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Abstract	- Investigate and communicate issues that cause variability in the train loading process, meanwhile generating idea that can be implemented to reduce the variation.
Category	- Logistics, Quality Assurance and Simulation
Declaration	
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Executive Summary

The study and documentation of business processes in organisations is one of the core methods of use to ensure continuous improvement. It is easier to improve a business that has procedures and processes fully described to such an extent that they can be easily understood by audiences and/or users of the process. Some industrial engineering principles and methods such as variables charts are used to establish quality levels within the processes. Inyanda coal is a mining business unit in Exxaro's spectrum.

It is important for Exxaro to ensure that the full potential of the business unit is unleashed. Logistics plays an integral part in the success of a business such as a coal mine since it is important to ensure that the required volumes of coal are transported to the customers. Trains are the two most important modes of transport utilised to deliver coal, the other being by road.

Transnet Freight Rail (TFR) is the company that provides the trains to transport coal. TFR, like any other organisation has rules and regulations under which it is operates. Some of the rules which will be focused on are the limited amount of time that a train can spend in the mine and the volume range that wagons can take. Due to the new SLA (Service Level Agreement) with TFR, Exxaro is experiencing a cost of approximately R5 million per year due to variability in both time and volumes.

This project will conduct studies, develop methods to identify and solve problems and also provide tools that will facilitate continuous improvement. The targeted is to reduce the turn-around-time by at least 20%. A simulation model will aid the decision making process in determining the optimal solution.

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Abbreviations and Terms

CAT	Caterpillar
FEL	Front end loader
KPI	Key Performance Indicator
RBCT	Richard Bay Coal Terminal
SLA	Service Level Agreement
TAT	Turn Around Times
TFR	Transnet Freight Rail
PUTLS	Precision Unit-Train Loading System
Blackhill	The technical term for type of coal being mined

Table 1: Abbreviations

1. Introduction and Background

1.1. Inyanda coal mine

Diversified miner Exxaro's coal mine, Inyanda is situated near Witbank, in Mpumalanga. It plays a significant role in supporting the Exxaro's 6.3-million-ton-a-year export entitlement through the Richards Bay Coal Terminal (RBCT), together with new developments and increased production from existing operations. Exxaro's coal commodity operations at Inyanda play a key role in the company's aim to build a strong position in the export coal market.

1.2. Logistics at Inyanda coal mine

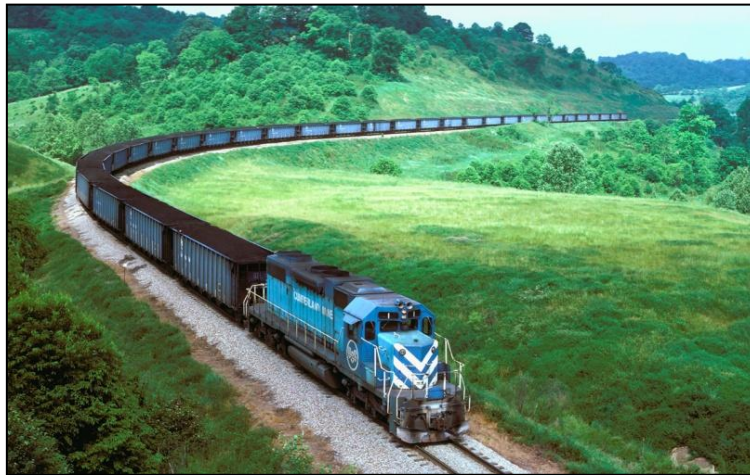


Figure 1: Loaded Train

Rail transport is the means that the mine utilizes in transporting coal to Richards Bay harbour Terminal (RBCT) for export. Rail serves as the better means of transport because it is economical and large volumes of coal can be railed in single trip as compared to that of road. Rail transport is not the most convenient mode of transport since it has low accessibility due to the fact that it can only travel on the railway lines which may be limited in reaching certain desired destinations, it is however not a problem in this case because there is a system of railway lines that connects the mine and the point at the harbour where the coal is offloaded and stored as stock piles and later loaded into large bulk carrier ships and shipped off to countries such as Australia and China. Rail transport is also used to carry coal to local markets around the country but the trend of its usage is declining while the trucks (road) are being used more to transport coal to the local customers.

2. Problem Statement

The new SLA (Service Level Agreement) being negotiated by TFR (Transnet Freight Rail) for rail services on the Coal Line, penalises extreme variation that results in under- or overloading or delays at loading sites in terms of financial (paying for a train that is cancelled) and capacity (losing the next train due to missing an earlier train's time slot) in its current format. It thus becomes clear that in order to rail the required volume of coal to RBCT, Exxaro has to address some issues that will help to reduce the variability at loading sites.

3. Project Aim

The aim of this project is to investigate and communicate the findings of a structured improvement methodology used to identify issues that cause variability in both TAT and volume during the loading process at Inyanda's Blackhill siding. The project will also through a simulation model study the utilisation of the FELs.

4. Literature Preview

4.1. Purpose of the literature review

According to Ridley (2008) the purpose of this review is to provide background for the problem and put the problem into historical perspective.

Literature review provides the following:

- informs the reader about the current concepts and state of research on the topic and any controversies;
- describes the pros and cons of particular studies and may suggest areas for further research;
- includes a discussions of relevant theories and concepts which support current research;
- It also provides supporting evidence for a practical problem or issue which the current research is addressing, thereby underlining its significance.

4.2. Economy and Export of Coal in South Africa

For almost 150 years, the mining industry has a significant contribution to the economic development of South Africa and has provided a platform for further development in other African countries. South African steam coal exports to Asia might increase again as growing demand for South African coal is being experienced from India (Wait 2011:17).

In 2006 South Africa exported coal to 28 countries, of which 88% was exported to the European Union of which Great Britain, Spain, France, the Netherlands, Italy, Germany, Denmark and Belgium were the largest customers. Of the 245-million tons of coal sold during 2006, about 28%, worth some R21.5-billion, was exported at an average price of R314 a ton, which is about 3.4 times higher than the average local price.

According to International Energy Agency; the world's hard coal continued to show strong growth in 2006 after three years of record growth. China, the world's biggest producer, became a net importer of coal earlier this year (2007), limiting supplies to other Asian nations. Richards Bay, South Africa, the world's largest export port for fuel, has been constrained by transport bottlenecks (Bezuidenhout 2007:26&28).

In 2010, the coal industry produced 254 million tons of saleable coal, of which 66 million tons, worth R36.4-billion, was exported to foreign countries (Hannah 2011:22).

Exxaro, TFR and RBCT

According to Faurie (2011:14) Exxaro resources reported that South Africa is missing out on a significant opportunity presented by the growing global demand for commodities like coal because of TFR's logistics inefficiencies. Exxaro still has no clarity on when its logistical corridor will be free of impairments so that the as a company it can take the full advantage of the upswing in global demand for coal. Richards Bay Coal Terminal (RBCT) is currently the world's largest coal export terminal, has the capacity to export 91-billion tons of coal a year while TFR currently has the capacity to transport only 61 billion tons a year to RBCT.

4.3. Loading processes

There are different methods currently used at the coal mines to load the coal onto the wagons. The two methods described in this report are:

1. Precision Unit-Train Loading Systems (PUTLS).
2. Front End Loader technique.

1. Precision Unit-Train Loading System



Figure 2: Precision unit-train loading system

According to Miller and Walker (2004:22-28) the system was constructed in the early 1980's, and the majority of systems in operation today. It consists of a 250- to 300-ton surge bin positioned above a 100- to 130-ton weigh bin. Four bi-parting gates usually control the transfer of coal from the surge bin into the weigh bin. Today, loading coal trains involves more than simply placing coal into the railcars. Rail weights and coal quality specifications are extremely important. These systems are now capable of loading up to 12,000-tons per hour. After some coal mines had been built, it became necessary to retrofit high capacity precision loading systems to the originally designed volumetric loading systems.

