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THE IMPROVEMENT OF SMELTER OPERATIONAL RISKS BY USING RISK MANAGEMENT SYSTEM

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Abstract

Mining Law No. 4/2009 had regulated the policy of increased mineral added value, thus mining companies are obligated to build a refining facility or smelter in Indonesia prior to exporting their products. Smelter activities have higher complexity than mining in many aspects and causes new operational risks to be managed; which are classified into operation, safety, and environment category. The objectives of this study are to conduct operational risk assessment and develop risk treatment plan, with the case study in iron smelter company. Risk management process is following ISO 31000 standard and constructed using semi-qualitative method. There are a total of 121 risks in iron smelter operational that had been identified, analyzed, and evaluated. Those risks consist of 65 risks in operation, 45 risks in safety, and 11 risks in environment category; with risk rating score being estimated using consequence, likelihood, and detection matrix. Risk treatment in terms of mitigation plans are developed only for extreme and high risks rating score. There are 11 action plans created in operation category, 9 action plans in safety category, and 4 action plans in environment category. Risk assessment and treatment plan results can support the company to overcome smelter operation complexity and generate quality products in safe manner and environment friendly condition.

Keywords: Iron Smelter, ISO 31000, Operational Risk, Risk Management.

1. Introduction

Indonesia mineral and coal mining businesses are regulated by Mineral and Coal Mining Law No. 4/2009, with one important point being the policy of increasing mineral added value through domestic processing and refining activities. As consequences of the new regulation, companies that hold mining business license have the compulsory task of upgrading their mining product content by building processing or refining facilities in Indonesia, prior to export of its products.

Mineral processing and refining plant utilize extractive metallurgy principle. The targeted metals are extracted from raw material using either high temperature method with pyrometallurgy technology or aqueous solutions reactions with hydrometallurgy technology. The most common and proven technology used in this industry is pyrometallurgy which generally consist of roasting, smelting, converting, and refining units.

This study will take one company as case study, a national iron ore mining and processing company which holds the mining business license and has plan to build processing and refining facilities in South Kalimantan province. The company business field can be divided into a mining and smelter area, with general business process illustrated in Figure 1.

There are significant differences between mining and smelter plant, which are explored by comparing several items in the iron smelter company as presented in Table 1.

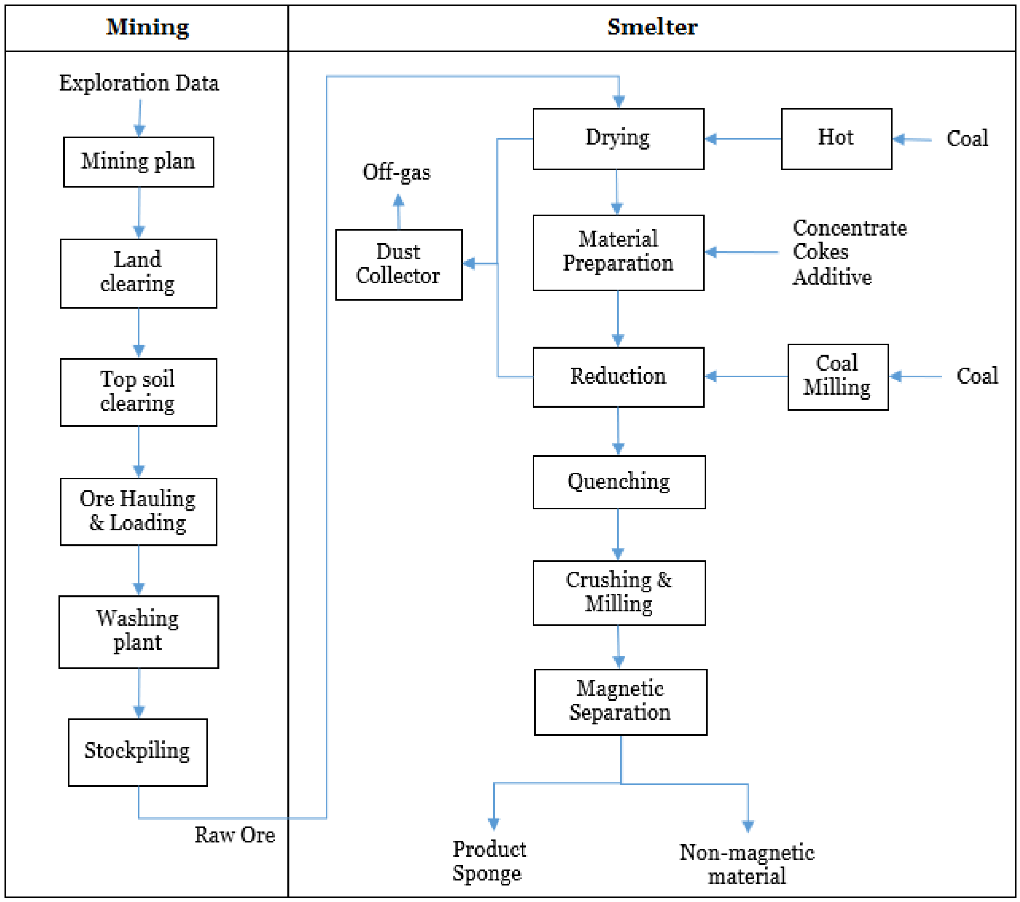

Figure 1. Iron Smelter General Business Process

Iron smelter operational activities can be considered more complex than iron mining; with the fact that iron smelter involves more main equipment type, more main process type, involving high temperature, more type of material to be handle, and deals with off-gas emission. The expanded business scope from mining to smelter area can raise new operational risks that most likely did not exist before the mining activities.

