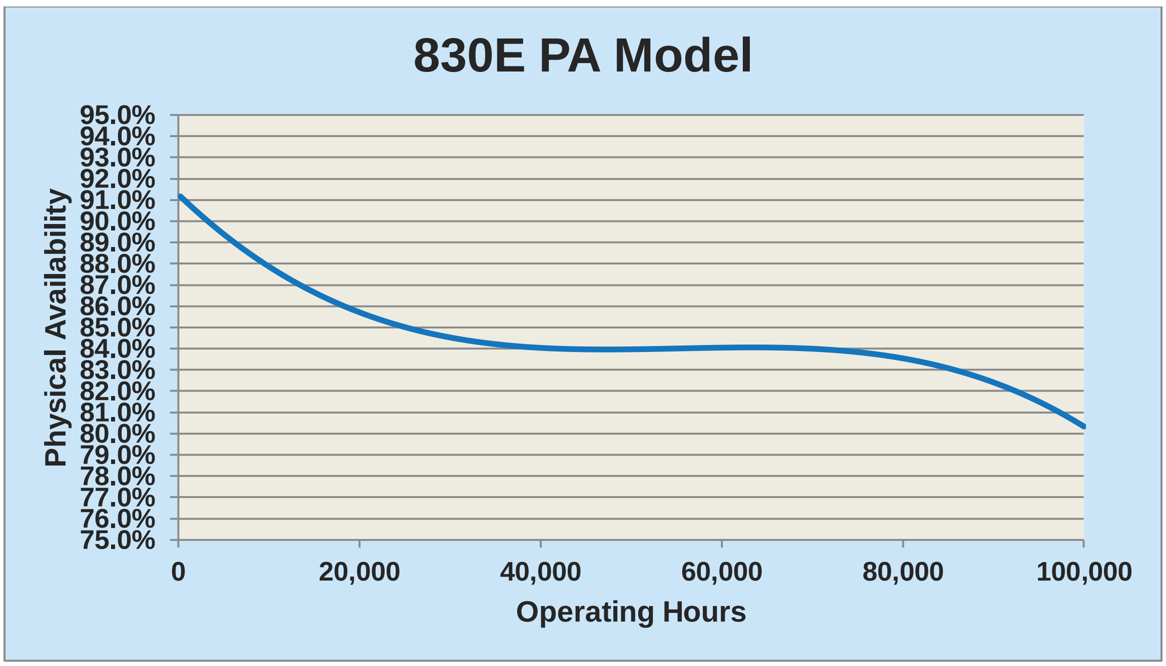
	Estimated Useful Life (years)	Estimated Operating Hours	Method of Depreciation
Mobile mining equipment			
Haul truck	18*	100,000	Operating hrs
Drill	22*	120,000	Operating hrs
Scraper	10#	30,000	Operating hrs
Dozer- Rubber tire	10^	60,000	Operating hrs
Dozer- Track	7	48,000	Operating hrs
Loader	11*	60,000	Operating hrs
Grader	8^	45,000	Operating hrs
Shovel- electric	20^	120,000	Operating hrs
Shovel- hydraulic	13^	80,000	Operating hrs
Shovel tracks (component)	4^	25,000	Operating hrs
Backhoe	15#	45,000	Operating hrs
Other	Useful life	Useful hours	Operating hrs
Buildings	Useful life	N/A	Straight-line
Plant equipment	Useful life	N/A	Straight-line
Service equipment			
Fuel/lube truck	10	N/A	Straight-line
Water truck	10	N/A	Straight-line
Lowbed trailer	15	N/A	Straight-line
Crane	15	N/A	Straight-line
Other	Useful life	N/A	Straight-line
Other equipment	Useful life	N/A	Straight-line
MPD	Reserves	N/A	Unit of production

Source – Teck Coal Accounting Policy Supplement

The following two graphs summarize how Teck Coal's 830E haul truck data was utilized to establish it's haul truck life of 18 yrs. and 100,000 operating hours.

