Analysis of Material Handling Flow Process on Tin Smelting: a Case Study in Indonesia

Eko Zunianto S
School of Business and Management
Akbar Adhiutama
Institute Technology of Bandung

Abstract: *Indonesia is one of the largest tin producers in the world. Tin industry is growing and flourishing in Indonesia. In Indonesia, the processing of tin ore to tin metal uses reverberatory furnace. Effectiveness on flow of material handling process becomes the determining factor in keeping Work in Process (WIP) material inventory levels and increasing productivity. The purpose of this study is to analyze the flow of material handling processes in order to minimize WIP material inventory and increase productivity. Value Stream Mapping (VSM) is used as a tool to analyze the process flow. Direct field observations and analysis of production data are developed into current VSM. The result reveals that there are some wastes or muda in the process flow. One of the occurring wastes is on the lead time process of the WIP handling which is longer than the cycle time of melting process; therefore, this causes an accumulation of WIP material that results in productivity decreasing of the tin production. Waste elimination can trim the processing time of WIP material handling so that it will be able to reduce the accumulation of WIP material as much as 53% and increase tin production by 5%*

Keywords: *tin, smelting process, value stream mapping, WIP inventory, cycle time, reverberatory furnace*

Abstrak: Indonesia merupakan salah satu produsen logam timah terbesar di Indonesia. Industri timah tumbuh dan berkembang dengan pesat di Indonesia. Tanur jenis *reverberatory* pada umumnya digunakan untuk proses peleburan bijih timah. Efektifitas proses penanganan material menjadi salah satu faktor yang menentukan dalam menjaga tingkat *inventory meterial WIP* dan meningkatkan produktifitas. Tujuan dari penelitian ini adalah untuk menganalisis alur proses untuk mengurangi *inventory WIP* dan meningkatkan produktifitas. VSM digunakan sebagai alat untuk menganalisis alur proses. Pengamatan dan data di lapangan digunakan untuk menyusun *current VSM*. Hasil analisis menunjukkan adanya *waste*/muda dalam alur proses. Salah satu waste yang terjadi adalah lead time proses penanganan WIP yang lebih lama dibandingkan dengan cycle time proses peleburan, sehingga mengakibatkan terjadinya akumulasi WIP dan berdampak terhadap turunnya produsi logam. Eliminasi *waste* dapat memperpendek proses dan mengurangi akumulasi material WIP sebesar 53% dan meningkatkan produksi sebesar 5%.

Kata Kunci: timah, proses peleburan, *value stream mapping, inventory WIP, cycle time, tanur reverberatory*

Tin metal is very important in industrial world. Globally tin metal is used in solder industry, tinplate, chemical, and others. In 2011, Asia is the largest tin producer in the world (LME, 2011). China through Yunnan Tin is the largest tin producer in the world. Indonesia is the second largest tin producer in the world, with a predominance of production owned by PT Timah (Kettle, 2010). PT Timah currently is using reverb furnace technology for smelting tin ore to tin metal. The use of the reverberatory furnace has several advantages (Smith, 1996). Firstly, the advantage is to be able to use coal as a fuel as well as reducing agent for smelting process. Secondly, this type of furnace

Alamat Korespondensi:
Eko Zunianto S, School of Business and Management
eko.zunianto@sbm-itb.ac.id , *akbar@sbm-itb.ac.id*

is able to melt tin ore of high grade above 55%, where tin ore is in accordance with the characteristics of raw material resources in Indonesia, which is generally an alluvial mineral.

Standard smelting with reverberatory furnace uses two stages of smelting (Smith, 1996) (Figure 1). The first stage is the process of smelting tin ore, tin dust, dross and FeSn alloy. The resulting products of this first phase are crude tin and slag 1. The next step is crude tin will be refined into tin metal while slag 1 will be processed on second stage of smelting. During the first stage of the melting process takes place in the form of WIP material generated tin dust. Then tin dust is processed back at the first stage of melting. While in the process of refining will be resulted form of WIP namely dross. Dross will be processed in the first stage of smelting. The form of slag 1 in the first stage will be processed in second stage of smelting to produce alloy FeSn and slag 2. Slag 1 cannot be directly merged in the first stage of smelting because it has a very different chemical composition of tin ore. Remelting of FeSn alloy on the second phase will be processed in the first phase along with smelting of tin ore, tin dust and dross. While slag 2 is not able to be processed anymore, because the content of tin is very small, less than 1% (Smith, 1996).

