Implementing Lean Principle into Mining Industry Issues and Challenges

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The lean production concept has its origin in automotive industry and is widely used in manufacturing sectors. What makes its applicability in mining difficult is the dynamic nature of mining operations bringing high degree of uncertainty in various unit operations. To reduce the wastage of efforts, one needs to remove uncertainty and predict the process behaviour as correct as possible. Furthermore, to achieve lean approach in mining, the entire mining chain needs to be considered starting from Mine exploration, mine planning, drilling operation, blasting, loading and transportation, ore dressing processes, reclamation, etc. To be lean in mining is not only dependent on mine production systems consisting of equipments and machines but it also depends on quality and reliability of information flow in real time generating action plans. Also, the reliability and maintenance preparedness have major influence on the degree of waste being generated in the process. For example if ore body is not correctly delineated/characterised or drilling operations not performed correctly, wrong charging process and wrong loading process- all may lead to wastage of resources. In fact Lean production has its origin (leans on) in JIT, TQM and TPM. The common denominator of all these philosophies is the human in the process. To improve any process one needs to measure the current status so that any change in current status can be recorded. The paper presents issues and challenges associated with implementation of Lean Principles in Mining industries.

Key words: Lean principle, Mining

1. Introduction

Lean principles have been revolutionizing manufacturing industry since it derived from the Toyota Production System. Over the past 30 years it has been applied almost in all type of manufacturing industry and started to penetrate toward other types of industry including mining industry. Why mining industry should also adopt lean principle into their business process? There are two reasons, first is the decreasing of the mining industry' profitability due to the rising cost pressures associated with the social and environmental demands of sustainable development (Humphreys, 2001), need to be compensated by reducing production cost. Management innovation (*e.g*. lean principle) that has good reputation in cost reduction should be integrated to current management of mining industry (Klippel, *et al*., 2008). Second is, in spite of the differences, both automotive and mining industries sharing common view (Colard, *et al*., 2007):

- Both rely on effective business processes
- Both rely on efficiency within the Value Stream

- Both strive to maximize operational efficiency
- Both rely on an extensive supply chain
- Both sectors have ruthless focus on safety

Those similarities bring an opportunity to successfully apply lean principle into mining industry.

Many companies in various industries have implemented some of the principles of lean principles with attempt to replicate Toyota's success, however only few have matched the dramatic improvements achieved by Toyota. Primary reason is many companies have embraced lean tools but lack of understanding on what makes them work together in a system (Liker, 2004). Lean principle is not just adapting the tool but how to change the culture, 'a true culture of continuous improvement'. In contrast to innovation approach which emphasize on a quick improvement/change, lean principle is a continuous improvement approach which emphasize on a small but constantly improves.

In applying into mining industry, one should understand that lean principle is an operating philosophy in its original context (automotive industry) that had particular values, needs and characteristics. Mining work is characterized as dynamic, uncertain, volatile and risky work environment. Dunstan, *et al*., 2006 underlines differences between resource and mineral processing industry and automotive industry, some that related to mining industry are shown in Table 1.

Table 1: Comparison of Mining industry and Automotive industry

Mining industry	Automotive industry
Physically challenging environment	Ambient environment
Inherently variable environment	Stable work environment
Geographically spread output teams	Compact plants
Inherently variable raw materials	Controlled raw materials
Remote locations	Large centers

Source: adapted from Dunstan, et al., 2006

Those differences bring a consequence on the dissimilarity of values, needs and characteristics that if do not deliberate carefully lead to potential pitfalls.

This paper portrays the issues and challenges in applying lean principle into mining industry, especially underground mining.

2. Lean Principle

Womack and Jones (1996) suggest five lean principles;

1. *Identify customer and specific value*
   The fundament of this principle is to identify the specific value of the end customer in terms of the most important features of the market offering. The complexity of this principle is that there might be slightly contradictory perceptions of value within different market segments. Failure to exactly identify the value might result in highly inefficient operations that are not fully delivering there right value and as a result of this are undertaking non value adding activities, all the non added value activities can be targeted for removal.
2. *Identify and map the value stream*

The Value Stream is the entire set of activities across all parts of the organization involved in jointly delivering the product or service. This represents the end-to-end process that delivers the value to the customer. Activities that do not add value should be modified or eliminated from the process.