The iron smelter company is classifying operational risks into three categories which are operation, safety, and environment risk. Those risks are necessary to be assessed and proper mitigation plans needs to be developed to ensure the future business sustainability.

The objectives of this study are to conduct operational risk assessment and develop risk treatment plan for the iron smelter company. This study assumes that iron smelter operational risks can be identified, analyzed, and evaluated from internal company personnel; and the risk treatment implementation plan can become a tool to manage those operational risks.

Qualitative research method is applied during the study by interview sessions with relevant personnel from internal company. This study's outcome can be used to support the future iron smelter operation sustainability, to help the company to overcome the complexity of iron smelter operation and to generate product as targeted specification in safe manner and environment friendly condition.

Table 1. Comparison between Iron Mining and Smelter Operational

No	Description	Mining	Smelter		Note
1	Main Equipment Type	a. Belt conveyor b. Crusher c. Screen d. Magnetic separator e. Dump truck f. Wheel loader g. Excavator	a. Belt conveyor b. Rotary dryer c. Hot stove d. Crusher e. Screen f. Rotary mixer g. Briquette machine h. Reduction kiln i. Air blower	j. Coal mill k. Nitrogen generator l. Cyclone m. Bag filter n. Ball mill o. Magnetic separator p. Dump truck q. Wheel loader r. Excavator	Smelter involves more equipment type (18 type) compared with Mining (7 type).
2	Main Process	a. Land clearing b. Top soil clearing c. Raw ore loading & hauling d. Washing plant e. Raw ore stockpiling	a. Drying b. Reduction process c. Crushing d. Milling e. Magnetic separation	f. Dust collection g. Coal combustion h. Coal grinding	Smelter has 8 main processes and involves high temperature condition, compared with Mining which has 5 main processes and ambient temperature condition.
3	Material Consumption	a. Iron ore	a. Iron ore b. Coal	c. Cokes d. Additives	Smelter involves more material consumption (4 type) compared with Mining (1 type).
4	Maintenance	a. Mechanical b. Electrical c. Instrumentation d. Focus on mobile equipment	a. Mechanical b. Electrical c. Instrumentation d. Focus on fixed equipment		Both Mining and Smelter involves maintenance disciplines of mechanical, electrical, and instrumentation.
5	Environment Treatment	a. Liquid effluent b. Solid waste	a. Liquid effluent b. Solid waste c. Off-gas emission		Environment aspect in Mining includes liquid effluent and solid waste; meanwhile Smelter has additional off-gas emission to be handle.

2. Literature Review

The mineral industry is widely applying risk assessment and risk management, particularly in the perspective of health and safety because potential hazards are considered as the natural parts of the operation. (McLellan & Corder, 2013). Metal smelting and refining would need to deal with waste treatment because it produces gaseous and particulate matter emissions, wastewater, and solid wastes. (Dudka & Adriano, 1997). A Smelter plant also concerns itself with quality management system as part of continuous improvement system, with example ISO 9001 quality management system and ISO 14001 environment management system implementation in Arcelor Mittal stainless steel plant in Poland. (Gajdzik, 2008).

Risk is defined as the effect of uncertainty for organization to achieve its objectives, due to internal and external factors. Risk management is the coordinated activities to direct and control an organization with regard of risk. Organization manages risk by identifying, analyzing and evaluating it, whether the risk should be modified by treatment plan in order to satisfy the risk criteria. (ISO 31000, 2009).

International Organization for Standardization established ISO 31000 to provide principles and general guidelines to design, implementing, monitoring and review, and continual improvement of risk management in the organization. ISO 31000 describes the risk management principles, framework, and process to help organization managing all kind of risks in systematic way within any scope and context. Risk management process is part of implementing risk management which consist of communication & consultation; establishing the context; risk assessment which includes risk identification, risk analysis, and risk evaluation; risk treatment, and monitoring & review.

Risk treatment in terms of control hierarchy can be adopted from safety terms, which described in order of effectiveness as eliminating hazard and risks through system design; substitute with less hazardous method, process, materials or equipment; engineering controls and work re-organization; apply administrative controls and provide personal protective equipment. (ISO 45001, 2017).