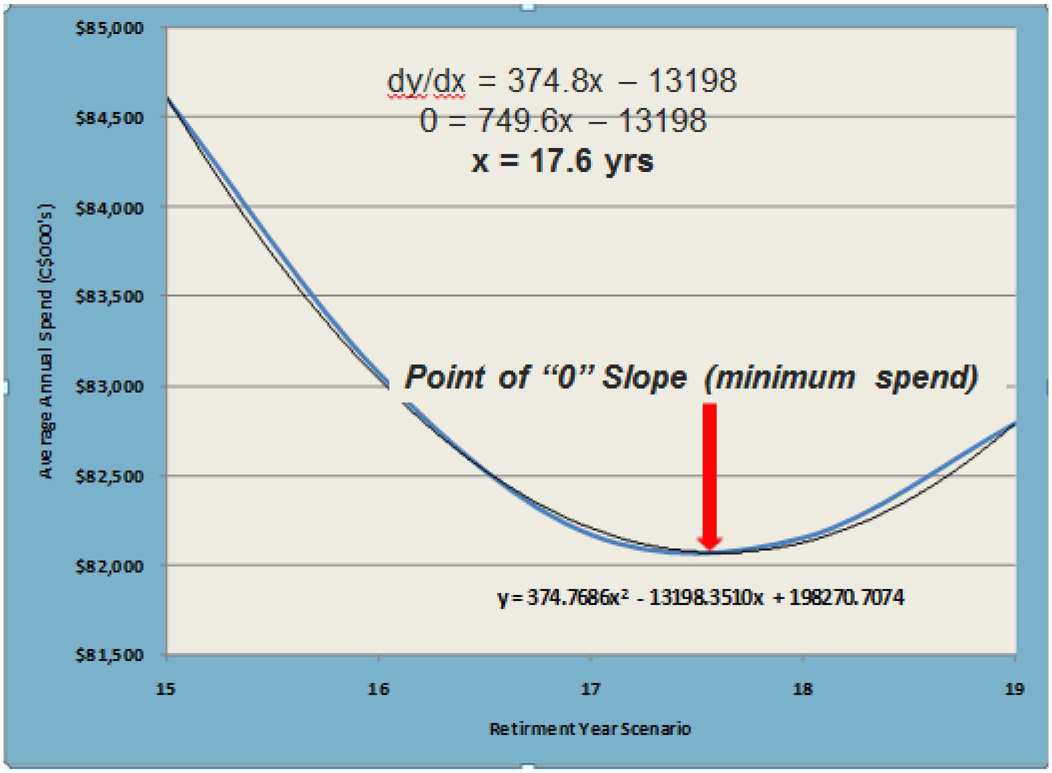
Teck Coal had very robust data as they were running 830E model trucks at their Elkview, Fording River, Greenhills, Coal Mountain and Cardinal River mines. The respective data was collected from each of the mine's repositories and the physical availability was calculated in the same way from each mine's data.

Figure 17 **-** Teck Coal Physical Availability Data Normalized and PA Model Created.



Source – Teck Coal 2009

Figure 18 **-** Graph Depicting the Point of Minimum Annual Spend and 17.6 Year Optimum Life.

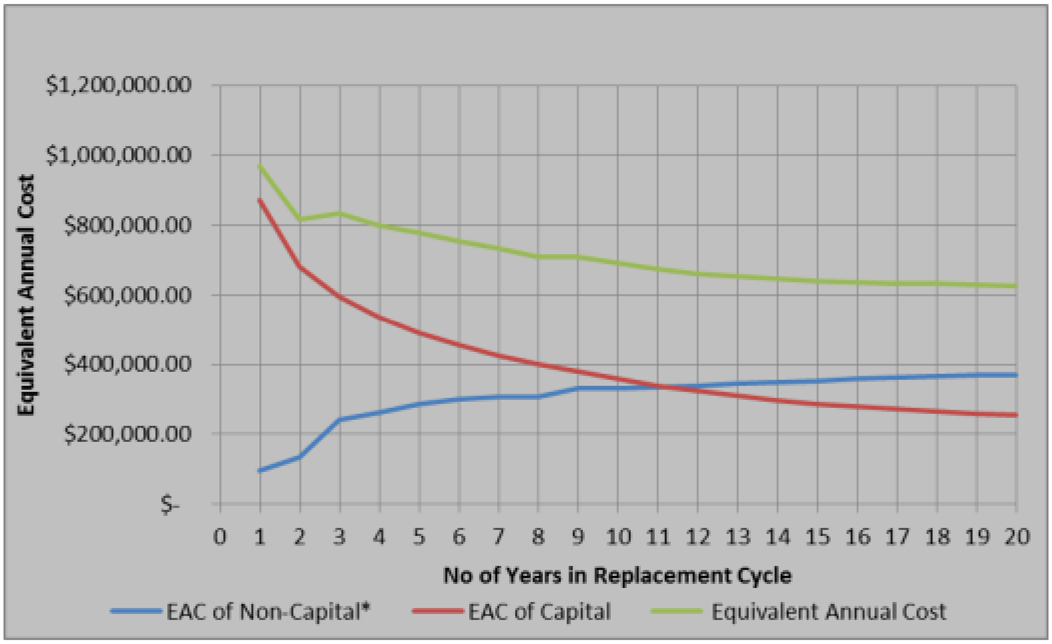


Source – Teck Coal 2009

Teck Highland Valley Copper took into consideration the work illustrated above from Teck Coal, replacement hours used by its peers in copper mining (Appendix A) and the costs that HVC has experienced over its haul truck fleet's lives.

The chart below utilizes HVC 793 haul truck fleet maintenance costs from 2001 thru 2009. The chart shows that the EAC becomes flat around the 16th year that corresponds to approximately 90,000 operating hours. The analysis assumes that there are no significant frame issues.

Figure 19 **-** Teck Highland Valley Copper – Graph of Equivalent Annual Cost



* Maintenance costs, including tire repairs, but not tire replacements.

Source – Teck Highland Valley Maintenance Reliability Group

Teck Highland Valley Copper's haul truck replacement guideline of 90,000 operating hours is utilized by the strategic planning group to create the LOM plans. The maintenance and operations departments utilize the guideline to create the capital replacement plans for the next year and LOM. These plans feed into our annual and long term capital forecasts.

