Breakthrough Process Improvement

Optimizing Lining Material inventory

Lean Six Sigma Project

DMAIC Methodology
Introduction

Dubai Aluminium ("DUBAL") owns and operates one of the world's largest aluminium smelters

Vision: To be one of the best companies in the global Aluminium industry

Products and services:
- 330 individual products to 300 customers
- More than 1 million metric tonnes /50 countries
- 3800+ employees
- 34 nationalities

In line with the vision, continual improvements are the driving factors for success in DUBAL
Potroom Operation & Supply in DUBAL

DUBAL OPERATION
- SMELTER
- POWER PLANT
- CAST HOUSE

SUPPLY
- WAREHOUSE
- PURCHASE

GREEN MILL, BAKING KILN, RODDING & DOCK
- POTROOMS

WAREHOUSE
- STRATEGIC MATERIAL PURCHASE

POTROOMS
Focus on value addition through operational and service excellence

Inventory Plays a Major Role in Aluminium Smelting

The Business Case: Project Selection

To be one of the best companies in the global Aluminium industry

Focus on value addition through operational and service excellence

MAXIMIZE LONG TERM SHAREHOLDER’S VALUE

F1
F2
F3 Optimize Working Capital
F4

EXCEED CUSTOMER EXPECTATIONS

C1
C2
C3

ACHIEVE OPERATIONAL EXCELLENCE

P1
EHS Smelter CH P&D Support
P2
P3

ACHIEVE CORPORATE SOCIAL RECOGNITION AS EMPLOYER OF CHOICE

P4

OPTIMIZE INVENTORY

Project was aligned to Corporate Strategic objective

Improve Cash flow

P5
P6
P7

P8
P9
P10
P11

MARKET & BUSINESS DEVELOPMENT

L1
L2
L3
L4

Learning & Growth

Internal Processes

Drivers

Outcomes

Inventory Plays a Major Role in Aluminium Smelting

Reducing lining material inventory variation and Optimize Inventory
Define the problem.
Pot Lining and Electrolysis Cell

Adapted from: Relining Rationale.ppt, Morten Sorlie, Elkem

Electrolyte
Molten Aluminum
Cathode with Collector Bar

Frozen Bath
Dense Refractory
Bottom Insulation (Lining Material)

Strong Steel Support Structure

Carbon anode

Different Designs
- D18
- CD20
- D20
- DX

Each set of lining material cost's approximately 0.6 mAED

Adapted from: Relining Rationale.ppt, Morten Sorlie, Elkem
Project Charter

Problem Statement:
In H1-2009, Lining materials inventory variation against the target (20 pot sets for each design), in warehouse was very high (parameter of difference distribution mean=20.8, std. dev.29.5) and this variation was leading to

- Having variation between different materials in one BOM design
- High inventory in some items
- Very low inventory in other items
- Generating expiry of some shelf life items

Large variation in inventory of lining materials against target.
Define

Cell-lining PROCESS

SUPPLIERS
- External Supplier for lining material
- Purchase

INPUTS
- Cathode Blocks
- Collector Bars
- Refractories
- Pig Iron
- Ramming Material

PROCESS
Cell Lining Inventory

OUTPUTS
- Issue of Lining Material and Inventory stock at warehouse
- Cell Lining

CUSTOMERS

Requirement Schedule from Potline Ops & Process Control
MRP by Warehouse and PR to purchase
PO from purchase to supplier
Lining material supplies from supplier to warehouse
Material Request from area
Material Issue

Through SIPOC all stakeholders and areas related to the problem identified
# Project Charter

## Project Target:
- **Reduce average excess inventory from avg. 21 to ~12 pot sets by**
  - Reducing lining material inventory variation by 50% and
  - Optimizing inventory

### Project Scope
- Warehouse, Purchase, Shipping, Pot repair.

### Project out of Scope
- Potlines

### CTQ
- Lining inventory

### Process Indicator
- Variation in inventory at the time of physical verification

### Measurable Benefit
- Reduction in total inventory cost by ~5 million AED
### Project Team

**Project Sponsor**

<table>
<thead>
<tr>
<th>Dr Ali H.A.M. Al Zarouni</th>
</tr>
</thead>
<tbody>
<tr>
<td>V.P. Smelter operations</td>
</tr>
</tbody>
</table>

**Project Leader**

<table>
<thead>
<tr>
<th>Dr Maryam Mohamed AlJallaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snr Manager PCPR &amp; PCCL</td>
</tr>
</tbody>
</table>