Risk assessment process in this study is focusing only on operational risks in the iron smelter plant, which are divided into three categories of:

- Operation risks, which emphasize the failure mode that impacting product quality and production rate in process and maintenance area. Quality is defined as the degree to which the set of inherent characteristics of an object can satisfy the requirements. (ISO 9001, 2015).
- Safety risks, which emphasize the hazards in process and maintenance area. Hazard is defined as the source or the agent with has potential to cause personnel injury and ill health. (ISO 45001, 2017).
- Environment risks, which emphasize the environment aspects in process and maintenance area. Environment aspect is the element of organization's activities, products or services that interacts with the surrounding environments. (ISO 14001, 2015).

Those risks are further classified into sub-category of process and maintenance, since the iron smelter operational activities mainly deal with those two sub-categories.

3. Methodology

This study uses qualitative research methodology to identify, analyze, evaluate, and treat the operational risks of iron smelter plant. The analysis framework is based on ISO 31000 risk management process; and presented in Figure 2.

The process is initiated by identifying business issue faced by the company and conducting the relevant literature review. Primary data collection is obtained through discussion and interview method. Discussion is conducted with General Manager of Ore Processing, which has purposes to gain insight about the internal context, external context, and risk management context of the company. Interview sessions are held with total eight persons from Operation and Maintenance department, with objectives to identify, analyze, and evaluate operational risks and develop the risk treatment. Data collection is also gained using secondary data by exploring the company documents that relevant with this study. Those documents include the company profile, feasibility study of smelter development, Standard Operating Procedures from Operation and Maintenance departments.

Two frameworks are applied to establish the external context of the iron smelter company, which are the PESTEL and Porter's Five Forces frameworks. Meanwhile, the Resource Based framework and Value Chain analysis are generated for internal context development. Both external and internal contexts are merged into SWOT matrix to evaluate the organization existing condition and future prospect. The step then continues with developing strategic analysis based on the SWOT matrix.

Some highlighted results from the strategic analysis are to initiate quality management system to ensure iron smelter product quality and customer satisfaction, along with developing and improving safety and environment management system. International Standard Organization had published standard for Quality Management System ISO 9001:2015; Occupational Health and Safety Management Systems ISO 45001:2017; and Environment Management System ISO 14001:2015 that can be taken as references. One similar component in all those three management systems is to determine risks and opportunities, and to develop action plan to address them; with purpose to obtain the organization target, to improve the positive or compulsory effects, to minimize or prevent unwanted effects, and to achieve continuous improvement.