WIP material in the form of slag 1, tin dust, dross, and FeSn alloy cannot be directly melted in the subsequent smelting process since it requires handling (preparation) before the melting process. Time required for handling each material WIP before reprocessing. WIP material handling time is longer than the cycle time of smelting process causes the material can not be immediately processed. As the result, it would be an accumulation of WIP material at the end of the production period. Because this is still WIP material has a high tin content, then this accumulation resulted in delay of tin content in WIP is to be converted into metal tin (opportunity loss in production).

The purpose of this study is to analyze and identify waste arising in handling process of WIP material. VSM method is used as a tool to analyze and identify the process flow has been shown to be effective for use in the manufacturing and mining industries as a means to help improve productivity (Ade & Deshpande, 2012); (Barani, Sindhar, & Rajenthirakumar, 2013); (karunesh & Thotappa, 2013); (Rahani & al-Ashraf, 2012); (Wang, Ren, & Sarker, 2005); (Williams & Tetteh, 2008).

Research objective is to reduce the accumulation of WIP material. The existence of high inventory levels caused a large amount of Sn content were barred produced into tin. With a decrease in the accumulation of WIP means there are a number of Sn content that was originally held in the WIP can be processed for tin products. Thus it can increase metal production in order to contribute to the achievement of production targets. The solution that will be selected must be able to reduce the accumulation of WIP material and can be implemented within 1 year. The selected solution should consider the cost of the investment, is not depend on external circumstances (regulations, availability of supply of the ore), and can be implemented in the long term

LITERATURE REVIEW

Many companies implement the concepts of lean manufacturing in order to get competitive advantage over other companies. Value Stream Mapping (VSM) is a very important tool in the implementation of lean manufacturing. There are several stages in developing VSM (Womack, 2006). Firstly is identify the product family, secondly is using VSM to determine the problems that currently occur, and finally is proposing futures VSM that can increase the value of the process. The basis of lean production is to identify and eliminate the waste. Activities conducted within a process can be classified into three groups (Chen & Meng, 2010). The first is the value added work that is a plus for the company in which consumers are willing to pay for it. The second is all activities that are not value added but required to support value added. The third is a non-value added that is a waste in the production process and must be eliminated, in the form of excess inventory, waiting for the high lead time, excessive in processes, excessive movement in process, transportation of materials and products that are not needed, and the defective product. VSM analysis can help reduce lead time and WIP, improve product quality and capacity of equipment, reduce rework and inventory levels and may reduce the indirect costs (Wang, Ren, & Sarker,