Table 5: Teck Highland Valley Copper – Example of Annual Capital Spend Forecast

	SubL Name			Approved AR	2013 planned spend per AR	2013 planned spend per Budget	Actual 2013 Spend to June 30	2013 remainder forecast spend
PP & E - Sustaining								
*	SS Tailings	2011-044	budgeted	58,500,000	26,000,000	27,300,000	18,178,999	1,866,559
*	Shovel rebuild	2012-012	budgeted	9,925,000	8,425,000	8,425,000	6,288,378	336,622
*	Wireless Upgrade	2012-016	budgeted	485,000	-	200,000	89,146	-
*	L2B SRC Drive	2012-021	budgeted	897,000	697,000	697,000	6,206	690,794
*	MEM	2012-022	budgeted	850,100	507,482	507,000	278,533	228,949
*	53-01 Sand Truck	2012-027	budgeted	155,000	-	155,000	-	155,000
*	49R BE Drill	2012-032	budgeted	5,940,000	4,748,240	4,748,000	3,201,438	-
*	MWC Rebuild	2012-036	budgeted	360,000	-	-	62,979	-
*	Replace 57-72	2013-003	budgeted	489,000	489,000	489,000	486,340	
*	Water trucks	2013-005	budgeted	4,300,000	4,300,000	2,600,000	1,289,371	3,010,629
*	BI495 tracks	2013-006	budgeted	1,435,845	1,435,845	900,000	15,801	1,420,044
*	Replace 50-09 fuel truck	2013-008	budgeted	253,000	253,000	230,000	1,519	251,481
*	Mine to Mill Software	2013-009	unbudgeted	150,000	150,000	-	45,073	104,928
*	Security scales	2013-010	unbudgeted	335,000	335,000	-	174,598	160,402
*	Pit WiFi upgrade	2013-011	budgeted	485,657	485,657	500,000	9,453	476,205
*	Core Facility	2013-012	budgeted	2,290,000	2,290,000	2,600,000	184,081	2,105,919
*	Witches Brook Upgrade	2013-012	budgeted	1,028,440	1,028,440	1,000,000	-	1,028,440
*	Mobile Equipment Computers	2013-015	budgeted	749,000	749,000	700,000	735	748,265
*	Capital Spare BI 495	2013-016	budgeted	499,500	499,500	600,000	509,625	-
*	Shop rover truck	2013-017	unbudgeted	195,000	195,000	-	-	195,000
*	Domestic Hotwater System	2013-019	unbudgeted	500,000	500,000	-	-	500,000
*	Valley Dewatering	2013-020	budgeted	2,440,000	2,440,000	2,500,000	-	2,440,000
*	Moly Flotation Circuit Regrind	2013-021	unbudgeted	885,000	885,000	-	-	-
*	Var Support	2013-022	budgeted	1,100,000	1,100,000	1,100,000	-	1,100,000
*	Leach Plant Bulk HCL Storage	2013-023	unbudgeted	164,100	164,100	-	-	164,100
	Phz 1 Mine Engineering dry/parking lot expansion		unbudgeted	1,000,000	1,000,000	-	-	1,000,000
	Axon replacement for Wenco		budgeted	700,000	****	700,000	-	-
	Chev C70 (Hiab/Welder)		budgeted	140,000	****	140,000	-	140,000
	Mobile Lunchroom		budgeted	400,000	****	400,000	-	100,000
	495 shovel fleet		budgeted	600,000	****	600,000	-	-
	Tractor & Float		budgeted	300,000	****	300,000	-	-
	Stemming Truck		budgeted	400,000	****	400,000	-	-
	Pumper Truck		budgeted	550,000	****	550,000	-	-
	Pumper Truck		budgeted	550,000	****	550,000	-	-
	Replacement belting		budgeted	1,300,000	****	1,300,000	-	1,300,000
	MCC Replacements		budgeted	250,000	****	250,000	-	250,000
	Crusher Move (Phz 1 early works & engineering)		budgeted	4,500,000	****	4,500,000	-	2,500,000
	Pukaist Creek Water Management Engineering		budgeted	1,000,000	****	1,000,000	-	250,000
	Trojan Pond Diversion		budgeted	1,500,000	****	1,500,000	-	800,000
	Mill Water Emergency Dump Engineering		budgeted	4,500,000	****	4,500,000	-	766,000
	LL Dam Substation		budgeted	1,700,000	****	1,700,000	-	-
	MIS - Core Network Infras		budgeted	150,000	****	150,000	-	150,000
						73,791,000	30,822,275	24,239,337
PP & E - Development								
*	MOP	2011-038	budgeted	550,000,000	264,515,000	312,287,000	203,963,487	150,379,982
Capitalized Development								
*	2013 RDP Drilling				22,400,000	22,400,000	5,874,619	13,993,955

Source – Teck Highland Valley Copper Accounting Group 2013

5: Understanding the Highland Valley Copper 793 Haul Fleet

5.1 Mobile Asset Availability and Reliability

Mobile asset availability provides the operating hours to the mine department in order to allow them to execute on both short and long- term mine plans. For this paper, we will be focussing on the 793 haul truck fleet. Availability is the percentage of calendar time less excluded-calendar time that the equipment was physically available for work. It is a measure of equipment runtime capacity. (Teck Standard Metrics, 2014)

Availability = Available Time / Available Time – Maintenance Time

Mobile asset reliability is the measure of the chance that an asset will operate long enough to perform its duty. In mining, we would like the asset to go from the shortest scheduled maintenance interval to the next scheduled maintenance interval. We measure reliability in MTBD (mean time between downs).