3. *Create flow by eliminating waste*
   Create flow is focusing on process design and establishment of capabilities that enable continuous movement throughout the process without any interruption, detour or waiting by eliminating waste.
4. *Pull*
   Pull means meeting consumer's rates of demand without overproduction. No activity is carried out unless the result of it is required downstream.
5. *Pursue perfection*
   The elimination of non-value-adding elements (waste) is a process of continuous improvement. It is a constant strive for improving the value specification, challenge the steps in the value stream and increasing the speed in the flow that hidden waste can be identified and eliminated.

Critical starting point for lean thinking is value. Value can only be defined by the ultimate customer; it begins with a concise attempt to precisely define value in terms of a specific product with specific capabilities offered at a specific time at a specific price through a dialogue with specific customers. Value is created by the producer, and from customer' perspective, this is why producer exist (Womack and Jones, 2003). Everything that does not add value to the product is waste and customer is not willing to pay for (Karlsson and Ahlstrom, 1996). Waste should be eliminated to make value flow. Lean principle identified seven types of waste known by acronym WORMPIT;

1. Waiting
2. Over Production
3. Repair
4. Motion
5. Processing (over)
6. Inventory
7. Transportation

Further on, another type of waste has added that is 'Human Talent', and now it is known as 7 + 1 waste. Lean principles are organized in a structure known as The Lean Temple (see figure 1).

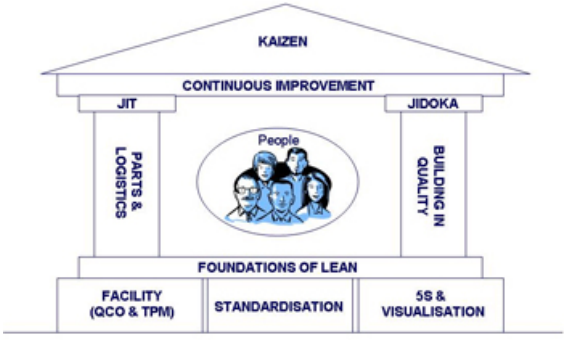

Figure 1: The Lean Temple
(source: Knowledge Management and Transfer, 2009)

The temple (also known as House of Toyota) lay on foundation consist of three blocks. First block is TPM (Total Productive Maintenance) and QCO (Quick Change Over). TPM aim on free equipment breakdown state, where operators perform routine maintenance and maintainer responsible for scheduled maintenance. QCO aim on shortening production downtime during operational change or scheduled maintenance. Second block is 5S and Visual Factory, key targets of this block are workplace morale, safety and efficiency. Third block is standardization which focus on the improvement of the way work done. “Where there is no standard, there can be no kaizen” (Taiichi Ohno). Temple has 2 pillars, first is Just in Time (JIT) which is philosophy to process or transport the right part at the right quantity and quality to the right place at the right time. Second is Jidoka or automation with a human touch. On the roof is the spirit of Kaizen or continuous improvement. And in the heart of temple is respect to people which means that workers are the centered of the activity.

3. Round cycle in mining

In mining industry, the overall sequence of activities can be grouped into 6 stages, they are;

1. Prospecting – searching for mineral deposit
2. Exploration – defining extent and value of ore, conducting feasibility study and making decision to abandon or develop
3. Development – opening up ore deposit for production
4. Exploitation – extracting ore in the large scale
5. Mineral processing – preparation
6. Marketing – selling

In this paper, scope is limited to stage four (exploitation).
Mining is a cyclic of series activities, where one activity is dependent to other activity. Failure in one activity leads to many delays. The round cycle in mining differ from one mine site to other mine sites. It is adjusted to deal with varying methods, scale and ground conditions. A typical round cycle in underground mining is shown in figure 2. By nature all activities in mining is under uncertainty condition due to dynamic movement of the ground and instability of rock formation.

- During drilling activity, rock hardness inside the face is difficult to predict.
- In charging, volume of filling explosion gel also has a great variation.
- In blasting, unexpected results may be obtained due to the unobserved rock formation such as inside crack.
- In mucking, volume and speed of loading is changing from time to time due to variation in the ore size.
- In scaling, volume of work is not known until work has been done, number of loss rock is very much depending on the rock formation.

All of uncertainty in each activities result in high uncertainty of the whole work cycle.