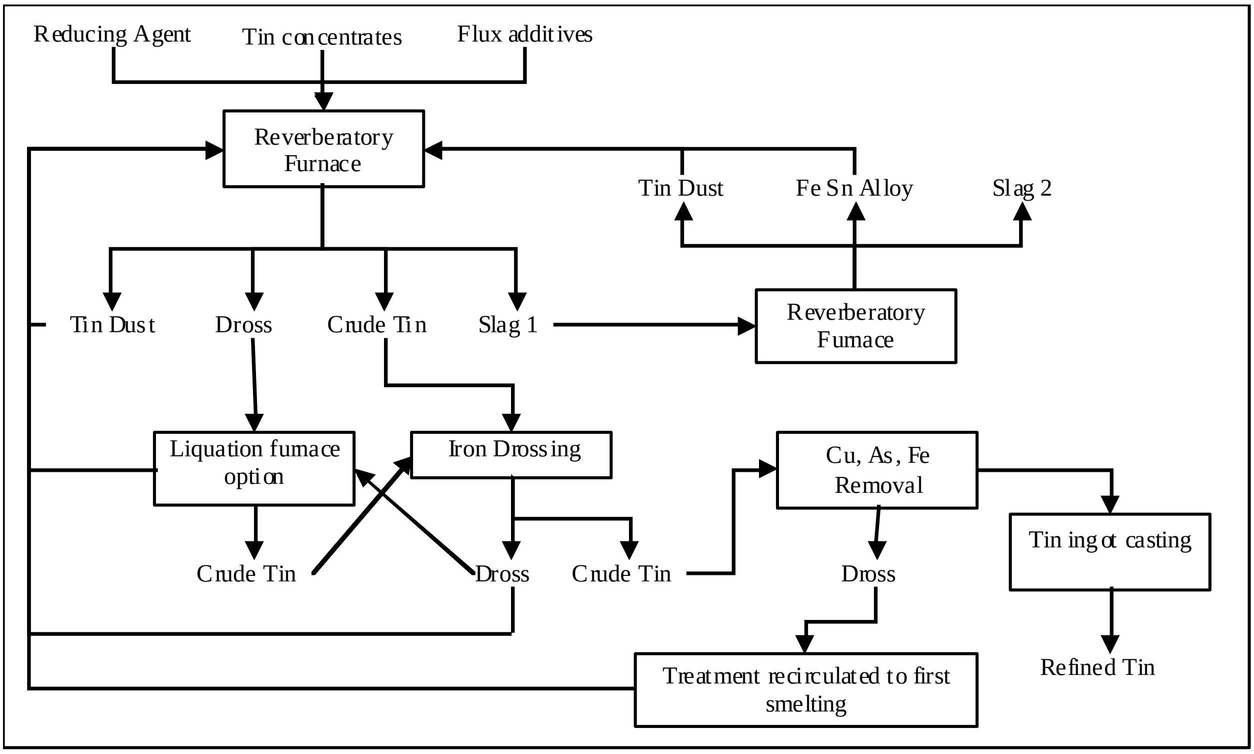

Figure 1. Tin ore smelting process through two stage smelting
(Source: Smith, 1996)

2005). Reduction in the lead time means the process of reducing the waiting time in the workflow process. This will provide the economic impact on the efficiency of processing time (Rahani & al-Ashraf, 2012). Implementation of value stream mapping in manufacturing sector can reduce the production lead time of up to 50% compared with the traditional process (karunesh & Thotappa, 2013). In the automobile manufacturing industry, productivity improvement process can be done by identifying the waste that occur in the process and then eliminate it so as to ensure the process can be carried out effectively (Belokar, Kharb, & Kumar, 2012)

The same approach can be done for the industry in the mining sector. Research on improving productivity in coal mining by using lean manufacturing approach has been done. The results showed that compared with traditional methods of production, lean manufacturing approach with the benefit of waste reduction, labor, production capacity, and investment in equipment as well as reduces inventory (Ade & Deshpande, 2012). In the mining industry, lean manufacturing system can work with a complementary system of Six Sigma so that improve corporate performance (Dunstan, et al., 2006). In lean manufacturing techniques can be used to control the implementation Six Sigma to improve company's performance. While methodology in Six Sigma can provide a sustainable implementation for lean production.

VSM analysis conducted on current mapping process. Analysis toward seven waste conducted against current mapping to determine clearly waste that occurs and what actions will be taken to eliminate the waste (Singh & Sharma, 2009). Plan activity that conducted by Keizen is to reduce cycle time on WIP handling process (Rahani & al-Ashraf, 2012). Analysis is performed by comparing the cycle time before and after the process improvement (Rahani & al-Ashraf, 2012).

This study uses VSM approach to the evaluation process in the WIP material handling process of the tin ore smelting in reverberatory furnace. This is done because it has not found research on the evaluation process material handling WIP at the tin smelting process using reverberatory furnace with VSM approach. Evaluation results will be used as the basis for the identification of waste throughout the process (Barani, Sindhar, & Rajenthirakumar, 2013). By eliminating waste, it will get a new process flow that can contribute in reducing the accumulation of material WIP inventory and increase productivity.

METHODOLOGY

Methodology of this research is to conduct direct observation of the process for a year. This observation is intended to get a clear picture of the stages of the process. The data relating to the stages of the process is taken as a baseline for data analysis and new process flow calculation. (Rahani & al-Ashraf, 2012; Belokar, Kharb, & Kumar, 2012; Gibbons & Kennedy, 2012). The data will be used is the cycle time on the material handling process of WIP, WIP average amount produced per batch melting, and the amount of WIP required for further processing. Based on the data obtained, then data is calculated how much material accumulated WIP that happens. On the stages of the process found waste will be marked for further activities in order to eliminate waste. It aims to look at the opportunities for improvement in the procedural stages. After the waste is removed, it is counted how much cycle time of a new stage of the process. Future VSM builds upon a new stage of cycle time. Amount of accumulated material from VSM futures accounted for compared with the amount of material accumulated before the improvement is done. Amount of material accumulated reduction of WIP during one year of operation is calculated as the potential for increased production of tin that can be done within one year of operation.

ANALYSIS AND FINDING

Process Background and Product Process Flow

Flow tin ore smelting process conducted by PT Timah using reverberatory furnace (figure 2) is done through two stages of melting. Melting process as described in the introduction. WIP material before it is processed through the handling and preparation process of gathering, classification and delivery back to the furnace. The process is carried out with consideration of the production of the previous batch has not been sufficient to process the next batch and each WIP has a different impurity content that needs to be classified before processing to ensure the quality of the metal.