MTBD = Utilized time / # of down events

The limitations and/or problems incurred by the asset between scheduled maintenance intervals are referred to as bad actors. These bad actors are tracked by the reliability group in order to effectively eliminate or extend the time between these occurrences. The time it takes to bring the asset back to full operating standards is referred to as the MTTR (mean time to repair). The reliability & maintenance group will look for ways to minimize this measure where possible. These efforts increase the reliability of the asset.

At Highland Valley Copper the availability of the 793 haul truck fleet is a key performance indicator and although the reliability is important, it is looked upon by the site as a performance indicator, but not key. As an asset ages and incurs greater operating hours, the reliability of the asset decreases as systems & components that make up the asset start to degrade and breakdown. This decrease in MTBDs can often frustrate both operations and maintenance groups as the asset’s life cycle progresses.

5.2 CBAM and 793 Haul Truck Components

A Caterpillar 793 haul truck contains many very expensive and complex components that are essential to the operation of the haul truck. Each of these components has an expected life, which is measured in operating hours. Upon reaching the expected operating hours, the haul truck is scheduled to come into the shop and the component is replaced with a rebuilt unit. Once the change is completed, we zero the hours on the component-tracking sheet and the truck is released back to operations. These expected operating hours generally come from the manufacturer and in some cases the site will increase or decrease these hours depending on the site's experience with the life of these components. As an operating mine site, we had changed our components in our mobile assets based on operating hours right up until two years ago.

Table 6: 793 Haul Truck Major Component Hours & Projected Change

COMPONENT	UNIT #	SER#	COMPONENT HOURS	HOURS REMAINING	DAYS REMAINING	PROJECTED CHANGE DATE
ENGINE	6189	8WM01844	14425	575	35	4/22/2014
15,000	6133	54Z00697	14207	793	60	5/18/2014
	6188	8WM01841	12912	2089	127	7/24/2014
	6187	8WM01148	12843	2157	131	7/28/2014
	6184	8WM01268	12814	2186	133	7/30/2014
	6171	8WM02674	12586	2414	147	8/12/2014
	6176	8WM00921	11457	3543	216	10/20/2014
	6177	8WM00911	11419	3581	218	10/22/2014
TRANS	6128	9332727	13577	-3577	-272	6/19/2013
15,000	6107	2BE00631	12999	-2999	-228	8/2/2013
	6180	4GX00847	15055	-55	-4	3/15/2014
	6164	4GX02090	13843	1157	78	6/5/2014
	6124	2BE00671	8612	1388	106	7/2/2014
	6182	JGG00982	12582	2418	163	8/29/2014
	6190	JGX00683	12498	2502	169	9/4/2014
	6166	T10395	12370	2630	178	9/12/2014
TORQUE	6133	99T00089	14207	-207	-16	3/3/2014
15,000	6179	T5C01145	13190	1811	122	7/19/2014
	6187	3KT00674	12843	2157	146	8/11/2014
	6188	3KT01619	12827	2173	147	8/12/2014
	6171	3KT00998	12586	2414	163	8/29/2014
	6182	T5C00290	12582	2418	163	8/29/2014
	6166	3KT00386	12370	2630	178	9/12/2014
	6177	T5C01144	12137	2863	194	9/28/2014
DIFF	6107	CATD127	15939	-3939	-299	5/23/2013
15,000	6128	CATD150U	13939	-1939	-147	10/22/2013
	6176	CATD207	15114	-114	-8	3/11/2014
	6180	CATD205	15055	-55	-4	3/15/2014
	6163	CATD216	14344	656	44	5/2/2014
	6169	CATD222	14301	700	47	5/5/2014
	6178	CATD213	14152	848	57	5/15/2014
	6136	CATD132	11055	945	72	5/29/2014
PLANETS	6163	P965	26433	-1433	-97	12/12/2013
25,000	6187	P948	26216	-1216	-82	12/26/2013
	6187	P964	26216	-1216	-82	12/26/2013
	6167	P923	26116	-1116	-75	1/2/2014
	6167	P936	26116	-1116	-75	1/2/2014
	6163	P930	25714	-714	-48	1/29/2014
	6204	P990	24807	193	13	4/1/2014
	6204	P991	24806.7	193	13	4/1/2014
F. SUSP	6163	CATFS526	28016	-3016	-204	8/27/2013
25,000	6175	CATFS502	27767	-2767	-187	9/12/2013
	6175	CATFS544	27767	-2767	-187	9/12/2013
	6177	CATFS535	26993	-1993	-135	11/4/2013
	6177	CATFS534	26965	-1965	-133	11/6/2013
	6181	CATFS536	26937	-1937	-131	11/8/2013
	6176	CATFS510	26625	-1625	-110	11/29/2013
	6180	CATFS582	26249	-1249	-84	12/24/2013
R. SUSP	6182	CATRS645	24503.2	-6503	-440	1/3/2013
18,000	6207	CATRS694	24057.7	-6058	-409	2/2/2013
	6202	CATRS684	23948.4	-5948	-402	2/9/2013
	6202	CATRS685	23948.4	-5948	-402	2/9/2013
	6189	CATRS606	23703.3	-5703	-386	2/26/2013
	6189	CATRS651	23703.3	-5703	-386	2/26/2013
	6208	CATRS696	23535	-5535	-374	3/9/2013
	6208	CATRS697	23535	-5535	-374	3/9/2013
HOIST	6172	CATH141	25635	-1635	-111	11/28/2013
25,000	6172	CATH185	24991	-991	-67	1/11/2014
	6162	CATH119	24859	-859	-58	1/19/2014
	6162	CATH166	24859	-859	-58	1/19/2014
	6204	CATH191	24806.7	-807	-55	1/23/2014
	6204	CATH192	24806.7	-807	-55	1/23/2014
	6205	CATH193	24666	-666	-45	2/2/2014
	6205	CATH194	24665.7	-666	-45	2/2/2014