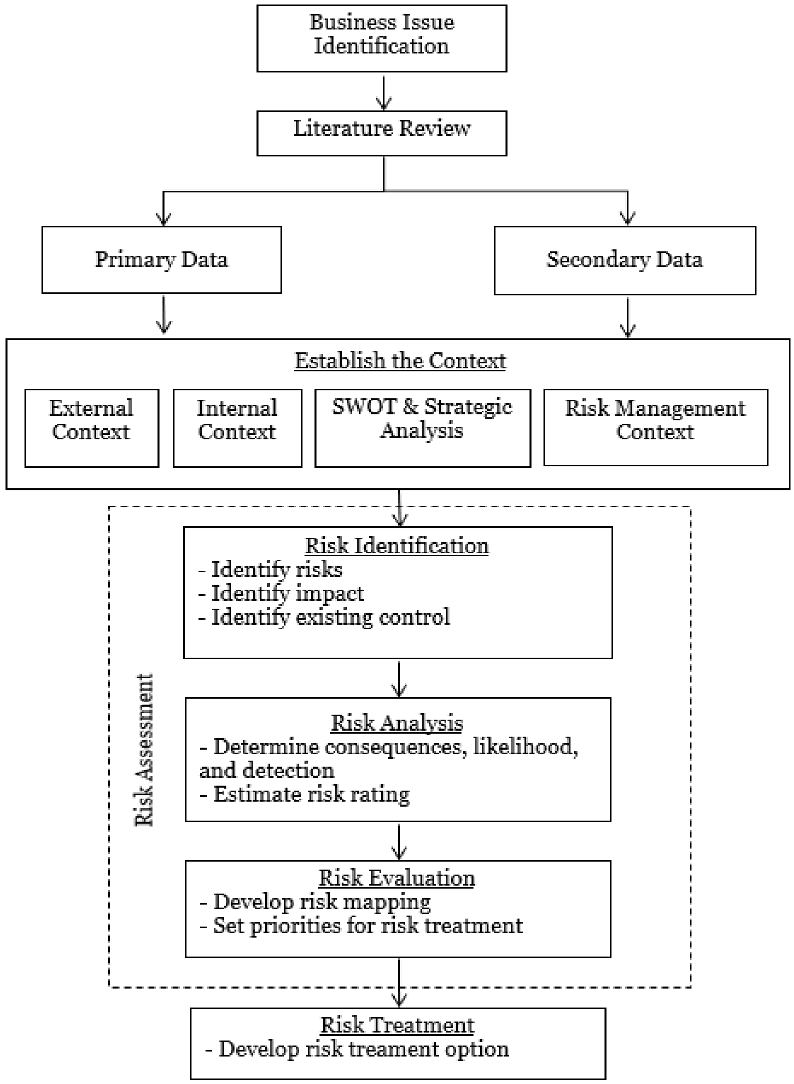

Figure 2. Analysis Framework for Operational Risk Assessment in Iron Smelter

The iron smelter company is measuring operational risk with rating score by combining three factors; which are consequence, likelihood, and detection. Consequence is defined as the outcome of an event that can give positive or negative effects to organization objectives. Likelihood is the chance of a certain consequence which will be occurred from a risk. Detection is the ranking number related with the best control based on the criteria from the detection scale. The consequences, likelihood, and detection matrix with semi qualitative rating of 1-5 are presented in Table 2, Table 3, and Table 4.

Risk rating score can be calculated by analyzing the consequences, likelihood and detection, and then applying the following formula:

Risk rating score (1-125) = Consequence (1-5) x Likelihood (1-5) x Detection (1-5)

From the risk rating score, the company can determine which risk rating ranges are acceptable or need further risk treatments. The company is considering low and moderate risks is tolerable with the existing control, meanwhile high and extreme risks is not tolerable and would need further risk treatment plan. Detail risk rating score range is presented in Table 5.

Table 2. Consequence Matrix in the Iron Smelter Company

Rating	Descriptor	Financial	Safety	Operation	Environment	Product Quality
1	Very minor	< USD 10,000	First aid	Very minor equipment damage. Do not disrupt operation	Minor impact within site location, with no environmental effect.	Do not affect product specification
2	Minor	USD 10,000 - 100,000	Minor injury No permanent	Minor equipment damage. Potential of operation slowdown mode.	Contained impact within site location	Small quantity of product off-spec
3	Moderate	USD 100,000 - 1 million	Major injury Permanent disability	Moderate equipment damage. Potential of operation delay time < 1 day	Uncontained impact, but still repairable on site	Medium quantity of product off-spec
4	Major	USD 1 - 5 million	Multiple permanent disability	Major equipment damage. Significant operation shutdown 1-7 days	Uncontained impact, but still repairable off site	Major quantity of product off-spec, intermittent
5	Catastrophic	> USD 5 million	Fatality	Loss/damage of critical equipment. Significant operation shutdown > 7 days	Significant impact and non-repairable	Major quantity of product off-spec, continuously

Table 3. Likelihood Matrix in the Iron Smelter Company

Rating	Descriptor	Description	Probability	Frequency
1	Rare	Event only occurred in exceptional conditions	< 5%	One in a year
2	Unlikely	Event could occurred at some time	5% - 35%	One in 6 months
3	Moderate	Event could occurred in some conditions	35% - 65%	One in 3 months
4	Likely	Event could occurred in most conditions	65% - 90%	One in a month
5	Almost certain	Event is expected to occur in most conditions	90% - 100%	One in a week

Table 4. Detection Matrix in the Iron Smelter Company

Rating	Descriptor	Detection Criteria
1	Almost certain	Risk detection by online measurement devices, automated controls and interlock system.
2	High	Risk detection by online measurement devices & manual controls.
3	Moderate	Risk detection by operator with manual measurement devices and manual controls.
4	Low	Risk detection by operator - visual / tactile / audible means.
5	Almost impossible	No existing process control. Detection is not possible or analyzed.

Table 5. Risk Rating Score Criteria

Risk Rating Score	Risk Code	Descriptor
$64 \leq x \leq 125$	E	Extreme risk
$45 \leq x < 64$	H	High risk
$20 \leq x < 45$	M	Moderate risk
$1 \leq x < 20$	L	Low risk

Data collection in this study is obtained through interview with total eight respondents. Respondents are chosen based on their main roles, responsibility, and experiences in Operation and Maintenance department in the iron smelter company. Interview sessions are conducted separately for each respondent. Since eight respondents are given the same questions, then there are possibilities that more than one respondent can identify similar risks but with different risk rating score. Weight ratio is applied to overcome that differences, with ratio value based on respondent's position level and experiences as showed in Table 6.

Table 6. Respondent Profile and Risk Analysis Weigh Ratio

No	Initial	Position	Years of Experience	Risk Analysis Weight Ratio
1	AS	GM of Ore Processing	More than 20 years in smelter industry.	100%
2	TD	Manager of Process Plant	More than 30 years in smelter operational.	90%
3	AT	Manager of Laboratory	More than 10 years in Laboratory.	90%
4	KA	Process Engineer 1	More than 10 years in cement and smelter operational.	70%
5	RW	Process Engineer 2	2 years in smelter operational and project. Highly involved during iron smelter construction period.	70%
6	SI	Mechanical Supervisor	More than 20 years in mechanical maintenance in power plant, paper, and smelter plant.	80%
7	JJ	Instrument & Electrical Supervisor	More than 10 years in instrumentation and electrical maintenance.	80%
8	YK	Electrical specialist	More than 30 years in electrical maintenance and project.	70%

Interview sessions are held with structured questions to the respondents based on the study objectives. Those questions are designed to gather respondent opinion and thought about smelter operational risks; which includes risks identification, analysis, evaluation, and treatment plan. Questions list detail is presented in Table 7.