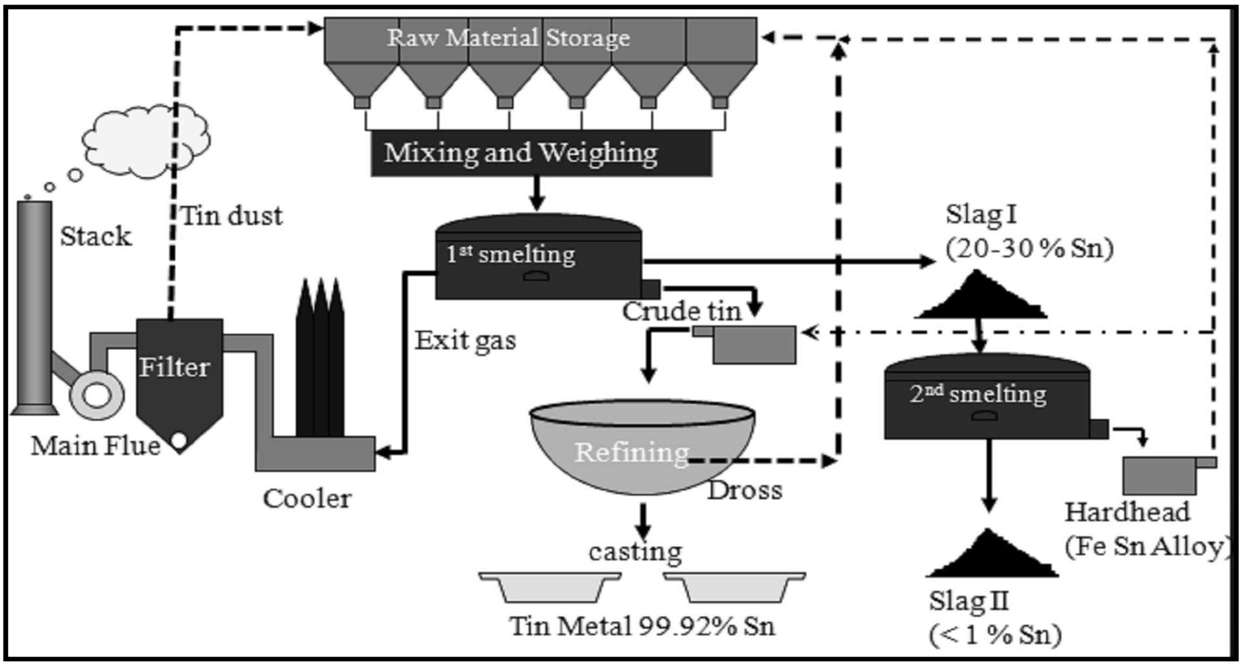

Figure 2. Flow process Tin Smelting in PT Timah

Current VSM

The first stage of the melting process and the second phase is done in batch with long of each batch for 24 hours. As explained earlier that the process will be generated after the WIP material. WIP material must go through the process of handling (preparation) before it merged (figure 3).

Handling process of Slag 1 started from first process that accepted in the first stage of smelting process. Slag 1 that received will be weighed and a sample taken for further analysis of element content. After the analysis, slag 1 will be classified by levels of lead. Then, Slag 1 is weighed and stored in a storage location before being delivered to the furnace for processing. Storage is done for 72 hours (three times the first phase of melting batch). The goal is to get a sufficient supply of slag 1 for the second phase of the next batch melting.

Handling process of tin dust starts from tin dust material receipt from the first stage smelting. Tin dust will be collected during five days of operation by the consideration that in a day just a little dust is produced. Dust samples are taken to analyze the content of tin. Furthermore the dust will be classified based on the tin content. The last process is the weighing process for recording inventory. Weighing up the collection process takes 130 hours. The collected tin dust pellets made through pelletizing process. It aims to become dust grains with a diameter of 1 cm so it does not fly during the melting process. Once used as pellets, dust packed weighed and then sent to the melting process.

Dross treatment process begins by weighing the material dross obtained from the process of refining crude tin. Collecting dross smelting wait three batches first phase (72 hours). Dross samples are taken for analysis of tin content and impurities. The analysis of results is used as the basis for classification. Dross that has been classified weighed and then sent to the first stage of the melting process.

Handling process of Alloy FeSn begins with receipt of material milled from the second stage. Material received is weighed and then stored in a stock yard before it is sent to the first stage of the melting process. Gathering material done during the second phase of the four batch melting (96 hours). During the process of gathering material, samples are taken for analysis of the content of the element. The final step of material collected is sent to the furnace to be melted.

The data cycle time for each WIP material preparation process is as follows table 1.

Based on the data found that the cycle time, WIP material handling process is much longer than the cycle time melting process. This means that not every process of melting could melt WIP material.