Source – Teck Highland Valley Copper Maintenance 2014

In 2012, the maintenance department embarked on CBAM or condition based asset management. With CBAM, you monitor the health of your asset and its components with oil analysis, vibration, thermography, ultrasonic testing and visual monitoring in order to ascertain and track the health of the component and hence the asset. When the component shows signs of wear or failure, you triage the component and rectify the problem as soon as practical in order to return the component and/or asset back to normal healthy state.

Monitoring and managing the health of your asset's components in this way, will increase the life of the components and hence lower the cost of running the asset. This will also increase the capacity of the asset due to the increased up time as the components are running longer. Condition based component change or CBCC is the method used to increase component life based on health. (Dingo, 2014) Key to condition based asset management is that you monitor the assets closer as they reach a pre-set life-cycle milestone but only change the component out when the health of the asset dictates that a change is required. Over the life of thousands of components and hundreds of assets, you will maximise capacity of the asset while operating at the lowest life-cycle cost.

5.3 793 Systems vs Components

Condition based asset management has normalized the life cycle of components due to the constant health monitoring. When the component's health deviates from the expected standard, the component is triaged and brought back to normal state of health. Components are rebuilt following a strict set of re-usability guidelines and this keeps the reliability of each component high and to the same standard. CBAM and maintaining high standards of rebuild nullify the effects of asset age on component changes. This indicates that the component will be expected to operate the same through its life cycle whether it is installed on a 15,000-hour asset or whether it is installed on an asset that has 85,000 operating hours on it. If components do not affect asset capacity through the life cycle, what is reducing the capacity of our asset as it ages?

Systems are the part of the asset that remains untouched for the most part during the life cycle of the asset. The electrical system, the hydraulic system, the air system, and the frame/chassis systems are mainstays in the asset that remain on the asset as the major and minor components are changed out during the asset's life cycle. Could these be reason for a reduction in capacity over time and increasing asset life operating hours?

5.4 "Bad Actors" in the old 793 haul trucks

When we analyse our oldest trucks in our 793 haul truck fleet, we can identify which parts of the truck make up the majority of the downtime and compare that down time to the downtime of our newest 793 haul trucks. This should help us identify the bad actors in our old 793 haul truck fleet.

Table 7: Impact to 793 Haul Truck Availability in 2014 (s/n 4AR- 14 units - *2000 to 2006)*

Description	% of Total	Avail. Impact
Engine	16.16%	3.20%
Chassis/Frame	13.28%	2.63%
Hydraulic System	12.26%	2.43%
PM	6.84%	1.35%
Steering	5.24%	1.04%
Electrical 24/12 Volt System	4.93%	0.98%
Tires	4.00%	0.79%
Suspension	3.75%	0.74%
Z-Space	3.53%	0.70%
Cooling System (eng.)	3.51%	0.69%
Brakes	3.35%	0.66%
Dump Body	3.10%	0.61%
Z-Mech. Manpower	3.08%	0.61%
Cleaning (Steaming)	2.60%	0.51%
Air Conditioning	2.09%	0.41%
Transmission	2.04%	0.40%
Air System	1.83%	0.36%
Torque Conv/PTO & Drivelines	1.28%	0.25%
Spindles/Hubs	1.19%	0.24%
Z-Weld. Manpower	1.14%	0.23%
Cab/House	0.69%	0.14%
Air System & Air Starting	0.66%	0.13%
Communication Devices	0.65%	0.13%
Lube System	0.64%	0.13%
Fire Suppression	0.59%	0.12%
Accident Repair	0.35%	0.07%
Z-Parts	0.26%	0.05%
Z-Tire Manpower	0.24%	0.05%
Z-No Operator/Coodination	0.19%	0.04%
Diffs. and Final Drives	0.17%	0.03%
Pre-PM	0.15%	0.03%
Alternator	0.06%	0.01%
Lights	0.05%	0.01%
Z-No Tools Or Equipment	0.02%	0.00%
Z-Elect. Manpower	0.01%	0.00%
Air Cooling	0.01%	0.00%
Fuel Tank And Supply	0.01%	0.00%
Tandem Drive	0.01%	0.00%
Z-Waiting For Maintenance	0.01%	0.00%
Total	**100.00%**	**19.79%**

Source – Teck Highland Valley Copper - *Continuous Improvement 2015*

Table 8: Impact to 793 Haul Truck Availability in 2014 (s/n SSP 2 units – 2013)