Table 7. Interview Questions List

No	Questions
1	Can you describe what are your roles and responsibility in this company?
2	What do you think about operational risk management concept and practice in this smelter plant?
3	How do you identify risk in this smelter plant?
4	Can you identify and explain what are the 'Operation-Process' risks, impact, unwanted event, and existing control in area: Rotary Dryer, Material Preparation, Reduction Kiln, Coal Mill & Coal Storage, Finish Product Handling, Utility, Sampling & Laboratory ?
5	Can you identify and explain what are the 'Operation-Maintenance' risks, impact, and existing control in all area?
6	Can you identify and explain what the 'Operation-Maintenance' safety risks, impact, and existing control in all area?
7	Can you identify and explain what are the 'Operation-Maintenance' environment risks, impact, and existing control in all
8	Can you estimate the consequences, likelihood, and detection rating for each risk identified in questions 4,5,6,7? By using the available consequences, likelihood and detection control matrix.
9	For risks that are considered not accepted due to high risk rating number, do you have any idea of additional control that might be applied?
10	Can you estimate the consequences, likelihood, and detection control for each residual risk identified in questions 9? By using the available consequences, likelihood and detection control matrix.

Respondent answers are compounded into one risk assessment table as presented in Appendix Table A.1, Table A.2, and Table A.3. Each respondents answer is marked with specific code, with purpose to distinct individual responses with another and to trace back any specific opinion to certain respondent. Code for interview answer is defined in the following format: [X_1.X_2.X_3], with detail explanation:

- X_1 contains the respondent sort number as mentioned in Table 6 which includes 1 for AS, 2 for TD, 3 for AT, 4 for KA, 5 for RW, 6 for SI, 7 for JJ, and 8 for YK.
- X_2 contains the type of operational risks that being discussed, which includes: OP (Operation-Process), OM (Operation-Maintenance), SP (Safety Process), SM (Safety Maintenance), EP (Environment-Maintenance), or EM (Environment-Maintenance).
- X_3 contains the question number in Table 7 that being answered by respondents.

4. Result

There are a total of 121 operational risks in the iron smelter plant that had been identified, analyzed, and evaluated from the interview sessions. Risk assessment distribution result among the category and sub-category is illustrated in Figure 3.

Risk treatment priority is given to risks with extreme and high classification, based on the company risk appetite. Risk treatment priority plan for operation category are presented in Appendix A, Table A.1. There are 1 extreme risk and 7 high risks in operation category. The risk rating scores spread from 45.0 to 71.6 and identified in rotary dryer, reduction kiln, finish product handling, and laboratory area. The proposed additional control is expected to reduce risks into low and medium classification with risk rating score range between 18.0 and 36.0.

Risks treatment priority plan for safety category are presented in Appendix A, Table A.2. There are 1 extreme risk and 6 high risks in safety category. The risk rating scores spread from 48.0 to 66.6 and identified in rotary dryer, material preparation, reduction kiln, and coal mill area. The proposed additional control is expected to reduce risks into low and medium classification with risk rating score range between 8.0 – 36.6.

Risks treatment priority plan for environment category are presented in Appendix A, Table A.3. There are 4 high risks in environment category. The risk rating scores spread from 48.0 to 60.0 and identified in rotary dryer, reduction kiln, and coal mill area. The proposed additional control is expected to reduce risks into low and medium classification with risk rating score range between 18.0 and 27.0.

Control hierarchy for extreme and high risks has been developed within the elimination, substitution, engineering control, administrative control, and personal protective equipment group. Both existing control and proposed additional control are counted for this risk control hierarchy. Majority of risk control hierarchy is included in the engineering and administrative control, which is presented in Table 8.

The implementation of mitigation plan is constructed based on the proposed additional control for extreme and high risks rating score. The detail implementation plan consists of time schedule, department area responsibility, and possible resources requirement to perform the action plan. There are 11 action plans for operation category, 9 action plans for safety category, and 4 action plans for environment category. The timeline for the implementation plan is made within 5 months for all category. Implementation plan summary is illustrated in Table 9.