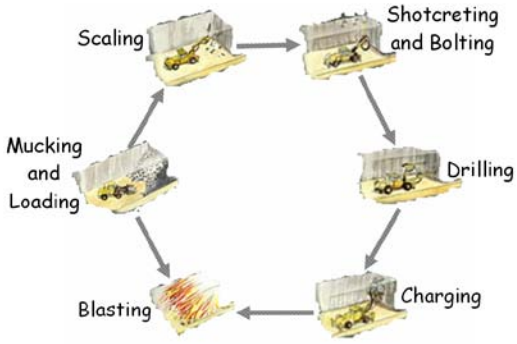

Figure 2: Typical Round Cycle in Underground Mining.

4. Applying Lean Principle into Mining Industry

Starting point for applying lean principle is to understand the value based on customer needs. In mining industry, especially base metal, product and customer have unique characteristics. Products deriving from mining industry are standard product that inherently has well defined specifications and requirements. Quality and price are established by market and there is no product differentiation between industries. Transaction occurs in stock market without direct contact between mining industry as a product provider and buyer. Thus "direct" customers (companies who buy the product) do not play as important role in this business. However in a broader view, mining industry has indirect customer who are passively or actively contribute in the role of business, they are stakeholder (society, government, media, etc). Their major interest is not quality of the product but quality behind the product, such as environment, human well-being, and economic prosperity of society. These needs are the current value of mining industry and it has been articulated in the vision of International Council on Mining and Metals (ICMM); "*respected mining and metals industry that is widely recognized as essential for society and as a key contributor to sustainable development*" (ICCM, 2009).

Second step in lean thinking is defining waste and its counter measure. 7 + 1 waste in the mining industry is described as follow:

1. *Wait*
   Muckpile wash or dust removal waiting period after blasting is major cause of waiting waste in mining. All activities have to be stop during this period. Engineering approach to reduce waiting time, such as better exhaust fans or duct system, need to be investigated. Another waiting waste is idle time of mobile equipment, utilization in underground mining is low. This low utilization is due to trade off between utilization of mining face, utilization of work force and utilization of mobile equipment, where attempt is to maximize the utilization of mining face. Cost and benefit study should be conducted to determine the optimum utilization.
2. *Over Production*
   Unlike automotive industry where ability of market to absorb product is fluctuating, mining industry has advantage that market is stable and it can be say that market can

always absorb in spite of volume of the product. Thus over production is not issues in mining industry.

3. *Repair/rework*
   In mining risk involving work to repair or to rework is high due to potential accident and cost related. In mining, repair or rework is not just due to imperfect work but also due to the nature. Dynamic and unstable environment introduce constantly possibility for rework and repair that can not be avoided. However, imperfect work can be reduce by standardize procedure and method to assure the quality of work.
4. *Motion*
   In mining this type of waste is related on how the work is done. Currently, training for the new operator is by mentoring system, which is done informally and non-structure. As a result, non standardized method is obtained, since variance of method between experience operators is present and trainee may perceive in the different way. Certification system is so far not applicable.
   Another trial for eliminated excess motion is by automation. As a requirement and load is shifting from physical to cognitive, training should be designed to cover not only skill and rule based learning but also knowledge based.
5. *Processing (over)*
   Most visible over processing waste is the dimension of tunnel, it is common to observe that dimension of tunnel is exceeding required dimension. Causes are not solely due to the unstable rock but also due to over work in facing work. So far scaling rock is a non standard work which is very much depending on the skill, knowledge and experience of the operator. An inexperience operator may end up by keeping scale the rock, and never done, because the termination of the work is based on the subjective judgment of the operator.
6. *Inventory*
   This type of waste is the most difficult to combat in mining. Very much higher cost of downtime compares to cost of inventory, make it a common believe that inventory is a positive. It is contrast to value of lean that inventory is root of evil. One way to tackle inventory problem is by improving reliability of equipment. It is a big challenge because majority of failure is random failure due to hostile environment. Design out Maintenance is one of the methods that can be utilized.
7. *Transportation*
   In mining issues of this type of waste deals with choice of mode of transport, equipment sizing, pick up location, form of material to be transported.
8. *Human Talent*
   This type of waste deal with under utilize of human resource in term of working hour and most important in term of capacity and capability. Based on the belief that the human factor holds 70% of the improvement potential within the mining industry, focus should be emphasized in this type of waste.