WIP is not melting material on subsequent smelting process causes the accumulation of material WIP inventory.

Based on production data can be calculated how many WIP materials produced each batch melting and how many WIP materials required for the next batch process (Table 2) and the amount of material accumulated WIP happens every time WIP management process implemented (Table 3).

WIP accumulation results are shown in Table 3 column 8. By considering tin content and the recovery of each material WIP (appendix 1) then there is a potential that the metal cannot be produced by 18.37 tons of tin (for each process handling WIP).

DISCUSSION

Waste of flow processes (Gibbons & Kennedy, 2012; Wang, Ren, & Sarker, 2005) consists of over-production, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary motion and defects. Identification of the waste that occurs in the process of handling WIP mapping can be done by observing the process is currently underway (Gahagan, 2007). In this case is handling process of WIP material.

For the preparation of tin dust identified the waste in the form of the length of time to wait and the process does not need to be done. With consideration to the amount of dust produced for two batches

Table 1. Current Total Cycle Time of WIP Material Handling

WIP	Slag 1	Dross	Tin Dust	Fe Sn Alloy
Cycle time (hours)	80	85	130	99

Table 2. Production of WIP material as batch process and WIP material requirement for next batch (current condition) – for 1 unit reverberatory furnace

WIP material	Production per smelting batch (kgs)	Requirement per smelting batch (kgs)
Slag 1	13,800	25,000
Dross	6,682	5,000
Tin Dust	1,254	1,500
Fe Sn Alloy	8,605	2,500

Table 3. Calculation accumulation of WIP inventory (current)

	Cycle time (hours)	Total batch of process	Inventory produce (kgs)	Requirement for next batch (kgs)	Total batch can be supplied	Total requirement materials (kgs)	Accumulation (kgs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Slag 1	80	3.00	41,400	25,000	1.00	25,000	16,400
Dross	85	3.00	20,046	5,000	3.00	15,000	5,046
Tin dust	130	5.00	6,271	1,500	4.00	6,000	271
Fe Sn Alloy	99	4.00	34,420	2,500	4.00	10,000	24,420

Table 4. Opportunity loss in tin metal production due to WIP inventory accumulation

	Accumulation (kgs)	Tin contents (%)	Recovery of tin (%)	Tin metal produced (kgs)
(1)	(2)	(3)	(4)	(5)
Slag 1	16,400	25%	70.23%	2,879
Dross	5,046	68%	75.23%	2,581
Tin dust	271	60%	74.05%	120
Fe Sn Alloy	24,420	69%	73.93%	12,457
Total opportunity loss				18,037

that have been sufficient for requirements of the next batch smelting, the collection process can be shortened from 120 hours to 48 hours. Based on observations in the field, the dust that is made become pellet would fall back on when entered into the furnace. Therefore pelletizing process of tin dust is a process that is not effective. This process can be removed and replaced with the process of mixing the dust with tin ore during material will be smelted at stage 1. For the handling of dross and Fe Sn alloy, material collection process can be done every day because of the amount of the production process has previously been sufficient to process the next batch, so the collection process can be shortened from four material batch process (96 hours) to one batch process (24 hours).

Future VSM

Design Future VSM is made to eliminate waste that occurs in the current VSM to obtain improvement of the process (Barani, Sindhar, & Rajenthirakumar, 2013). Waste that occurs in any material handling process described above. Based on observations of the smelting process, dust and FeSn alloy material consumption that are melted can be raised. So the amount of inventory accumulation of material WIP can be reduced.

Table 5. Proposes requirement WIP material Material requirment (kg) - current

	Material requirment (kg) – current	Material requirment (kg) – proposed
Slag 1	25,000	25,000
Dross	5,000	5,000
Dust 1	1,500	2,500
Fe Sn Alloy	2,500	5,000

Based on data above, futures VSM can be arranged as described in Figure 4. To ensure the effective and answer the VSM future problems occur, then simulation calculations of accumulation of WIP material conducted based on future VSM. Calculation results are described in Table 6.

With VSM future and increase the amount of WIP material consumption in the next batch process, there is found that a reduction in the accumulation of significant WIP material. In any process of accumulation of slag 1 material reduced from 16.4 tons to 2.6 tons, dross is reduced from 5.046 tons to 1.682 tons, lead dust from 271 kg to 8 kg, and FeSn alloy of 24.42 tons to 3.61 tons. Having regard to tin content in each material WIP and tin recovery of each material WIP (appendix 1) then there is a potential that the metal cannot be produced down to 3.16 tons of tin per WIP material handling process.