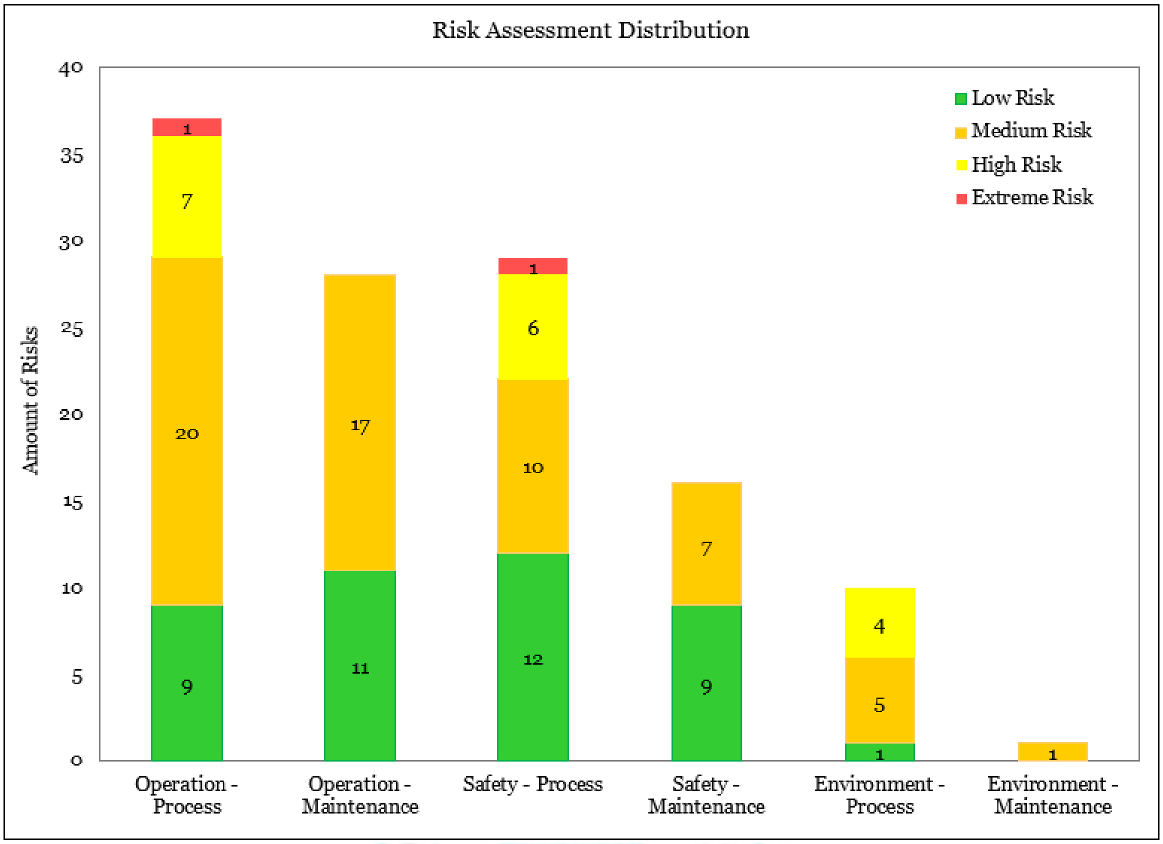

Figure 3. Risk Assessment Distribution Result

Table 8. Summary of Control Hierarchy for High & Extreme Risks

Risk Category	Risk Control Hierarchy					
	Elimination	Substitution	Engineering Control	Administrative Control	PPE	Total
Operation	0	0	12	11	0	23
Safety	1	0	10	10	5	26
Environment	0	0	7	4	1	12
Total	1	0	29	25	6	61

Table 9. Summary of Implementation Plan

No	Risk Category	Action Plan Item	Month 1	Month 2	Month 3	Month 4	Month 5
1	Operation	11					
2	Safety	9					
3	Environment	4					

Conclusion

The risk assessment methodology conducted in this study had able to identify, analyze, and evaluate iron smelter operational risks in systematic way. Operational risks are classified into operation, safety, and environment category; and managed by developing risk treatment for extreme and high rating score risks. Risk treatment in terms of mitigation plan is constructed for each category; and grouped within the risk control hierarchy of elimination, substitution, engineering control, administrative control, and personal protective equipment. The reduction of risk rating score can be achieved by implementation of the treatment plan, which estimated requires 5 months to be realized.

Risk assessment activities in this study are specifically designed for one iron smelter company as the study object. Different smelter companies can apply the similar risk assessment methodologies; however the result might be different depend on the business unit scope, risk management context, and respondent profiles. A possible future research idea to enrich this study topic can include combining operational risks with financial risks due to involvement of high capital expenditures in iron smelter development; thus the study can deliver better perspective to smelter management to manage the existing and future risks.