**Team Members**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ibrahim Baggash</td>
<td>Snr Manager Smelter Production Services</td>
</tr>
<tr>
<td>Najm Alawadhi</td>
<td>Snr Manager Purchasing – Strategic Materials</td>
</tr>
<tr>
<td>Abdul wahid Al Madani</td>
<td>Snr Manager Supply Chain</td>
</tr>
<tr>
<td>Abdulla .A</td>
<td>Manager Cell Relining</td>
</tr>
<tr>
<td>Asim Hassan</td>
<td>Manager Warehouse</td>
</tr>
<tr>
<td>Mohamed Tawfik Boraie</td>
<td>HOD Process control Cell Lining</td>
</tr>
<tr>
<td>Haiedeh Marashy</td>
<td>Warehouse</td>
</tr>
<tr>
<td>Saif Mohamed</td>
<td>Snr Planner Smelter Reductions</td>
</tr>
<tr>
<td>Daniel Whitfield</td>
<td>Snr Engineer Process Control Potrooms</td>
</tr>
<tr>
<td>Andries Louw</td>
<td>Snr Engineer Process Control Potrooms</td>
</tr>
<tr>
<td>Narendra Singh Rana</td>
<td>Plant Industrial Engineer</td>
</tr>
</tbody>
</table>

**Team selected is a cross-functional team involving all areas related to the project.**
## Stake Holder Model: ARMI Chart

<table>
<thead>
<tr>
<th>Approver</th>
<th>Resource</th>
<th>Member</th>
<th>Interested Party</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr Ali H.A.M. Al Zarouni</td>
<td>Warehouse</td>
<td>Dr Maryam Mohamed AlJallaf</td>
<td>VP-Smelter</td>
</tr>
<tr>
<td></td>
<td>Purchase</td>
<td>Ibrahim Baggash</td>
<td>VP-Finance</td>
</tr>
<tr>
<td></td>
<td>Smelter Services</td>
<td>Najm Alawadhi</td>
<td>VP-Supply</td>
</tr>
<tr>
<td></td>
<td>Process Control.</td>
<td>Abdul Wahid Al Madani</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Industrial Engineer</td>
<td>Abdulla .A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asim Hassan</td>
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<td></td>
<td>Narendra Singh Rana</td>
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</table>

Roles of Stakeholders have been identified through ARMI chart.
## Project Schedule

<table>
<thead>
<tr>
<th>Phase</th>
<th>Deliverables</th>
<th>End Date</th>
</tr>
</thead>
</table>
| Define  | • Project Charter  
          • SIPOC & Process Map  
          • Goal Setting  
          • ARMI Chart  
          • Schedule      | June’09     |
| Measure | • Unit Definition  
          • Data Collection Plan  
          • Baseline          | July’09     |
| Analyse | • Brainstorming  
          • Pareto             | August 09   |
| Improve | • Solution Selection Matrix  
          • Implementation Plan | November 09 |
| Control | • Control Charts  
          • Control Plan  
          • Review Meeting  | December’ 09|

**Defined project tollgates and milestones – agreed by the team**
Map out the current process.
Process Map

Cell Relining Process

Supplier — Warehouse — Pot Repair — Finished goods — Potroom

- Deliver material to inventory
- Issue material for production
- MRp for material procurement
- Build ready shells to inventory
- Issue for pot replacement

Point of CTQ Measurement

Suppliers’ requirements — Process Control

Issue prediction and dynamic buffer

Yearly Requirements

Purchase material
Data Collection Plan

Unit Definition
- Pot set (Quantity of lining materials available at end of the month)

Specification
- (One month consumption + buffer) ± 40 sets (set by pot failure prediction)

Defect Definition
- Any data point out of specification (± 40 sets).

Data Collection Plan

<table>
<thead>
<tr>
<th>Data</th>
<th>Frequency</th>
<th>Source</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation in inventory from target</td>
<td>Monthly</td>
<td>PCCL Records</td>
<td>Mohamed Tawfik</td>
</tr>
</tbody>
</table>

Dubai Aluminium
MSA – Data Verification

GR&R is not applicable as the measurement is count of inventory. Hence just data verification was done to ensure data accuracy.

- **Physical verification** of lining material inventories performed monthly.

- **Consumption data** verified between PCCL databases and iRPMS.

**Measurement system/ Data found satisfactory**
Baseline

Process Capability of 2009 QOH-Tgt

Cpk

PPM (Exp. Overall)

0.27

278,115

Very Low Cpk and High defect ppm – high number of data points out of specifications
ANALYZE

Identify the cause of the problem.