The figures below illustrate the PUTLS technique;



Figure 3: PUTLS (I)



Figure 4: PUTLS (II)

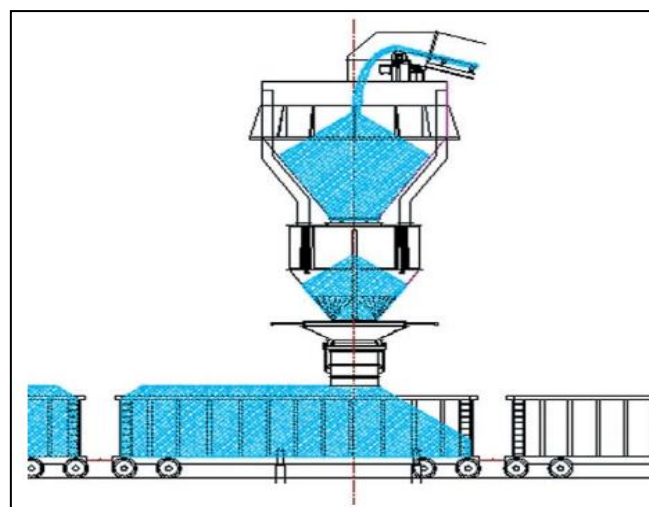


Figure 5: PUTLS (III)

In today's coal market, it is necessary for a coal producer to fully consider how coal loading systems can add value to an operation. By providing a precision unit train loading system that is precise both quantitatively and qualitatively, it is possible for a coal mine to minimize its capital investments and operational costs while simultaneously maximizing the value of its reserves.

2. Front end loader loading (FEL) technique



Figure 6: Front end loader

For this technique, the front end loaders (FELs) are used to load the coal onto the wagons. The FELs scoop the coal from the stockpiles nearby the rail line where the train is parked and then drive towards the wagons to load. The problem with this technique is that it is slower than the precision unit-train loading system and it is not precise in terms of how much coal should be loaded, hence resulting in more variation in terms of loading time and the volume of coal in each wagon.

4.4. Process map

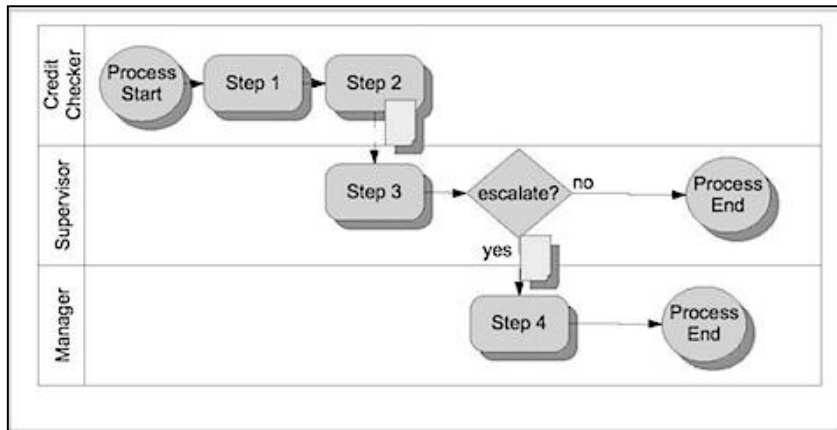


Figure 7: Process map procedure

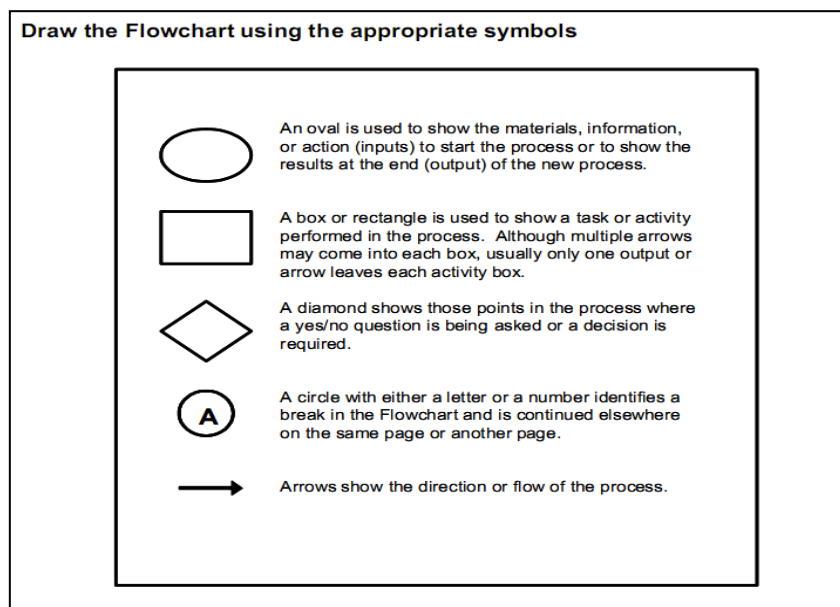


Figure 8: Process symbols

According to “Process Mapping Associates” a process map is a tool used to visually illustrate how work flows. It is also a communication tool, a business planning tool and a tool to help manage the business. Every process is key variables that govern it.

The key variables of a process are:

1. inputs;
2. outputs;
3. activity steps;
4. decision points;
5. Functions.

The process helps the users to see:

1. what is happening;
2. where it is happening;
3. when it is happening;
4. who is doing it;
5. How inputs and outputs are handled and distributed in the process.

Purpose of process mapping

The purpose of process mapping is for better understanding process's functioning. It involves gathering and organizing of facts about the work and displaying them such that they can be questioned and improved by knowledgeable people. Process maps aid in understanding by abstracting, using visual charting symbols consistently and masking unnecessary details. Process mapping improves understanding of processes and, in essence, boosts understanding of business and operational performance.

Some of the benefits of a well-prepared process map are as follows:

1. Employees can participate in constructing a process map. This is one of the most important benefits because it gives employees an opportunity to experience a shared view. The methodology is the catalyst to give businesses and organizations access to more diversity, creativity and innovation.
2. Process mapping allows users to visually illustrate and convey the essential details of a process in a way that written procedures cannot do. A process map can replace many pages of words.
3. They can save time and simplify projects.

4. Process maps help in understanding the important characteristics of a process, allowing users to generate useful analytical data in order to derive findings, draw conclusions and formulate recommendations. Furthermore, process maps one to systematically ask many important probing questions that lead to developing a view on business process improvement.

Processes are the most effective way to manage an organization at any level and eventually support its overall goals. By improving processes, a business or organization can improve internal efficiencies, effectiveness, adaptability and customer service levels.

Business applications for process maps

1. Business process improvement, business process redesign and reengineering initiatives.
2. Training: create training and reference manuals.
3. Quality: six sigma - process maps are used in the analyze phase to create "As-Is" maps and in the improve phase to create the "To-Be" process maps.
4. Simulation: gather process related information and create a static model in preparation for simulation projects.
5. Information technology: prepare an organization to make the transition into system requirements analysis because they describe how the functions would interact with a system to complete an activity step.
6. Work measurement: gather information on the elements of a process in preparation for a work measurement or activity sampling study.
7. Document, review and analyze current-state processes: mapping the current-state is an important first step in process improvement projects and other major corporate initiatives.
8. Design future-state business & operational processes: visualize future-state processes before making changes to current-state or investing in major capital.
9. Integration of processes for acquisitions, mergers and new services.
10. Selling and decommission of business operations.



4.5. Fish bone diagram

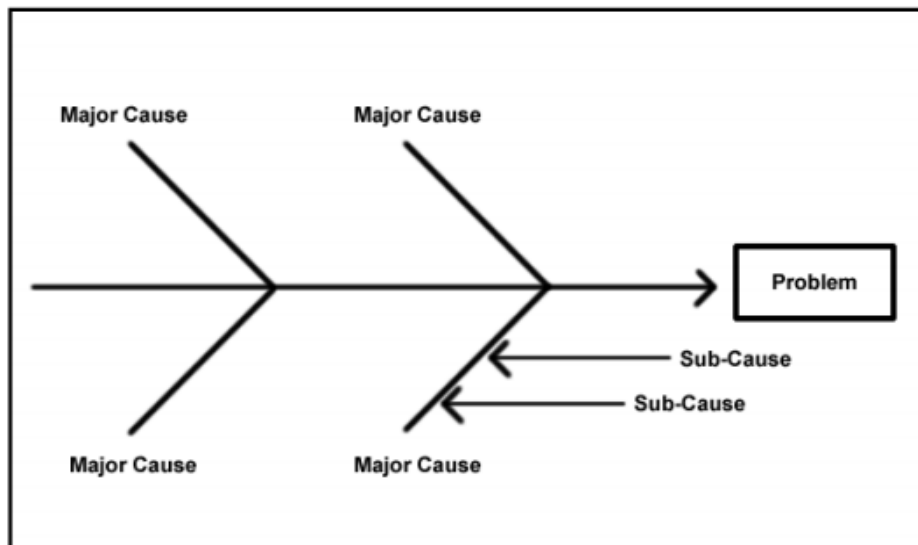


Figure 9: Fishbone diagram

Description of Fishbone diagram

Ishikawa (1986) defines the fishbone diagram as a tool for analyzing process dispersion. The diagram illustrates the main causes and sub-causes leading to an effect. It is a team's brainstorming tool used to identify potential root causes to problems. Based on its function it may be referred to as a cause-effect diagram.