In applying lean principle into mining industry, one should understand that lean principle is an operating philosophy in its original context (automotive industry) that had particular values, needs and characteristics. Relevant issues for this matter is describe in a structure of the temple of lean. Each element of temple has unique issues as follow:

- *Standardization*

Standardization is critical foundation of lean principle, it need a rigorous work to do it and is applicable to all other lean tools. In mining standardization is a difficult task as a work in mining is very much depends on the uncontrollable factors, such as rock movement. Variation of work from time to time is high, different condition need different way of work. However to some extends standardization can be done in mining. One example is rock bolting. Naturally number of bolt and location of installation much depend on the condition of the rock. Soft rock required more bolt than hard rock, and also depend on the movement of the rock which is quite difficult to predict. Putting more bolt than it's needed introduce over work while putting less bolt will introduce a potential for rework. Standardization can be done by letting the worse rock condition be used as a standard and number and location of bolt determined by this condition. Off course it will create extra cost due to additional material, man hour, machine hour time, and process. However it will reduce a variation on process time allowing establishing standard time that is needed for line balancing by distributing the workload. It also reduces variation of the way how work is done and by means of improvement; a standard work method can also be established. Another dimension to be considered is work quality, without standardization quality of work has to be inspected visually by operator which very much relies on their judgment and knowledge. Incorrect decision in quality control may introduce rework in the future and risk of a failure. Once standard work method is established quality control will be diminished, and it shift from quality control to quality assurance. Standardization is critical foundation in lean principle, as Taiichi Ohno said; "Where there is no standard, there can be no Kaizen".

- *TPM (Total Productive Maintenance) and QCO (Quick Change Over).*
  TPM is a philosophy of bringing operator and maintainers in cooperation, where operator perform autonomous maintenance encourage operator and maintainers conduct scheduled and non-routine maintenance. The line between routine and non-routine have to be defined carefully. In practice, due to the remote location of work site, operator is encouraged to do a simple non-routine maintenance (in case of breakdown maintenance). This approach has two edges, in one hand it will reduce the downtime as a waiting time maintainer is eliminated, but it other hand if operator do not have sufficient skill and especially knowledge about best practice of maintenance work, it might increase the downtime as the rework or frequency of failure due to imperfect maintenance job. One common example is changing broken hydraulic hose, it is simple maintenance work with less requirement of skill, however without sufficient knowledge of current hydraulics system imperfect work likely occurred as a current hydraulics system utilize a low viscosity oil which is more sensitive toward dust or dirt.
  Issues of QCO application in mining mostly related to scheduled maintenance. It deals on maintainability of equipment, how ease of equipment to be maintained. Attention should be given from the design stage (design out maintenance and design for maintenance) to operation stage. Intense communication and cooperation between end user and equipment developer is encouraged.
- *5S and Visual Factory,*
  5S and visual factory concerns the cleanliness, organization and accessibility of workplace. Commonly this tool is used as entry point for lean thinking. It is usually

well accepted among employee. But outsource and sub-contract work has a potential to be a hindrance in applying lean. In contrast to automotive industry where delegation of work to second party is in form of long partnership, in mining industry, outsource and sub-contract work is a common practice. This type of relation create potential problem as the second party may not share common value. Practically it is not surprising that second party refuse to involve in 5S and visual factory simply because it is not part of the contract.

- *Just in Time (JIT)*
  JIT is one of weakest spot in applying lean tool in mining. Remote location and tendency of large batch operation are seen as major obstacle. However as lean thinking is not just applying tool but more on understanding the philosophy of lean thinking. Investigation of customized JIT method that suit to characteristics of mining industry is essential.
- *Jidoka*
  Jidoka is defined as automation with a human touch. Trend in today mining industry is shifting from on-board operator to remote operator. It result in changing of work demand from physical need to cognitive need that need to be tackle in holistic way to maintain level of productivity. Study on intelligent control with a human touch is strongly emphasized.
- *Respect to people*
  As important resources in the business process, empowerment and skill up through structural training is needed. One of challenge in mining industry is that workforce turnover is high, thus much effort have been emphasized on training for new worker.

5. Concluding Remarks

Lean principle has a potential to be successfully applied to mining industry. However many issues have to take into consideration and challenges have to be manage in a smart way. Applying lean principle is not just utilizing tool but more on changing the culture. It is a slow process and need a total devotion toward the alteration of culture. One approach is to apply the concept of Overall Production Effectiveness to eliminate waste and increase the operational reliability, production quality and performance through engagement of all personnel (Nakajima, 1994). How to engage all personnel – A TPM approach can be applied

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