Description	% of Total	Avail. Impact
PM	26.13%	3.18%
Engine	14.57%	1.77%
Electrical 24/12 Volt System	9.60%	1.17%
Chassis/Frame	9.23%	1.12%
Cleaning (Steaming)	5.26%	0.64%
Brakes	3.94%	0.48%
Cab/House	3.57%	0.43%
Fire Suppression	3.29%	0.40%
Z-Mech. Manpower	3.19%	0.39%
Tires	2.75%	0.33%
Hydraulic System	2.53%	0.31%
Dump Body	2.51%	0.31%
Air Conditioning	1.85%	0.22%
Transmission	1.84%	0.22%
Steering	1.70%	0.21%
Z-Space	1.60%	0.20%
Cooling System (eng.)	1.23%	0.15%
Torque Conv/PTO & Drivelines	1.12%	0.14%
Air System	0.83%	0.10%
Lube System	0.80%	0.10%
Pre-PM	0.70%	0.08%
Suspension	0.51%	0.06%
Alternator	0.50%	0.06%
Z-Tire Manpower	0.25%	0.03%
Spindles/Hubs	0.21%	0.03%
Communication Devices	0.15%	0.02%
Diffs. and Final Drives	0.06%	0.01%
Air System & Air Starting	0.06%	0.01%
Z-Parts	0.05%	0.01%
CR Down	0.00%	0.00%
Total	**100.00%**	**12.17%**

Source – Teck Highland Valley Copper - *Continuous Improvement 2015*

The average availability of the fourteen oldest 793 haul trucks at HVC was 80.2 % in 2014. The average availability of the two newest 793 haul trucks at HVC was 87.8%. The difference between our oldest and newest haul fleets is 7.6%. This is the opportunity!

The main bad actors on the older fleet relative to the new fleet become relevant in the table below.

Table 9: Comparison of the Top 7 Availability Impacts – Old vs. New Fleets

	% Old Flt Impact	% New Flt Impact	Availability Opportunity
Description			
Hydraulic System	2.43	0.31	2.12
Chassis/Frame	2.63	1.12	1.51
Engine	3.2	1.77	1.43
Steering System	1.04	0.21	0.83
Suspensions	0.74	0.06	0.68
Cooling System (eng.)	0.69	0.15	0.54
TOTAL AVAIL. OPPORTUNITY:			**7.11**

Source – Teck Highland Valley Copper – author, 2015

6: Developing a New Asset Management Strategy

We are planning to replace six older 793 haul trucks. The purchase of six haul trucks for use in 2016 will cost about 27.84 million in sustaining capital. The replacement haul trucks would be ready for work at the start of 2016.

The first obvious new strategy fits a mine site that has a near term end of mine life. This strategy would consist of only procuring one additional 793 haul truck to ensure capacity is maintained until the end of mine life. This additional truck would replace the operating hours lost from the older trucks in the fleet. This strategy would cost 4.64 million dollars.

In the case of HVC, we are already looking at pushing our mine life out to 2040 and therefore this short-term strategy would not fit well with the long-term resource plan we are developing. Understanding the opportunities in availability between the old and new fleets would suggest that there is an option here. This alternative strategy would take a truck out of service and target the rebuild of the truck such that the areas of rebuild would match the top 7 availability impact areas as identified in our table above. In order to ensure we do not adversely affect the mine operations hauling capacity, we would purchase one new 793 haul truck to maintain capacity throughout this process. With the new 793 haul truck in service, we would then look at taking the next five oldest trucks out of service one at a time and perform a targeted rebuild on each unit. The big question then becomes, which strategy is more cost effective – purchase six new trucks or purchase one new truck and perform a targeted rebuild on five old 793 haul trucks?

6.1 Targeted Precision Rebuild

Mining companies have rebuilt haul trucks in the past and the first lesson learned is that the sum of the parts adds up to more than the cost of the haul truck. Here is where precision must come into our execution. We must only perform the targeted work planned and be precise in execution in order to keep the costs in line. That means that when we remove our components during the tear down, all healthy components will be re-used. If we target properly and are precise in our execution, this may become the alternative to asset replacement. From this point forward, I will refer to this as a Targeted Precision Rebuild or TPR.

6.2 Estimated Cost of a Targeted Precision Rebuild on a 793 Haul Truck

Table 10: Cost Estimate for a Targeted Precision Rebuild of a 793 Haul Truck

U.S. to Canadian Conversion rate :	1.2		
793 TARGETED PRECISION REBUILD	**US $**	**CAN $**	**CAN $**
Description		HVC	Finning
290-9817 Frame Group	$350,000	$420,000	$420,000
198-5954 Upgraded Axle Box	$115,000	$138,000	$138,000
185-6377 A Frame	$42,000	$50,400	$50,400
259-6879 New Retrofit Cab Assembly	$113,000	$135,600	$135,600
All Wiring Harnesses (complete)	$25,000	$30,000	$30,000
All hose assemblies (complete)	$75,000	$90,000	$90,000
Re-conditioned engine	$410,000	$492,000	$492,000
Re-conditioned torque	$35,000	$42,000	$42,000
Re-conditioned transmission	$58,000	$69,600	$69,600
Drive Shaft Assembly	$11,000	$13,200	$13,200
Applicable Pumps and Valves - incl hoist, front brk, PB/rear cooling, secondary prk brk pump/motor, dan foss valve, steer pump hoist, traction, PB release, acc. Bleed down, duel spool valve.	$55,000	$66,000	$66,000
Re-conditioned Rad		$16,700	$16,700
Re-conditioned Hoist Cylinders x 2		$19,200	$19,200
Front Wheel & Brake Assembly x2		$33,000	$33,000
Re-conditioned rear suspension x2		$14,000	$14,000
Re-conditioned fron suspension x2		$24,000	$24,000
Fuel Tank - HVC avg price		$7,500	$7,500
Hyd Tank - HVC avg price		$5,000	$5,000
Deck & Air Box refurb by HVC Welder - parts only		$10,000	$10,000
Box Refurbishment by HVC Welder - parts only		$40,000	$40,000
Est. Welding Labour 660 hrs @ $65/hr HVC or $140/hr Finning		$42,900	$92,400
Est. Mech. Labour to re & re 2000 hrs at $65/hr HVC of $140/HR Finning		$130,000	$280,000
Estimated Supervision/Coordination 660 hrs @ $85 per hour		$56,100	$0
Paint and Decals		$20,000	$20,000
		$1,965,200	$2,108,600