In a typical Fishbone diagram, the effect is usually a problem needs to be resolved, and is placed at the "fish head". The causes of the effect are then laid out along the "bones", and classified into different types along the branches. Further causes can be laid out alongside further side branches.

The benefits of the Fishbone diagram according to Brassard (1988) are that it:

1. helps determine root causes of problems;
2. encourages group participation;
3. uses an orderly, easy-to-read format to diagram cause-and-effect relationships;
4. indicates possible causes of variation;
5. increases knowledge of the process by helping everyone to learn more about the factors at work and how they relate to one another;
6. Identifies areas for collecting data.

4.6. Root cause diagram

A root cause analysis can be briefly defined as an investigative process in which both qualitative and quantitative data are systematically gathered and analysed with the purpose of identifying the underlying causes and contributory factors of a serious adverse event. The goal is to obtain knowledge and thereby prevent recurrence of the serious adverse event (Jensen: 2004).

The root cause analysis answers the following questions:

1. What happened?
2. Why did it happen?
3. How can it be prevented from happening again?

Steps of root cause analysis:

1. begin investigation of the adverse event;
2. determine the sequence of events;
3. identify contributory factors;
4. identify tentative root causes;
5. gather additional data and perform literature review;
6. discuss, determine and confirm identified root causes;
7. prepare action plan;
8. Generate report and obtain approval.

4.7. Prioritisation of issues/ideas (Priority matrix)

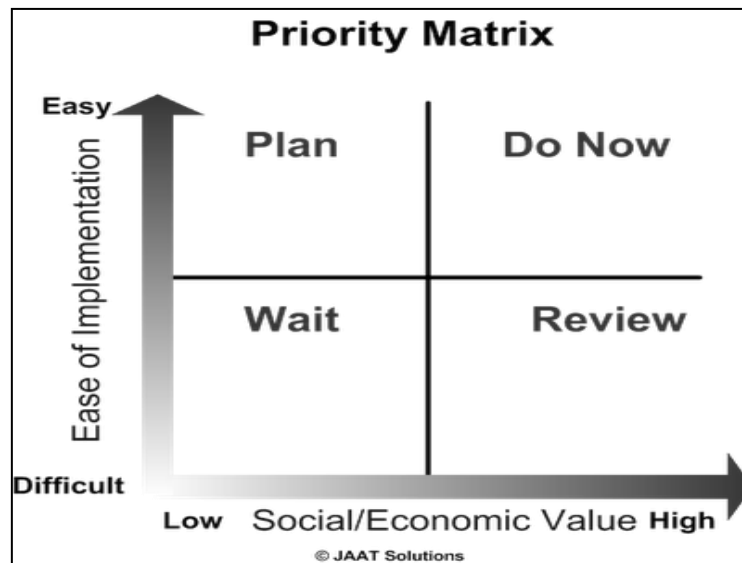


Figure 10: Priority matrix

The priority matrix is used to rank the solutions to the problem in terms of their level of ease to implement on one axis and also the costs involved on another axis—in a two axis plane. The technique helps the project managers to see the solutions that are more optimal and economical.

4.8. Time study

According to Kanawaty (1992:265) time study is a work measurement technique for recording the times of performing a certain specific job or its elements carried out under specified conditions, and for analysing the data so as to obtain the time necessary for an operator to carry it out at a defined rate of performance.

Essential equipments required to perform a time study are:

- stop watch;
- study board;
- Time study forms.

4.9. Simulation Model (SIMIO®)

According to Shannon (1975:1) management is becoming increasingly challenging as the man-organized systems of our society grow to be more complex than before. This level of complexity derives from the interrelations among the various elements within organisations and the physical systems with which they interact. Although this complexity has existed for a long time, we are just beginning to appreciate its importance.

Definition

Simulation is the use of a model (not necessarily a computer model) to conduct experiments which, by inference, convey an understanding of the behaviour of the system modelled as defined by Gogg & Mott (1992:1-1).

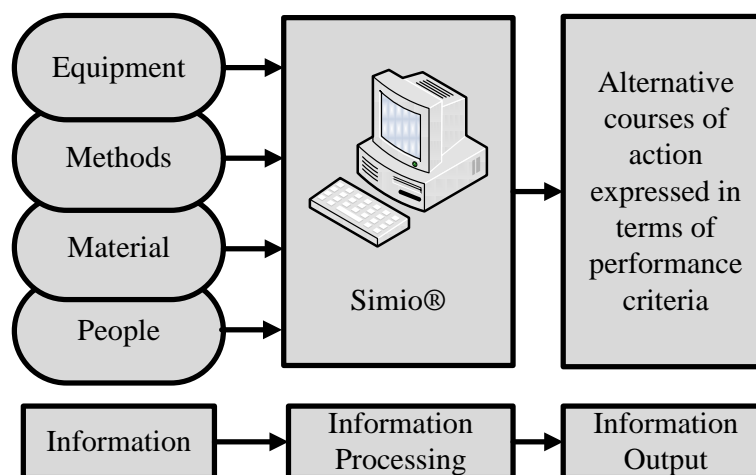


Figure 11: Simulation steps

Shannon (1975:4-5) also defines a model as a representation of an object, process, system or an idea in some form other than that of the entity itself. Its purpose is usually to aid the organisation in explaining, understanding, improving a system. A model of an object may be an exact replica or the object (although executed in a different material and different scale), or it may be an abstraction of the object's salient properties.

Five legitimate and common uses of models:

1. an aid to thought;
2. an aid to communication;
3. purpose of training and instruction;
4. a tool to predict;
5. An aid to experimentation.

Simulation can foster creative attitudes and enthusiasm for trying new ideas, many companies have resources that are under-utilized, resources which if fully employed, can bring about dramatic improvements in quality and productivity. It can also predict the outcomes for possible courses of action.

Testing a simulation model is a pre-requisite before implementation. Simulation models can be very cost effective in terms of time, computer based simulations packages have eliminated higher computer processing costs. The time required to build a model has been considerably reduced. Through simulation models, companies can now react more rapidly to problems that might occur within the process or a system.

Model verification is a term which implies that a model is operating in its intended manner. It also implies that the results generated by a model coincide with the results produced by the process or system being represented by the model. Models also constitute assumptions to simplify model building process but they can also influence the results and therefore it is necessary to limit them to an acceptable level.

Input parameters are the variable factors which directly influence the performance of the system. Examples are lot sizes, quantity of material, available equipment, speeds, schedules, cycle times and resources availability. The use of multiple runs for experiments helps in analysing the results and comparing the scenarios in order to make excellent decisions (Gogg & Mott 1992:11.1-1—14-1).

The results of the simulation model includes; utilization of resources and equipment, waiting, queuing and processing times for entities and consequently giving the management the idea of what needs to be improved in the process or system at hand.

5. Methods, Tools and Techniques

The following improvement tools and techniques will be used for the project:

Process map:

It enables a comprehensible recording of existing process tasks which allows the process to be inspected thoroughly by clarifying roles within the process, understanding delays and duplication and understanding of the time elements of the process.

Fish bone diagram:

This will a structured form of brainstorming that graphically show the problems that were identified within the process.

Root cause diagram:

This analysis helps identify what, how and why something happened, thus preventing recurrence.

Prioritisation of issues/ ideas (Priority matrix):

This is a process of ranking issues according to their effectiveness on the vertical axis, cost and level of simplicity in achieving the solution recommended on the horizontal axis. This was determined by an individual judgement and group consensus.

Time study:

A method used to determine the correct time it takes to complete a certain task. The purpose of the time study in this context was to verify the process tasks and time elements for the mapped process and highlight problems experienced.

Simulation Model (SIMIO®):

The simulation model will be focused on determining the utilization of the FELs, thus providing a solution for optimal number of FELs. The model may also assist discover bottlenecks within the process. Simio will be used to build the model.

The structured methodology was used in brainstorming session with the supervisor and FEL operators from Imperial Logistics as well as the Exxaro logistics coordinator and the Exxaro logistics supervisor at Blackhill site.

6. Development of Methods, Tools and Techniques

6.1. Process map

The process map was developed from discussions with the logistics coordinator. The process map is depicted in appendix A1 of the appendices.

The following time elements are recorded:

1. time power is switched on;
2. time loading of wagons start;
3. time loading of wagons is complete;
4. Time power switched off.

The TAT is calculated from the time the power was switched on by TFR to the time the power was switched off by TFR.

Based on the process experts knowledge of the process the following estimate times were identified per process activity. In the time study the observed activity times are compared to the equation below.