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Appendixes A. Risk Assessment Priority Result & Treatment Plan

Table A.1 Risk Assessment Priority Result & Treatment Plan for Operation Category

Risk Number	Risks	Impact	Existing Control	Existing Risk: Consequence	Existing Risk: Likelihood	Existing Risk: Detection	Existing Risk: Risk Rating	Existing Risk: Are risks acceptable?	Proposed Additional Controls	Residual Risk: Consequence	Residual Risk: Likelihood	Residual Risk: Detection	Residual Risk: Risk Rating	Residual Risk: Are risks acceptable?
15	Build-up ring formation inside kiln. [1.OP.4], [2.OP.4]	Production delay. [1.OP.4], [2.OP.4]	Adjust the balance between kiln heat input with material feed rate and kiln rotation. [1.OP.4] Unplug the build-up. [1.OP.4] Regular sampling and lab assay for kiln feed. [2.OP.4]	4.0	4.5	4.0	71.6	No	Develop SLA between Mining & Smelter for raw ore assay specification. [1.OP.9]. Review the proper kiln profile temperature for each zone. [1.OP.9]. Install O_2 plant to make build-up unplug more fast. [1.OP.9] Proposed to have raw ore blending to ensure raw ore specification. [2.OP.9]	2.5	2.3	4.0	22.3	Yes
24	Product loss from product pond. [1.OP.4], [4.OP.4], [5.OP.4]	Lower product rate. [1.OP.4], [4.OP.4], [5.OP.4] Product still contain 5% H2O. [1.OP.4]	Product spill solution will be directed to water pond and recycle back as water addition to ball mill. [1.OP.4], [4.OP.4], [5.OP.4]	3.7	4.3	4.0	63.7	No	Install filter press to reduce product spill and H2O content. [1.OP.9], [4.OP.4], [5.OP.4] Develop SOP for product handling and packaging. [1.OP.9]	2.6	3.0	4.0	31.3	Yes
29	Samples taken during manual sampling is not representing total population (quantity & size). [3.OP.4]	Contribute to assay error up to 70%. [3.OP.4]	-	4.0	5.0	3.0	60.0	No	Follow up consultant recommendation to improve sampling by install autosampler in several locations. [3.OP.9]	2.0	3.0	3.0	18.0	Yes
23	Ball mill product oversize. [1.OP.4], [2.OP.4], [4.OP.4]	Lower product recovery due to material goes to non-magnetic stream. [1.OP.4], [2.OP.4], [4.OP.4]	Regular changes of metal ball inside the ball mill. [1.OP.4], [2.OP.4], [4.OP.4] Setting the clearance / gap of magnetic separation. [1.OP.4]	3.0	4.3	4.0	52.2	No	Review material specification for balls inside ball mill. [1.OP.9], [2.OP.9], [4.OP.9] Install flow measurement device for magnetic and non-magnetic material streams. [1.OP.9]	3.0	3.3	3.3	32.8	Yes
1	Raw ore assay off-spec. [1.OP.4]	Product sponge off-spec and lead to waste. [1.OP.4]	Regular sampling and lab assay. [1.OP.4]	4.0	4.0	3.0	48.0	No	Develop SLA between Mining & Smelter. [1.OP.9]	4.0	3.0	3.0	36.0	Yes
3	Coal build-up in hot stove. [1.OP.4]	Production delay, to clean-up the build-up. [1.OP.4]	Coal rate limitation. [1.OP.4]	3.0	4.0	4.0	48.0	No	Set tighten coal specification to Procurement. [1.OP.9]	3.0	3.0	4.0	36.0	Yes
16	Unstable kiln burner. [1.OP.4]	Less heat input to kiln for LOI removal and reduction process. [1.OP.4] Production delay. [1.OP.4]	Adjustment between coal rate with air flow rate to burner. Manual flame burner monitoring. [1.OP.4]	3.0	4.0	4.0	48.0	No	Add control system to kiln burner, example with Burner Management System (BMS). [1.OP.9] Install control valve and flowmeter to better manage combustion air flow rate. [1.OP.9]	3.0	3.0	3.0	27.0	Yes
32	Jaw crusher output size off-spec > 2 mm. [3.OP.4]	Less heat input to kiln for LOI removal and reduction process. [1.OP.4] Production delay. [1.OP.4]	Work Instruction iron ore sample preparation. [3.OP.4]	3.0	5.0	3.0	45.0	No	Upgrade the existing jaw crusher with roll crusher that can produce material size < 2 mm. [3.OP.9]	3.0	3.0	3.0	27.0	Yes