Source – Teck Highland Valley Copper – drawn by author 2015

The TPR would be $1,965,200 using our own labour and $2,108,600 using Finning labour. For this project, we will use the HVC labour. The period we would use for TPRs such as outlined above would be sixteen-week duration with a crew consisting of one supervisor, three

HD Mechanics and one welder. The total job would consist of thirty-two hundred HVC person-hours working a forty- hour week for sixteen weeks. This would allow us to complete three TPRs the first year and complete the last two TPRs in year two.

6.3 New Mine Asset Replacement Strategy vs. the Existing Strategy

Table 11: Teck Highland Valley Copper – Cost of New 793F Haul Truck

U.S. to Canadian Conversion rate :	1.2	
	US $	**CAN $**
Cost of new 793F Haul Truck		
Description		HVC
Brand New 793F w/o tires of dump body	$3,200,000	$3,840,000
plus local options, body, transport and build		$764,732
6 new tires	$237,000	$284,400
less salvage for old truck		-$250,000
Grand Total		**$4,639,132**

Source – Teck Highland Valley Purchasing Group

The new strategy will have us procuring one new 793 truck in 2016. This truck will cost approximately $4.64 million dollars. The three rebuilds to follow in 2017 will cost an additional $5.9 million dollars with the last two rebuilds occurring in 2018 for $3.94 million dollars. This brings the total of this new strategy to $14.4 million.

Table 12: Financial Comparison of Original Strategy vs Proposed Strategy

Financial Comparison					
	2016	**2017**	**2019**	**Total**	
Original Strategy - Purchase 6	27,840,000	-	-	27,840,000	
Cash cost after discounting and CCA	26,448,000	-	-	26,448,000	
New Strategy - Purchase 1, TPR 5	4,640,000	5,895,000	3,930,000	14,465,000	
Cash cost after discounting and CCA	4,408,000	4,809,491	2,497,589	11,715,079	
Total Cash savings including TVM				$ 14,732,921	
Total Cash savings not including TVM				$ 13,375,000	
TVM component (additional saving due to phased in spending)				$ 1,357,921	
Assumptions					
· A full year CCA is available at a rate of 25% (i.e. we had the equipment available on Jan 2016).					
· Tax rate estimate is based on a corporate tax rate of 40%					
· Discount factor is 8%					

Source – Teck Highland Valley Copper

The total cost of six new haul trucks is $27.8 million vs the new strategy of $14.4 million plus an additional $1.3 million savings based on the time value of money due to the phased spending in the TPR option. (See Appendix B & C for DCF calculations) The total difference between the original strategy and this new strategy is $14.7 million.

7: Conclusion

There is an alternative to the way Teck Highland Valley Copper has been managing its mine mobile asset replacement.

In the short term or in the case of a short remaining mine life, the procurement of a single asset can be used to make up and guard against capacity shortfall. Of course this can only occur until the shortfall in availability equals the capacity of the additional haul truck and then you must consider the purchase of another haul truck to once again guard against a capacity shortfall. This is indeed only a short term solution as the increase in fleet size and operators will be cost prohibitive in a longer term situation.

In the longer term or increasing life of mine situation, TPR or targeted precision rebuild of the current mobile mine assets will ensure that capacity can be maintained while providing a cost effective long term solution to mobile asset replacement. The 793 haul truck fleet example used as a proxy in this paper would be rebuilt in such a way as to maintain capacity while providing a $14.7 million dollar reduction in sustaining capital over the original strategy of straight asset replacement. This reduction in sustaining capital would come at a time when capital is constrained and cost reduction initiatives are being sought.

This is a viable strategic option to mine mobile asset replacement at Teck Highland Valley Copper.