Within one year of production, the type of reverberatory furnace unit can perform the first stage of the melting process is about 191 batches and 106 batches in the second stage (appendix 2). Number of process handling of WIP for current and future VSM described in Table 7 in columns 2 and 3. With this data can be calculated amount of accumulated reduction of WIP in one year of production operations.

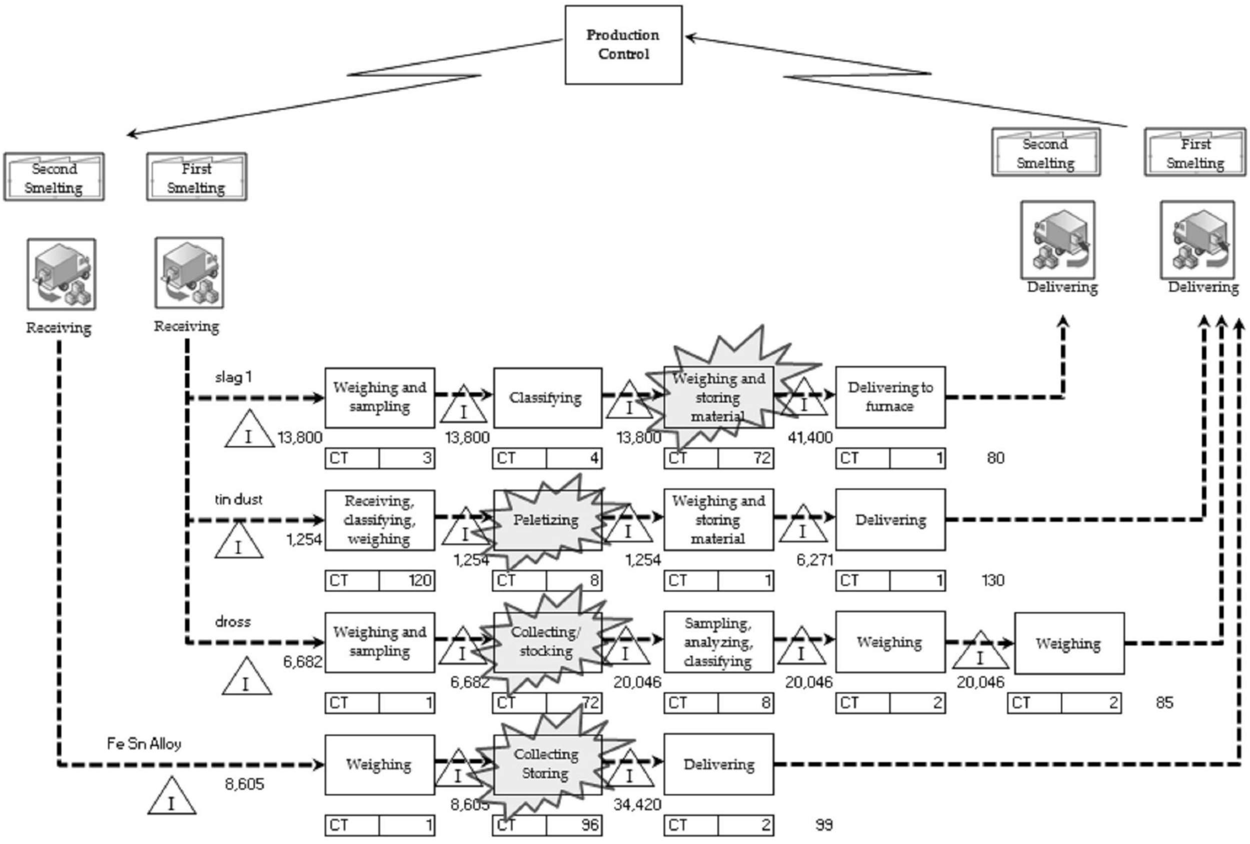

Figure 3. Current VSM

Table 6. Calculation accumulation of WIP inventory (future)

	Cycle time (hours)	Total batch of process	Inventory produce (kg)	Require ment for next batch (kg)	Total batch can be supplied	Total require-ment meterials (kg)	Accu-mula-tion (kgs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Slag 1	56	2.00	27,600	25,000	1.00	25,000	2,600
Dross	37	1.00	6,682	5,000	1.00	5,000	1,682
Tin dust	50	2.00	2,508	2,500	1.00	2,500	8
Fe Sn Alloy	27	1.00	8,605	5,000	1.00	5,000	3,605

Table 7. Comparison of WIP material accumulation between current and future VSM (per unit operation of reverberatory furnace)