Process time for 100 x 85 ton wagons

$$\begin{aligned}
 &= \text{Bring in train} + \text{Hand over time} + \text{Loading time} + \text{Hand over time} + \text{Release the train} \\
 &= 30 \text{ min} + 10 \text{ min} + 240 \text{ min} + 60 \text{ min} + 30 \text{ min} \\
 &= 370 \text{ min (6.2 hrs)}
 \end{aligned}$$

The loading process mapped will be verified through a time study of the loading process at Black hill siding.

6.2. Fish bone diagram

The fishbone diagram is depicted in appendix A2 of the appendices.

The brainstorming session on issues was conducted with the logistics coordinator and supervisors from Exxaro and the supervisor and FEL operators from Imperial logistics. The session highlighted two major issues raised by the group, the first was the issue of over and under loading wagons and the second was the high levels of downtime experienced by the FELs.

6.3. Root cause analysis

The root-cause diagram is depicted in appendix A3 of the appendices.

Of the issues raised the following conditions were identified as contributing to the primary effect of over or under loading:

1. Incorrect loading profile for the wagons that are loaded caused by not loading the wagons to the correct pattern due to less experience of the FEL operators and rushing to meet the 4 hour loading target.
2. The mass is not recorded while the FEL is loading due to the fact that there are no measuring instruments in place.
3. The FEL is not filling the wagon to its full capacity due to the level of the siding being lower than the rail line which occasionally results in the FEL arm not reaching the wagon consistently to enable effective and efficient loading to take place.
4. When the stockpile is full there is not sufficient space for the FELs to manoeuvre and this can result in over or under loading problems on the first 10 wagons loaded. Inyanda does not have sufficient stockpile capacity for small nuts and thus uses Black hill siding as an extended stockpile.
5. The weigh bridge is not calibrated properly and not all wagon weights are measured due to the locomotive standing on the weigh bridge. Further if the locomotive travels with speeds in excess of 10 km/hr, the weigh bridge also reads inaccurately.

The other issue of concern is the extensive downtimes experienced by the FELs due to the O-ring and differential failures. The current FELs are Holland and are relatively new with 1000 to 3000 hours on the machines. It is felt that the best make of FEL that would best handle the current loading conditions is a CAT FEL. The CAT machine depending on the bucket size may be slightly slower than the current Holland machines.

For increased FEL reliability the financial implication of replacing the current Holland to CAT FELs should be evaluated. Further the option of increasing the loading time target given to Imperial logistics should be extended to allow sufficient time to load wagons properly (obtain correct profile) and to allow the FELs to be operated within its limits to reduce unplanned downtimes. Alternatively the number of FELs could be increased to 5 from the current 4. A simulation model will be used in generating data that may justify the need for an extra FEL.

Due to the excessive FEL unplanned downtimes, the loading process is often sub contracted to a third party resulting to extra cost. The operators of the hired FELs are often not trained on the loading procedure and can thus add to the over/under loading problem.

The purchase of weight-o-meters to be installed onto the FELs has already been discussed and has been proposed that Exxaro would purchase and install instruments. Two questions arise, would Exxaro or Imperial be responsible for the maintenance of the instruments? The second question is due to the high unplanned downtime of the FELs; hiring third party FELs would render the installed weight-o-meters irrelevant.

6.4. Prioritisation of solutions (Priority matrix)

The priority matrix diagram is depicted in appendix A.4 of the appendices.

The solutions are prioritised with regard to effectiveness and low cost or easy to do.

Priority 1

- Lift the siding to the level of that of the rail line
- Document and train FEL operators on the correct loading procedure
- The supervisor to monitor and correct the profile while loading or immediately after loading (if it cannot be rectified during the loading process)

Priority 2

- Install weight meters on each FEL
- Move the weigh bridge closer to siding
- Calibrate the weigh bridge ever six months
- Train need to travel at 10km/hr or less

Priority 3

- N/A

Priority 4

- Get more small nuts customers

6.5. Simulation model (Simio[®])

Simio is an attractive simulation tool to use due to its capabilities of the allowing the user for rapid model building, flexibility of the model and integrated 3D animation. The model for this project is made up of three phases- (a) Functional Specification, (b) Model Formulation and (c) Test Run, Collecting Results and Recommendations.

6.5.1. Phase 1: Functional Specification

Background

Inyanda Colliery utilizes Front End Loaders to load the coal onto the wagons which transport coal from the mine to RBCT. The FELs are outsourced by the mine from an independent company on contractual basis. Exxaro therefore pays the company (FEL provider) an amount of money as agreed in the contract.

Area of interest for Simulation

The train arrives at the mine from TFR, it then go through different stages within the mine premises as the process map shows. The simulation model will focus on the loading site where the FELs are used to load the coal; it will simulate the FELs and the train entering the site. The train will be simulation when entering the loading site and FELs loading the coal (note: the model does not simulate the whole process as the process map shows, but only focus on the loading site).

Problem Definition

The new SLA (Service Level Agreement) being negotiated by TFR (Transnet Freight Rail) for rail services on the Coal Line, penalises extreme variation that results in under- or overloading or delays at loading sites in terms of financial (paying for a train that is cancelled) and capacity (losing the next train due to missing an earlier train's time slot) in its current format. It thus becomes clear that in order to rail the required volume of coal to RBCT, Exxaro has to address some issues that will help to reduce the variability at loading sites.

Objective of Simulation

The main objective of the model is to provide direction to making a decision for optimal number of FELs at the loading site. Currently there are four FELs in operating. The model will test for different scenarios when there are four, five and six FELs. Based on the results, it is then, when recommended number of FELs will be suggested so that they can help in reducing the TAT, it must be ensured that the solution provided is also economical/feasible.

Data requirements: Input Data

Required data for the simulation model; **Front End Loader and others**

Speed	14, 16 and 18 km/h
Load Capacity	1 entity equivalent to 1.5 tons
Reliability/Efficiency	95%
Un/Load Time	4-5 seconds
Train Capacity	The capacity of 100 wagons is 8400 tons, therefore the approximately 5600 buckets must be loaded, [1.5x5600 = 8400 tons]
Distance	Distance between the stockpiles and loading point is approximately 10 metres
Scenarios	Four, five and six FELs to be tested
Simulation run time span	100 hours

Table 2: Simulation data input

Data requirements: Output Data and Analysis

The data which is of interest are the average time it takes to service a train when using four, five or six FELs. Current investigations show that it takes approximately four hours to fill a 100 wagon-train with 4 FELs. The simulation results will show the difference and impact caused the using different number of FELs and as a result, it will be easy to make a decision as to whether a new FEL should be added or not. The model will also show the financial impact of changing the number of loaders. The level of efficiency for the FELs was determined to be 95%.

Assumptions and Constraints

1. Coal is always available at the stockpiles.
2. The trains are always at the station waiting to be loaded.
3. In order to ensure that the FEL is working at efficiency of 95%, it is assumed that an FEL will be operational for 57 seconds and down for 3 seconds for every 60 seconds.
4. FELs load one train at a time.