Appendices

Appendix A

Table 13: Copper Mine – 2012 Equipment Replacement Guideline Comparison

Peru Mine		HVC	Chile Mine 1	Chile Mine 2	Chile Mine 3	Chile Mine 4
Año 2012		Año 2012		año 2012	año 2012	año 2012
Flota	Horas de vida de equipo	Horas de vida de equipo	Horas de vida de equipo	Horas de vida de equipo	Horas de vida de equipo	Horas de vida de equipo
Equipos actuales						
Palas BUCYRUS 495 BI	100,000	120,000	80,000	100,000	120,000	80,000
Perforadoras BUCYRUS 49R III	80,000	100,000	60,000	70,000	65,000	
Camiones 793C	90,000	90,000	80,000	80,000	100,000	80,000
Camiones 793D	90,000	90,000	80,000	80,000	100,000	80,000
Camiones 777D	90,000		80,000	80,000	100,000	45,000
Cargadores Frontales CAT 994D	90,000		45,000		45,000	45,000
Cargadores Frontales CAT 994F	60,000		45,000		45,000	
Perforadoras IR DMM2	60,000		60,000		45,000	
Perforadoras IR ECM690	60,000				45,000	
Perforadora BPI T600	60,000					
Tractores de Orugas CAT D11R	60,000		45,000	60,000	45,000	
Tractores de Orugas CAT D10R	60,000	50,000	45,000	60,000	45,000	
Tractores de Orugas CAT D8R	60,000		45,000	60,000	45,000	
Tractor de Orugas CAT D6R	60,000		45,000	60,000	45,000	
Cargador Frontal CAT 992G	60,000			60,000		
Cargadores Frontales CAT 988F	60,000		40,000	60,000		
Cargadores Frontal CAT 924F	60,000			60,000		
Motoniveladoras CAT 24H	60,000	40,000 (24M)	45,000	60,000		
Motoniveladoras CAT 16H	60,000	50,000 (16M)	45,000	60,000		
Motoniveladora CAT 14H	60,000	60,000	45,000	60,000		
Tractor de Ruedas CAT 854G	60,000		45,000	60,000	65,000	
Tractores de Ruedas CAT 834B	60,000	60,000	45,000	60,000	65,000	
Excavadoras CAT 330CL	60,000			60,000		
Excavadoras CAT 330BL	60,000			60,000		
Excavadoras CAT 375L	60,000			60,000		
Excavadora CAT 385CL	60,000			60,000		
Compactadores CAT CS-533	60,000			60,000		
Retroexcavadora CAT 426C	60,000			60,000		
Equipos reemplazantes						
Perforadoras Viper	60,000					
Perforadoras ECM720	60,000					
Perforadora ROC830	60,000					
Excavadora CAT 385CL	60,000					
Equipos de expansión						
Motoniveladoras CAT 24M	60,000					
Tractores de Orugas CAT D10T	60,000					
Tractores de Orugas CAT D11T	60,000					
Excavadora CAT 385CL	60,000					
Camiones 793F	80,000		80,000	80,000		80,000
Camiones Komatsu 930E	90,000		80,000	80,000		80,000
Cargadores Frontales L2350	60,000					
Cargadores Frontal CAT 924H	60,000					
Tractor de Ruedas CAT 854K	60,000					
Palas P&H 4100XPC	100,000		80,000	100,000		
Perforadoras BUCYRUS 49HR	60,000					
Perforadora ROC830	60,000					
Camiones 785D	100,000					

Appendix B

Table 14: DCF Analysis of Original Mobile Equipment Replacement Strategy

Original Mobile Equipment Replacement Strategy - 793 Haul Trucks				
Discounted Cash Flow Analysis				
(CAPITAL PURCHASE MODEL)				
	2016	2017	2018	
Net Investment	27,840,000	0	0	27,840,000
Inventory Changes (Increase)				
Cost Savings	0	0	0	
Change in Cash Before Taxes	(27,840,000)	0	0	
Taxable Operating Savings	0	0	0	
C.C.A. on Investment		(6,960,000)	(5,220,000)	
Gross Savings Taxable	0	(6,960,000)	(5,220,000)	
Corporate Tax on Savings	0	2,784,000	2,088,000	
Net Cash (Outflow)	(27,840,000)	2,784,000	2,088,000	
Cumulative Cash Flow	(27,840,000)	(25,056,000)	(22,968,000)	
D.C.F. @ Prescribed Rate	(27,840,000)	2,577,778	1,790,123	
Cum. Discounted Cash Flow	(27,840,000)	(25,262,222)	(23,472,099)	
	FINANCIAL DATA			
		(Tax Financial Factors)		
		Corp. Tax Rate	0.4000	
		C.C.A. Rate	0.2500	
		D.C.F. Rate	0.0800	

Source – Teck Highland Valley Copper

Appendix C

Table 15: DCF Analysis of New Mobile Equipment Replacement Strategy

New Mobile Equipment Replacement Strategy - 793 Haul Trucks				
Discounted Cash Flow Analysis				
(CAPITAL PURCHASE MODEL)				
	2016	2017	2018	
Net Investment	4,640,000	5,895,000	3,930,000	14,465,000
Inventory Changes (Increase)	0	0	0	
Cost Savings	0	0	0	
Change in Cash Before Taxes	(4,640,000)	(5,895,000)	(3,930,000)	
Taxable Operating Savings	0	0	0	
C.C.A. on Investment		(1,896,875)	(2,650,781)	
Gross Savings Taxable	0	(1,896,875)	(2,650,781)	
Corporate Tax on Savings	0	758,750	1,060,313	
Net Cash (Outflow)	(4,640,000)	(5,136,250)	(2,869,688)	
Cumulative Cash Flow	(4,640,000)	(9,776,250)	(12,645,938)	
D.C.F. @ Prescribed Rate	(4,640,000)	(4,755,787)	(2,460,294)	
Cum. Discounted Cash Flow	(4,640,000)	(9,395,787)	(11,856,082)	
	FINANCIAL DATA			
	(Tax Financial Factors)			
		Corp. Tax Rate	0.4000	
		C.C.A. Rate	0.2500	
		D.C.F. Rate	0.0800	

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Interviews

Interview with Mr. Brad Price, Account Manager – Finning, March 30, 2015