	Total of material handling process annually		Accumulation material per handling process (kg)		Total accumulation WIP material annually (kg)		Total differences (kg)
	Current	Future	Current	Future	Current (2x4)	Future (3x5)	(6-7)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Slag 1	64	96	16,400	2,600	1,049,600	249,600	800,000
Dross	64	191	5,046	1,682	322,913	321,231	1,682
Tin dust	38	96	271	8	10,292	800	9,492
Fe Sn Alloy	27	106	24,420	3,605	659,348	382,138	277,210

Within one year of production are significantly decreased the accumulation of WIP. This accumulation of WIP reduction would be equivalent to an additional amount of WIP that is processed in the smelting process. Based on the recovery process (Appendix 1) and based on the same calculation steps in Table 4, futures VSM will help increase production of 286.94 tons of metal. This calculation is based on data for one year of production operations by operating one unit of furnace. With two furnace units operated by the company, then there is potential for an increase in metal production as much as 573.88 tons per year. This result is supported by the results of other studies (Gurumurthy & Kodali, 2011; Ade & Deshpande, 2012; Wang, Ren, & Sarker, 2005) which concluded that the value stream process improvement can improve productivity and reduce the accumulation of WIP material.

Managerial Impact

Changes in the material handling process flow of WIP caused consequences to be implemented in the operational managerial smelting. Process flow changes must be accompanied by changes in standards of service operations (SOP) and work instruction according to the future VSM has been built. Not only change SOP and work instruction, but also necessary outreach to supervisors and operators and make sure they understand and implement the new process. Change of process flow causes the number of material handling activities will increase in one year of operation. This must be balanced with the provision of adequate facilities. Management must be able to prepare the land and a new building for the new VSM supports the future addition of equipment and materials for the preparation of (additional investment costs). Management must operate smelting furnace with balance smelting system that is the balance between the melting processes of the first stage and the second stage. The comparison between the first stage and the second stage is 20:11 days (appendix 2). If management is more concerned with the first stage of melting metal for the purpose of producing too much will result in a change in the material handling process flow WIP will not have a significant impact.

For the integration of the mining process with metal production process, related to supply of tin ore, management should change the flow of planning process for the production of ores, metals and metal sales. Making change work plans starting from mining plan (tin ore) then translated into metal production plan. This is done because process production of tin ore (mining) have a higher uncertainty than the metal production plan.

CONCLUSION

In the tin industry, with the VSM approach can be used to identify waste in the process so that to improve the effectiveness and productivity of production. Waste elimination and redesign process flow thus shortening cycle time. WIP material handling process cycle time approaching the smelting process of the first stage and the second stage can reduce the accumulation of WIP material and increase the production of tin metal. Operation for one year with two reverberatory furnaces operated projected additional production of 573.88 tons of tin metal. Key to success in this implementation is the contribution of the operator to adjust the flow process with a new process flow and commitment of the management to deploy an operating policy with respect to balance smelting as well as additional investment costs to make changes to the material handling process flow WIP.

BIBLIOGRAPHY

Ade, M., & Deshpande, V. 2012. Lean manufacturing and productivity improvement in coal mining. *International Journal of Engineering Science and Technology*, 2293 - 2299.

Barani, Sindhar, & Rajenthirakumar. 2013. Lean manufacturing for productivity improvement: A manufactur-