D M Analyze I C

This image cannot currently be displayed.
Identify Possible causes

Problem
• Variation in inventory & non-optimized inventory

Tool Used
• Brain Storming

Possible Causes
1. Prediction Model Error
2. Variation in delivery
3. Change in schedule for early delivery by procurement planning
4. Lead time
5. High Buffer level
Filtering the Root causes

**Possible Causes**
1. Prediction Model Error
2. Variation in delivery
3. Change in schedule for early delivery by procurement planning
4. Lead time
5. High Buffer level

**Tool Used**
1. Process Capability
2. Why why & Histogram
3. Why why & VSM
4. Process Knowledge
5. Inventory Model & Control chart

**Why Used**
1. To check Model is capable of giving desired accuracy
2. To identify root cause and validate
3. To identify root cause and validate
4. To study controllable or uncontrollable cause
5. To identify whether buffer level acceptable or not

This summarises the tool used for filtration of root causes from possible causes
Possible Cause 1: **Prediction Model Error**
(Process Capability of prediction)

Hence prediction error is well within the tolerance of ± 10 pot sets. Expected error ppm is 4044, which is acceptable for the above process.

**Conclusion:**
As Capability analysis and Control chart suggest that prediction error is within control, hence it is **not a root cause**.
Possible Cause 2: Variation in Delivery
(Why-Why Analysis)

Why
- Why variation in delivery occurs?
  - Due to variation in delivery date.

Why
- Why variation in delivery date occurs?
  - Due to poor commitment from supplier.

Root cause Validation

Hence, Poor commitment from supplier is root cause for inventory variation.
Possible Cause 3: Change in schedule for early delivery by procurement planning (Why-Why Analysis)

Why
- Why change in schedule occurs?
  - Due to lower than planned inventory at warehouse.

Why
- Why lower than planned inventory at warehouse?
  - Due to no visibility of WIP and Finished Goods inventory to procurement planning.

Hence No visibility of Finished Goods and WIP inventory to procurement planning is *root cause* for inventory variation.
Possible Cause 3: Change in schedule for early delivery by procurement planning (Why-Why Analysis)

High WIP & F.G. inventory (VSM Analysis)

Hence No visibility of Finished Goods and WIP inventory to procurement planning is root cause for inventory variation.
Possible Cause 4: High Lead Time

Why
- Why high lead time causes inventory variation?
  - Due to high max to min difference between inventory levels

Why
- Why high difference between inventory levels?
  - Due to supplier delivering material in bulk and we need to cover for long lead time.

Why
- Why supplier delivering material in bulk?
  - Due to material being exclusive to us supplier produces material at certain quantity.

Hence, lead time causes inventory variations but it is not a controllable root cause, although some other actions like
- Making some material as consignment stock, were proposed by the team.
Possible Cause 5: **High Buffer level**

- **Why**
  - Why high buffer level?
  - Due to wrong setting of buffer level

- **Why**
  - Why wrong setting of buffer level?
  - Due to no scientific basis for buffer level setting

**Root Cause Validation**

- Actual pot failure variation is within +/- 10 pot sets and we are keeping a buffer of 20 pot sets

*Hence no scientific basis for buffer level setting is a root cause for high inventory.*

*Value depends on material type and its lead time.*
Filtering of Root causes

Variation in inventory and high buffer level

1. Prediction Model Error
2. Variation in delivery
   - Poor commitment from supplier
3. Change in schedule for early delivery by procurement planning
   - No visibility of WIP and Finished Goods inventory to procurement planning
4. Lead Time
5. High Buffer level
   - No scientific basis for buffer level setting

This summarises the filtration of root causes from possible causes
Summary of final root causes

1. Poor Supplier Commitment

2. No visibility of Finished Goods & WIP

3. No scientific basis for buffer level setting
Implement and verify the solution.
# Brainstorming: List of Possible Solutions

<table>
<thead>
<tr>
<th>Root Causes</th>
<th>Counter-Measures/ Solutions</th>
</tr>
</thead>
</table>
| **1. Poor commitment from supplier**     | A. Agree with supplier at year beginning for full year delivery schedule.  
                                           B. Follow up with supplier before each shipment.  
                                           C. Communicate to user about any expected variation.  
                                           D. Change packing standard.                        |
| **2. No visibility of Finished Goods and WIP inventory** | A. Change concept of inventory to overall process inventory, considering: Raw material, WIP and Finished Goods.  
                                                        B. Consignment stock from major lining material and to be paid only when used. |
| **3. No scientific basis for buffer level setting** | A. Dynamic buffer for each design to be calculated every year based on past process variation.                                                            |
## Solution Selection Matrix

<table>
<thead>
<tr>
<th>Root Cause</th>
<th>Solution</th>
<th>Cost</th>
<th>Difficulty in Implementation</th>
<th>Rating (Cost x Difficulty)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor commitment from supplier</td>
<td>Agree with supplier at for full year delivery schedule.</td>
<td>5</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Follow up before each shipment</td>
<td>4</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Communicate to user about any expected variation</td>
<td>5</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Change packing standard.</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>No visibility of Finished Goods and WIP inventory</td>
<td>Change concept of inventory to overall process inventory, considering: Raw material, WIP and Finished Goods.</td>
<td>5</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Consignment stock from major lining material.</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>No scientific basis for buffer level setting</td>
<td>Dynamic buffer for each design to be calculated every year based on past process variation.</td>
<td>4</td>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>