6.5.2. Phase 2: Model Formulation (description)

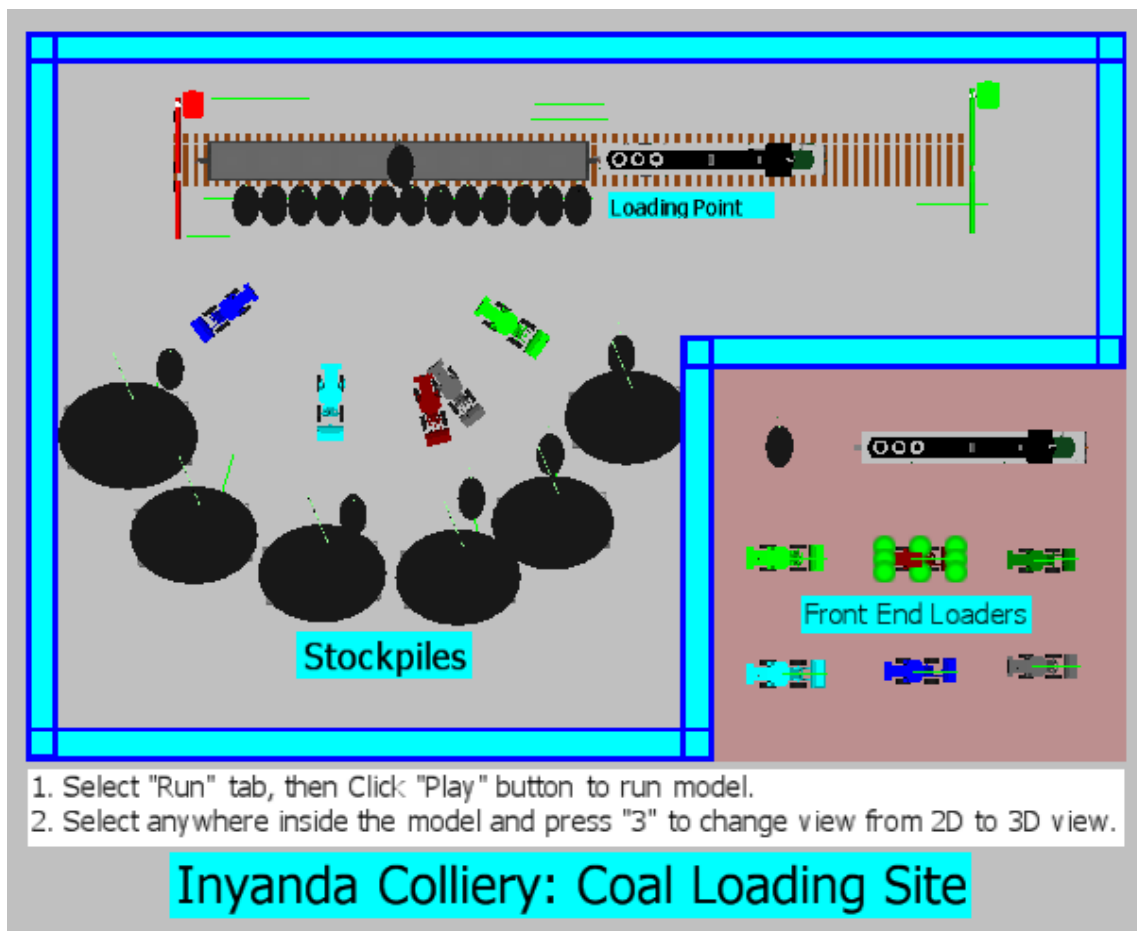


Figure 12: 2D Simulation model (Inyanda)

Figure above is the pictorial view of the site in the simulation model.

The table below lists objects used to build the model;

Objects	Objects Names	Description
Source	-Stockpile1, Stockpile2, Stockpile3, Stockpile4, Stockpile5 - Entry	- Stockpiles represent where the coal is located before loaded onto wagons - Entry is the gate for the train to enter the loading site
Combiner	- Loading Station	- Train is combined with the required number of loads by FELs before exiting the system
Vehicles	- FEL1, FEL2, FEL3, FEL4, FEL5, FEL6	- Front End Loaders are used to pick up coal from stockpiles to wagons and hence load the wagons
Model Entities	- Coal - Train	
Sink	- Exit	- Exit gate for the train after it has been loaded

Table 3: Objects description

6.5.3. Phase 3: Model Run, Results Summary and Recommendations

The model tests for three scenarios which are for four, five and six FELs. The result to be focused on is the average time that the train spends to get full while being loaded.

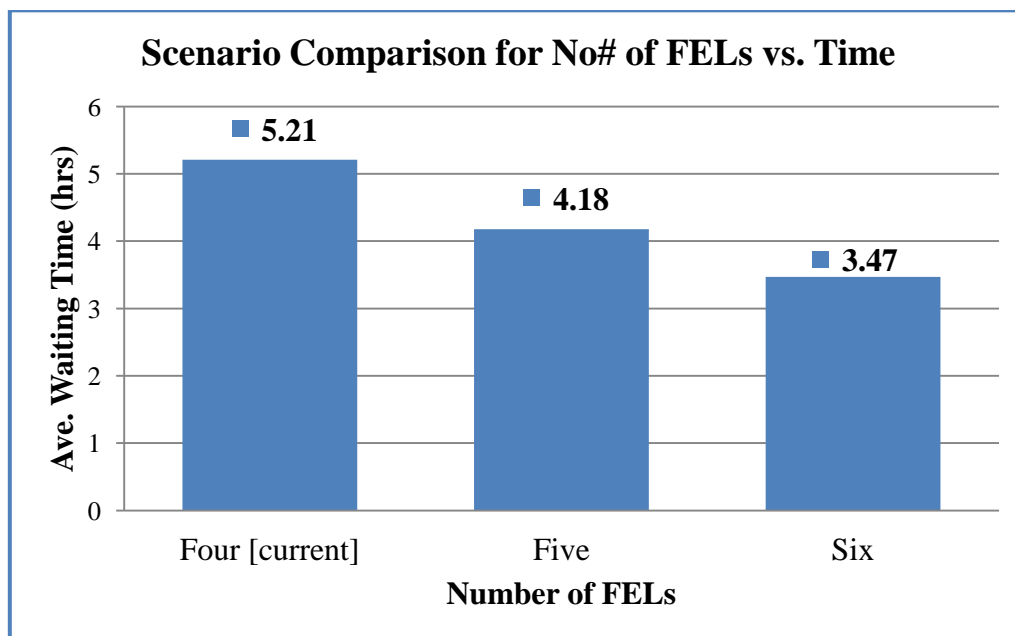


Figure 13: Comparison: No. of FELs vs. Time

The figure 13 above shows the average time that the train spends in the system when four, five and six FELs are used. Based on the results, it is recommended that an extra FEL must be added so that the time the train spends in the system is reduced. The process map shows that the train spends approximately four hours with the current number of FELs and the results from the simulation fairly support the finding.

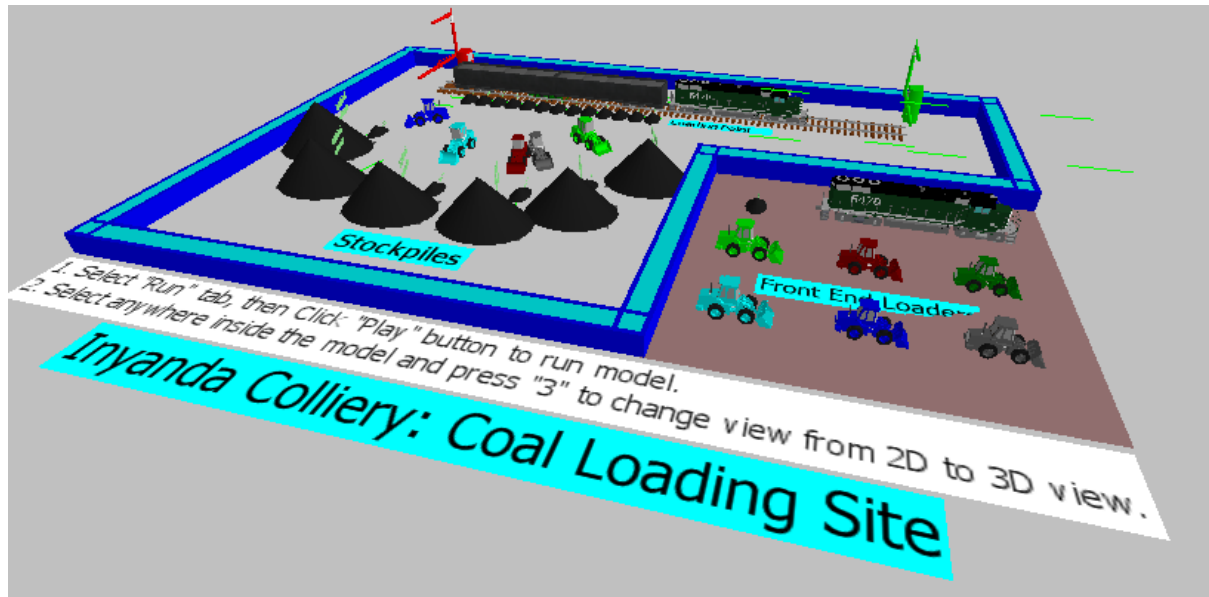


Figure 14: 3D model view



Figure 15: 3D view: FELs and Train

7. Economic Feasibility

The main aim of financial analysis is to help determine whether the project is worth investing into or not. It may occur that solutions are provided to a specific problem but are not be worth investing in due to the fact that they do not benefit the company or break-even in terms of costs to implement against revenue. It is therefore important to ensure that the solutions provided bring about returns (revenue) to the company.