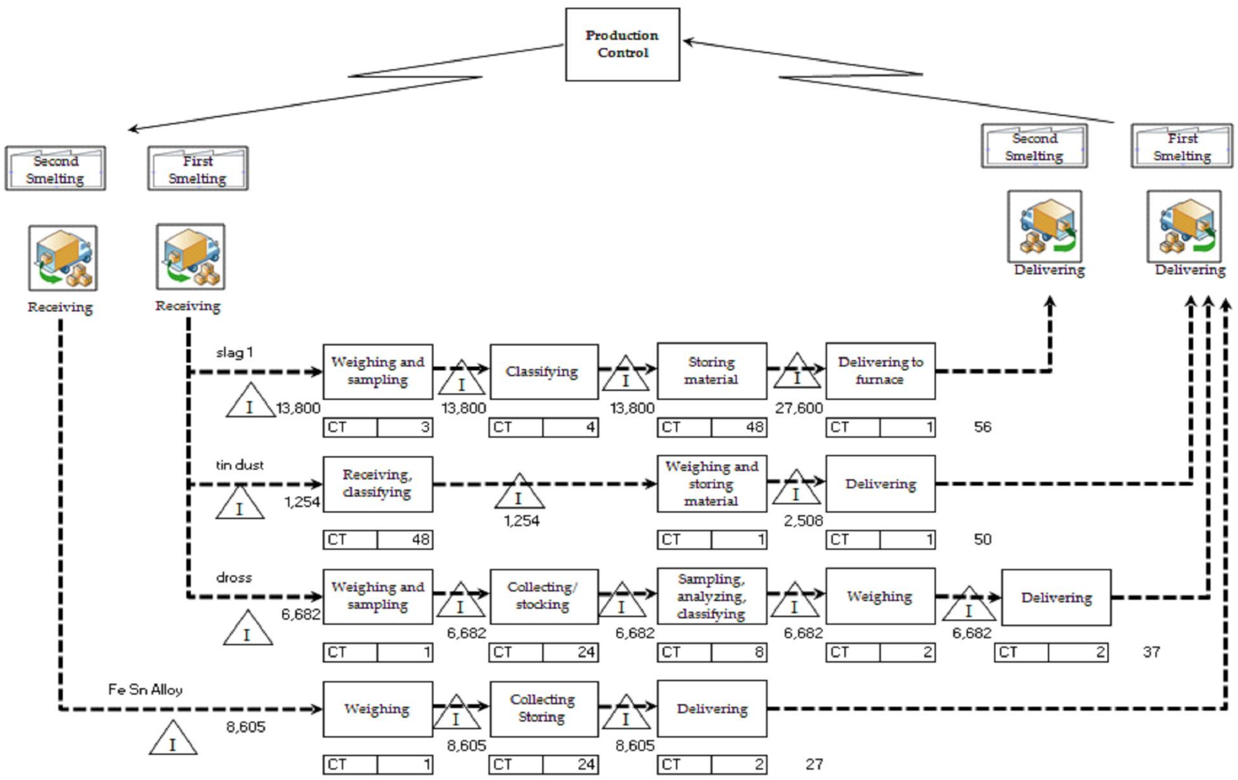

Figure 4. Future VSM

ing sector case study. *Proceedings of the national conference on manufacturing innovation strategies & appealing advancements* .

Belokar, R., Kharb, S.S., & Kumar, V. 2012. An Application of Value Stream Mapping In Automobile Industry: A Case Study. *International Journal of Innovative Technology and Exploring Engineering (IJITEE) Vol I* .

Chen, L., & Meng, B. 2010. The application of value stream mapping based lean production system. *International journal of Business and Management*, 203–209.

Dunstan, K., Lavin, B., & Sanford, R. 2006. The application of lean manufacturing in a mining environment. *International Mine Management Conference*, 145–157.

Gahagan, S.M. 2007. Adding Value to Value Stream Mapping: A Simulation Model Template For VSM. *IIE Annual Conference Proceedings* , 712–717.

Gibbons, P. M., & Kennedy, C. 2012. The development of a lean resource mapping framework: introducing an 8th waste. *International journal of lean six sigma vol 3*, 4–27.

Gurumurthy, A., & Kodali, R. 2011. Design of lean manufacturing systems using value stream mapping with simulation. *Journal of Manufacturing Technology Management Vol 22 No 4* , 444–473.

Karunesh, & Thotappa, C. 2013. Lead time reduction in order execution of horizontal slurry pump using lean concepts for mining equipment manufacturing company. *International Journal of Scientific & Engineering Research Vol 4* .

Kettle, P. 2010. *Historical trends in tin usage*. Retrieved July 20, 2013, from ITRI: https://www.itri.co.uk/index.php? option = com_ mtree & task = viewlink & link_id=49603&Itemid=11

LME. 2011. *London Metal Exchange : Production and Consuption*. Retrieved July 20, 2013, from London Metal Exchange: http://www.lme.com/en-gb/metals/non-ferrous/tin/production-and-consumption/

Rahani, & al-Ashraf, M. 2012. Production flow analysis through value stream mapping: A lean manufacturing process case study. *International symposium on robotics and intelligent sensors* , 1727–1734.

Singh, B., & Sharma, S. 2009. Value stream mapping as a versatile tool for lean implementation: an Indian case study of a manufacturing firm. *Measuring business excelence vol 13 no 3* , 58-68.

Smith, R. 1996. An Analysis of The Processes for Smelting Tin. *Mining History: The Bulletin of Peak District Mine Historical Society Vol 13 No 2*.

Wang, S., Ren, Y., & Sarker, B. R. (2005). Minimizing WIP for unbalanced assembly line in value stream mapping. *Annual Conference Proceeding* .

Williams, D. L., & Tetteh, E.G. 2008. Value-stream mapping to improve productivity in transmission case machining. *Proceesings of The 2008 Industrial Engineering Research Conference* , 1061–1065.

Womack, P. J. 2006. Value Stream Mapping. *Manufacturing Engineering 136* .