Table A.2 Risk Assessment Priority Result & Treatment Plan for Safety Category

Risk Number	Risk	Impact	Existing Control	Existing Risk: Consequence	Likelihood	Detection	Risk Rating	Are risks acceptable?	Proposed Additional Controls	Residual Risk: Consequence	Likelihood	Detection	Risk Rating	Are risks acceptable?
74	Kiln product bypass stream to emergency pond (fall in from ± 10 m height). [2.SP.6], [4.SP.6]	Personnel exposed to hot water or material splashed. [2.SP.6], [4.SP.6] Equipment damaged due to hot material splashed. [2.SP.6]	Put barricade in surrounding of emergency pond area. [2.SP.6], [4.SP.6]	4.4	3.0	5.0	66.6	No	Extend launder from kiln product bypass to reach emergency pond, and install shield to minimize hot water or material splashed to surrounding area. [1.SP.9], [4.SP.9]	3.0	2.4	5.0	36.6	Yes
73	Hot gas back pressure from kiln burner area. [1.SP.6], [2.SP.6], [4.SP.6]	Personnel exposed to hot gas, causing major injury. [1.SP.6], [2.SP.6], [4.SP.6]	Provide special PPE (aluminized body shield) for personnel working in kiln burner area. [1.SP.6], [2.SP.6], [4.SP.6] SOP kiln operation. [1.SP.6]	3.7	3.3	5.0	61.0	No	Add interlock system between ID fan with kiln burner air blower and fine coal feeder. [1.SP.9], [2.SP.9], [4.SP.9]	3.7	2.3	2.0	16.9	Yes
70	Steep angle degree of box conveyor stair. [2.SP.6], [4.SP.6]	Personnel fall over or slipped from stair. [2.SP.6], [4.SP.6]	Install handrail on box conveyor stair. [2.SP.6], [4.SP.6]	4.0	3.0	5.0	60.0	No	Re-design the stair to have less steep or slope angle. [2.SP.9], [4.SP.9]	4.0	2.0	4.4	35.5	Yes
88	Manual sampling in conveyor. [3.SP.6]	Personnel major injury due to dragged or pinched in conveyor components. [3.SP.6]	PPE for personnel. [3.SP.6]	3.0	4.0	5.0	60.0	No	Follow up consultant recommendation to improve sampling by install autosampler in several locations. [3.SP.9]	1.0	2.0	4.0	8.0	Yes
67	Hot gas back pressure from dryer's hot stove. [1.SP.6], [2.SP.6], [4.SP.6]	Personnel exposed to hot gas, causing major injury. [1.SP.6], [2.SP.6], [4.SP.6]	Install explosion door in dryer's hot stove. [2.SP.6] SOP furnace operation. [1.SP.6] Provide special PPE (aluminized body shield) for personnel working in hot stove area. [1.SP.6], [2.SP.6], [4.SP.6]	4.0	3.4	4.3	58.8	No	Add interlock system between ID fan with hot stove air blower and coal feeder. [1.SP.9], [2.SP.9], [4.SP.9]	4.0	2.7	2.0	21.2	Yes
78	Pulverized coal size off-spec, too fine +170 mesh < 20%. [1.SP.6]	Increased pulverized coal fire risk in coal mill system. [1.SP.6]	Sampling and size analysis of pulverized coal product. [1.SP.6] SOP coal mill operation. [1.SP.6]	4.0	4.0	3.0	48.0	No	Engineering review to optimize classifier rotation with mill grinding pressure. [1.SP.6] Install autosampler to sampling pulverized coal automatically. [1.SP.6]	4.0	3.0	3.0	36.0	Yes
79	Pulverized coal H_2O too low < 3%. [1.SP.6]	Increased pulverized coal fire risk in coal mill system. [1.SP.6]	Sampling and size analysis of pulverized coal product. [1.SP.6] SOP coal mill operation. [1.SP.6]	4.0	4.0	3.0	48.0	No	Engineering review to automate heat input to furnace with fine coal H_2O result. [1.SP.6] Install autosampler to sampling pulverized coal automatically. [1.SP.6]	4.0	3.0	3.0	36.0	Yes

Table A.3 Risk Assessment Priority Result & Treatment Plan for Environment Category

Risk Number	Risk	Impact	Existing Control	Existing Risk: Consequence	Likelihood	Detection	Risk Rating	Are risks acceptable?	Proposed Additional Controls	Residual Risk: Consequence	Likelihood	Detection	Risk Rating	Are risks acceptable?
116	Dusty condition during manual dust handling and transporting using loader. [2.EP.7]	Poor air quality in working place. [2.EP.7]	Add water spray on dust outlet location. [2.EP.7]	3.0	5.0	4.0	60.0	No	Design and build more proper dust transportation system such as pneumatic system and further dust processing. [2.EP.9]	2.0	3.0	4.0	24.0	Yes
111	Waste water effluent. [1.EP.7]	Waste water effluent pollution to environment. [1.EP.7]	Build sediment pond and design closed loop water circulation system. [1.EP.7]	4.0	3.0	4.0	48.0	No	Review to build additional sediment pond. [1.EP.9]	3.0	3.0	3.0	27.0	Yes
115	Off-gas emission from reduction kiln's stack. [1.EP.7], [4.EP.7]	Poor air quality due to particulate and emission from stack. [1.EP.7], [4.EP.7]	Install cyclone and dust collector to capture particulate from off-gas. [1.EP.7], [4.EP.7]	3.0	4.0	4.0	48.0	No	Install online off-gas emission measurement in kiln stack. [1.EP.9], [4.EP.9]	3.2	3.2	2.1	21.6	Yes
117	Off-gas emission from coal mill's stack. [1.EP.7]	Poor air quality due to particulate and emission from stack. [1.EP.7]	Install dust collector to capture particulate from off-gas. [1.EP.7]	3.0	4.0	4.0	48.0	No	Install online off-gas emission measurement in coal mill stack. [1.EP.9]	3.0	3.0	2.0	18.0	Yes