The following analysis provides costs involved within the project and the impact the solutions have on the project in monetary terms. Inyanda Colliery is currently outsourcing the FELs used to load the coal onto the trains on contractual basis. The table below shows the costs involved as per agreement in the contract with the outsourced company per year. The table below shows the costs incurred by Inyanda;

Cost Category	Cost (Rand)	Comments/ Explanations
Fixed cost for current four FELs	R 948 000/yr	- Each FEL costs R 19 750/month
Tonnage charge below four hours	R 1.20	- The charge per ton on the if below the required four hour target
Tonnage charge over four hours	R 1.91	- The charge activated if TAT has exceeded four hours
Penalty/ton	R 1.91 – R 1.20 = R 0.71	- Charge per ton released below 4 hours and over 4 hours is R1.20 and R1.91 respectively, one train carrying 8400 tons pays a penalty of; *8400 tons x R0.71 = R5 964
Current penalties	R 5 000 000/yr	- The recorded amount on the previous year's penalties

Table 4: Costs incurred by Inyanda

The tables below compare three candidate scenarios; (1) *implement the solutions provided and keep the current number of FELs*, (2) *implement the solutions and add one extra FEL*, (3) *implement the solutions and add two extra FEL*.

**The solutions provided are aimed to achieve 20% reduction in loading time.*

Scenario 1: Current number of FELs (4)

Recommendation	Impact	Total Cost	Comments/ Explanations
Continue the current number of FELs (4)	Reduce TAT	R 948 000 / yr	- Each FEL costs R19 750/month
Lift the siding to the level of that of the rail line	The drivers will be able to see the level of coal in the wagon	R 10 000	- Hire machinery and provide sand of which can be dug from anywhere around the premises
Document and train FEL operators on the correct loading procedure	Improve loading	R 0.00	- The training facilities are available at mine site
Install weight meters on each FEL	Reduce the variability in weight	R 100 000	- Each weigh-meter costs R20 000
Install the weight trackers next to the weigh bridge	The train will no longer travel back and forth to weigh	R 30 000	- This keeps track of the weight of the trains as they are being loaded
Calibrate the weigh bridge every six months	Produce correct readings	R 0.00	- This is TFR's responsibility as stated in the contract
Total Cost		R 1 088 000	

Table 5: Scenario 1 total costs

The simulation results for **four (current)** FELs show that the holding time of the train at the loading point is 5.21 hours, should 20% time reduction be achieved, the holding time will be reduced by 1.04 hour to approximately 4.17 hours. The above solution does not have any FEL added to the current four. The holding time is not below the maximum four hours and therefore not recommended as the best option but more investigations may be conducted in order to reduce the holding time to below four hours and hence the TAT. This solution does not guarantee avoidance on the penalties. The total cost involved with this solution is R1 088 000 but the R5 000 000 penalty may not be avoided.

Scenario 2: Add one extra FEL (5)

Recommendation	Impact	Total Cost	Comments/ Explanations
Add one FEL to current four (Simulation)	Reduce TAT	R 1 185 000/yr	- Each FEL costs R19 750/month
Lift the siding to the level of that of the rail line	The drivers will be able to see the level of coal in the wagon	R 10 000	- Hire machinery and provide sand of which can be dug from anywhere around the premises
Document and train FEL operators on the correct loading procedure	Improve loading	R 0.00	- The training facilities are available at mine site
Install weight meters on each FEL	Reduce the variability in weight	R 100 000	- Each weigh-meter costs R20 000
Install the weight trackers next to the weigh bridge	The train will no longer travel back and forth to weigh	R 30 000	- This keeps track of the weight of the trains as they are being loaded
Calibrate the weigh bridge every six months	Produce correct readings	R 0.00	- This is TFR's responsibility as stated in the contract
Total Cost		R 1 325 000	

Table 6: Scenario 2 total costs

The simulation results for **five (one extra FEL)** FELs show that the holding time of the train at the loading point is reduced from previous (four FELs) 5.21 hours to 4.18 hours, the impact of an extra FEL has brought about a difference of 1.03 hours. If the 20% time reduction is achieved due to other recommended solutions, the final holding time will be approximately 3.34 hours. This solution achieves the required target/s with safe margin of 0.66 hours and hence the best option to consider. The total cost for this solution is R1 325 000 and it prevents the R5 000 000 penalty completely.

Scenario 3: Add two extra FEL (6)

Recommendation	Impact	Total Cost	Comments/ Explanations
Add two FEL to current four (Simulation)	Reduce TAT	R 1 422 000/yr	- Each FEL costs R19 750/month
Lift the siding to the level of that of the rail line	The drivers will be able to see the level of coal in the wagon	R 10 000	- Hire machinery and provide sand of which can be dug from anywhere around the premises
Document and train FEL operators on the correct loading procedure	Improve loading	R 0.00	- The training facilities are available at mine site
Install weight meters on each FEL	Reduce the variability in weight	R 100 000	- Each weigh-meter costs R20 000
Install the weight trackers next to the weigh bridge	The train will no longer travel back and forth to weigh	R 30 000	- This keeps track of the weight of the trains as they are being loaded
Calibrate the weigh bridge every six months	Produce correct readings	R 0.00	- This is TFR's responsibility as stated in the contract
	Total Cost	R 1 562 000	

Table 7: Scenario 3 total costs

The simulation model shows that if six FELs are used, the holding time is 3.47 hours and with 20% time reduction target achieved, the final holding time is approximately 2.78 hours. This solution may not be necessary in this case while it may be considered if more customers for Blackhill are marketed and generated.

8. Conclusion

During implementation clear tracking KPI's (Key Performance Indicators) must be tracked until ideas are sustainable. The structured improvement methodology revisited at regular intervals will assist to mitigate issues that may arise and allow the process experts to use a structured method to facilitate problem-solving.

It has been reported that some of the solutions which were recommended are being considered and they so far seem to have an impact in reducing the turn-around-times of the trains. Some of the solutions being implemented are installation of weigh meters onto the FELs so that the driver can be able to read off the amount of coal loaded onto the wagons from inside the FEL. The solutions provided cannot easily be translated to the minutes that may be reduced even though it is certain that there will be a difference in the TAT of the train.

The project is technically and economically feasible as the illustrated in the project economic feasibility. Scenario 2 of the financial analysis proves to be more economical; it can therefore be concluded that it will be beneficial for the company to invest in the project to reduce the turn-around times since the solutions provided are showing that the penalties can be brought down from R5 000 000 to R0.00 a year with the cost of implementation being 27% (R1 325 000) of the current losses (R5 000 000).

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Appendices

Appendix A1: Process map

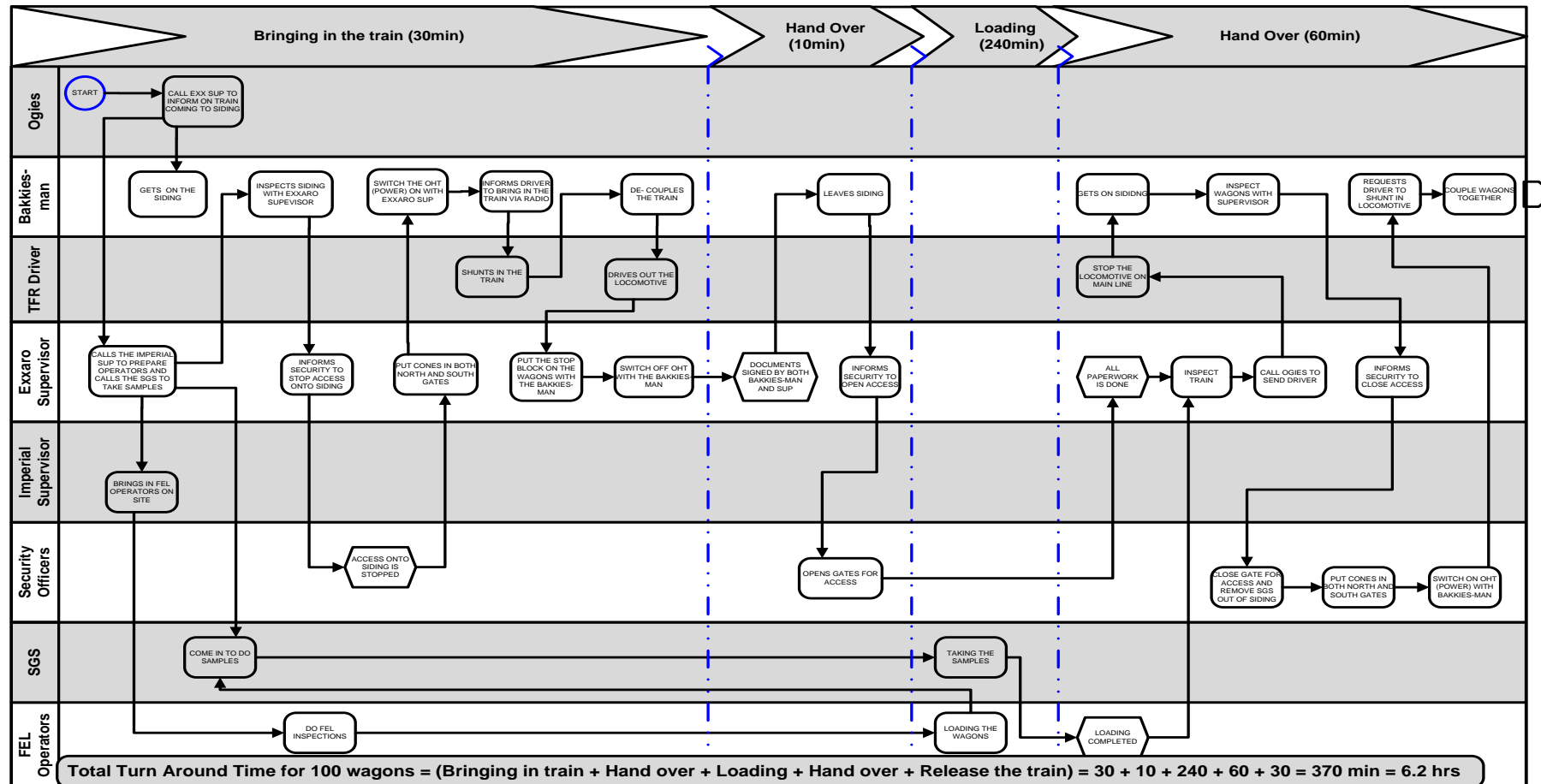


Figure 16: Process map (Inyanda) (a)

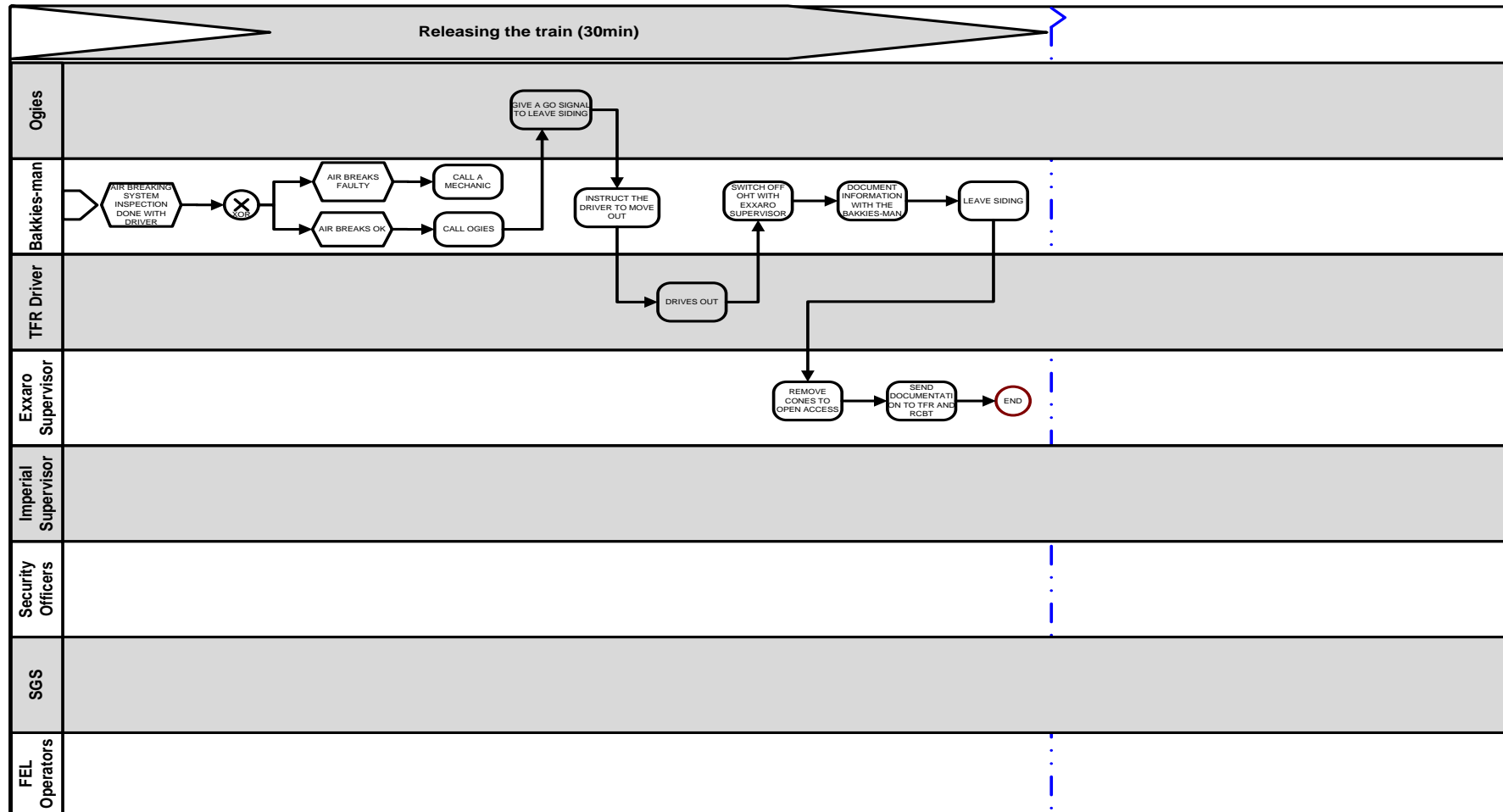


Figure 17: Process map (Inyanda) (b)

Appendix A2: Fishbone diagram

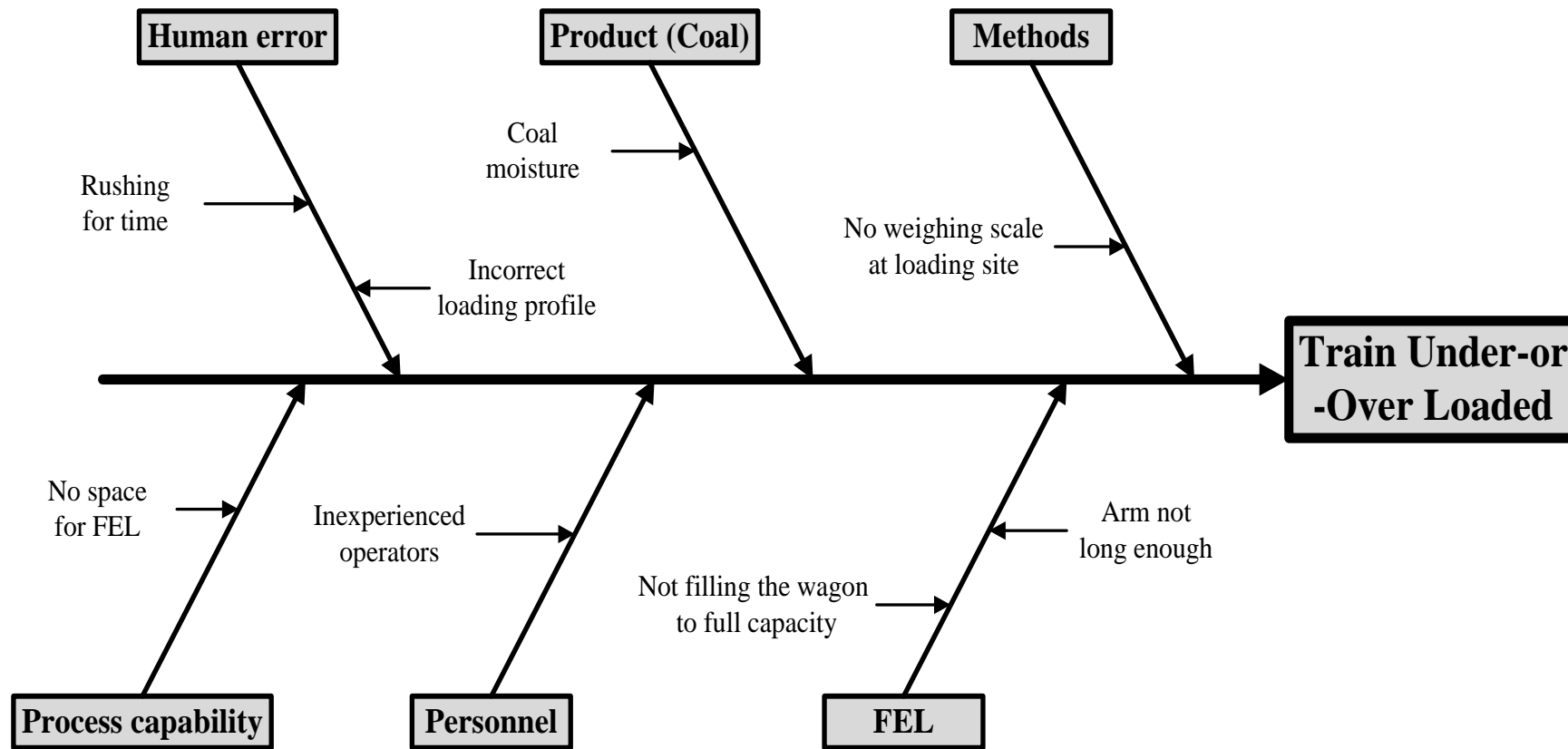


Figure 18: Fishbone diagram (Inyanda)

Appendix A3: Root-cause analysis

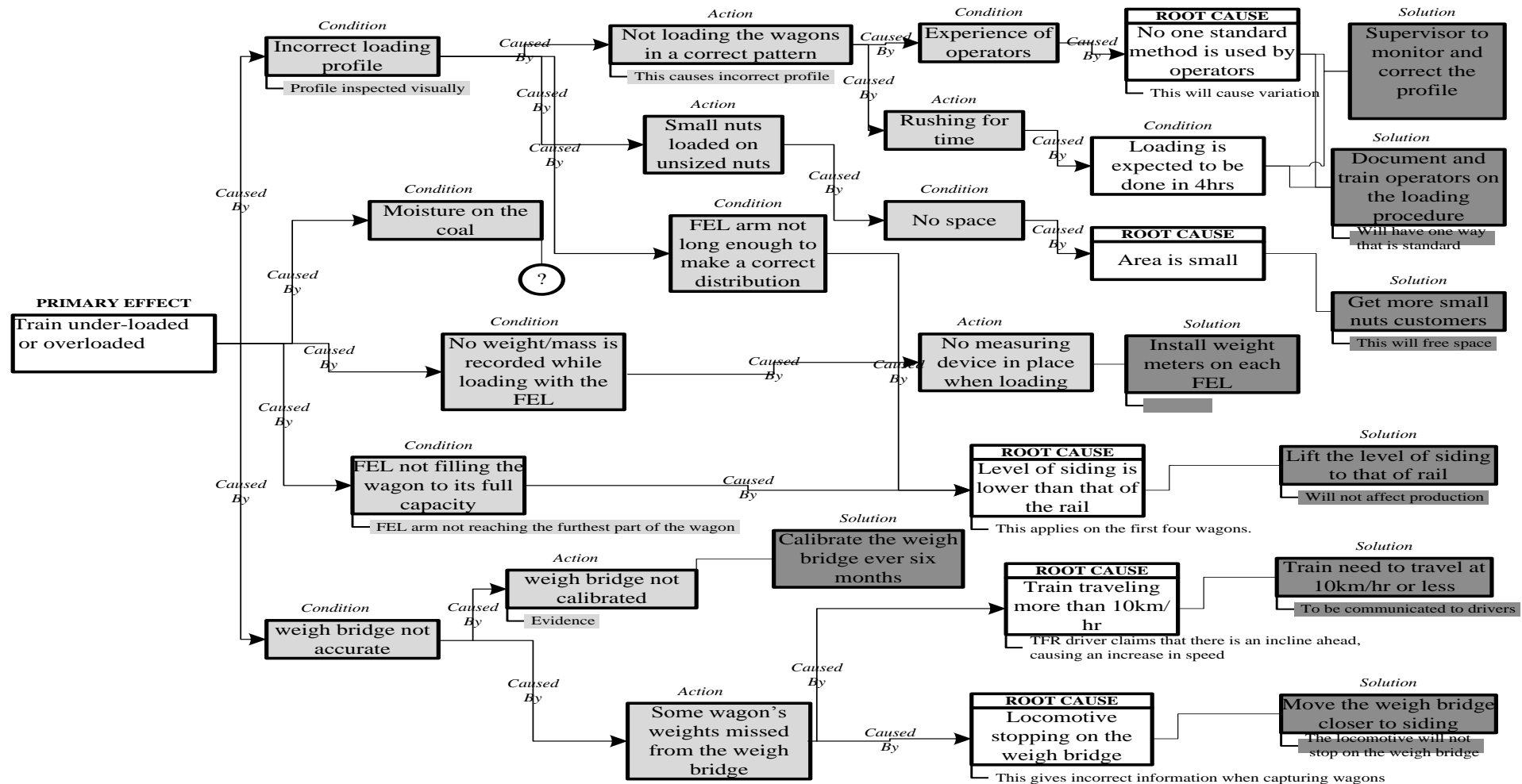


Figure 19: Root-Cause analysis (Inyanda)

Appendix A4: Priority matrix

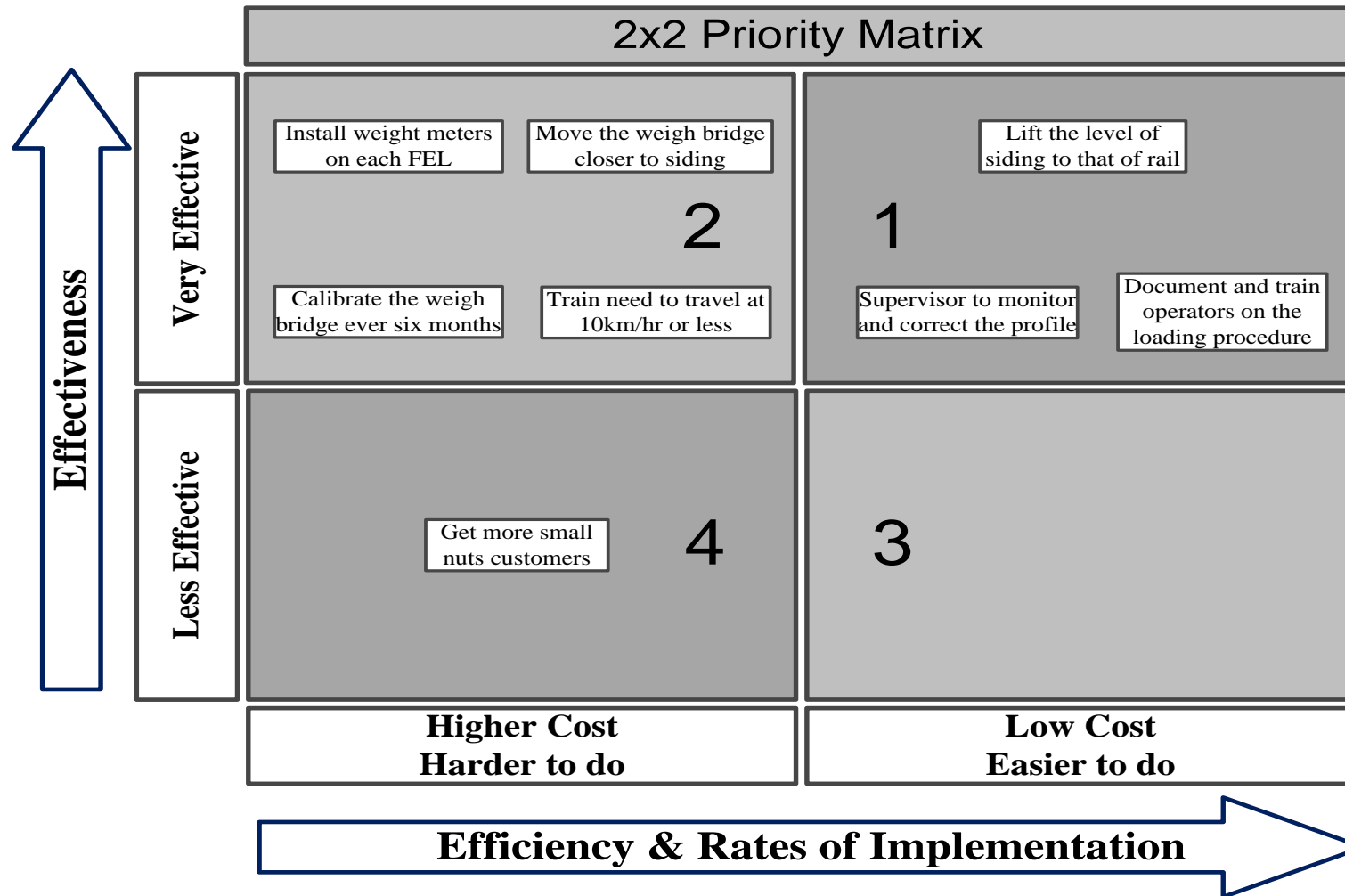


Figure 20: Priority matrix (Inyanda)