### Rating Scale

<table>
<thead>
<tr>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
</tr>
<tr>
<td>LOW</td>
</tr>
</tbody>
</table>

DIFFICULT IMPLEMENTATION
# Implementation Plan

<table>
<thead>
<tr>
<th>No.</th>
<th>Particular</th>
<th>Action Points</th>
<th>Responsibility</th>
<th>Target Date</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Poor commitment from supplier</td>
<td>Agree with supplier at for full year delivery schedule.</td>
<td>Najm AlWadahi</td>
<td>Nov 2009</td>
<td>Dec 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Follow up before each shipment</td>
<td>Najm AlWadahi</td>
<td>Jan 2010</td>
<td>Jan 2010 (Continuous)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Communicate to user about any expected variation</td>
<td>Najm AlWadahi</td>
<td>Nov 2009</td>
<td>Nov 2009</td>
</tr>
<tr>
<td>2</td>
<td>No visibility of Finished Goods and WIP inventory</td>
<td>Change concept of inventory to overall process inventory, considering: Raw material, WIP and Finished Goods.</td>
<td>All</td>
<td>Jun 2009</td>
<td>Jun 2009</td>
</tr>
<tr>
<td>3</td>
<td>No scientific basis for buffer level setting</td>
<td>Dynamic buffer for each design to be calculated every year based on past process variation.</td>
<td>Maryam Mohamed Aljallaf</td>
<td>Oct 2009</td>
<td>Oct 2009</td>
</tr>
</tbody>
</table>

Actions were monitored and implemented as per the plan.
Process performance before and after implementation

**BEFORE**

<table>
<thead>
<tr>
<th>Process Capability of 2009 QOH-Tgt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Data</td>
</tr>
<tr>
<td>LSL: 246</td>
</tr>
<tr>
<td>Target: 246</td>
</tr>
<tr>
<td>USL: 49</td>
</tr>
<tr>
<td>Sample Mean: 29.875</td>
</tr>
<tr>
<td>Sample Stdev: 23.9934</td>
</tr>
<tr>
<td>Sample N: 72</td>
</tr>
<tr>
<td>StdDev(Within): 23.9934</td>
</tr>
<tr>
<td>StdDev(Overall): 29.5184</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observed Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPM &lt; LSL: 31,150</td>
</tr>
<tr>
<td>PPM = LSL: 187,000</td>
</tr>
<tr>
<td>PPM &gt; LSL: 21,875</td>
</tr>
<tr>
<td>PPM Total: 218,750.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exp. Within Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPM &lt; LSL: 19,877</td>
</tr>
<tr>
<td>PPM = LSL: 21,697.83</td>
</tr>
<tr>
<td>PPM &gt; LSL: 20,836.83</td>
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<td>PPM Total: 21,836.83</td>
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<table>
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<th>Exp. Overall Performance</th>
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**AFTER**

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<td>PPM Total: 218,750.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cpk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before: 0.27</td>
</tr>
<tr>
<td>After: 1.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PPM (Exp. Overall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before: 278,115</td>
</tr>
<tr>
<td>After: 4,326</td>
</tr>
</tbody>
</table>

Significant improvement in excess lining inventory variations
Process performance before and after implementation

Supplier Commitment

Lining Martial Physical inventory actual vs Target

Significant improvement in excess lining inventory variations
Control

To sustain the improved results following control methods were institutionalized in the system and being continuously monitored.

- **Sharing of draft annual plan** with all the stakeholders in year beginning.

- **Regular Bi-weekly meeting** between stakeholders.

- **Department objective for controlling** lining material inventory reported and reviewed through BSC.

- **MRP procedure modified** for not reacting to common cause variations.

---

BPR Report with month by month objective vs actual performance on KPIs

Modified MRP Procedure
## Control Plan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measurement Method</th>
<th>Responsibility</th>
<th>Actions: If Out Of Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer level</td>
<td>Difference between Actual failure and predicted failure within control limit</td>
<td>◦ Cell Lining Process Control, HOD</td>
<td>Re calibrate the level if some unexpected event happens.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>◦ Plant Industrial Engineer, Smelter</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>◦ Sr. Mgr., PC PR &amp; CL</td>
<td></td>
</tr>
<tr>
<td>Physical Inventory</td>
<td>Physical Inspection</td>
<td>Cell Lining Process Control, HOD</td>
<td>- Inform all stakeholders and decide if changes are required in future delivery schedule</td>
</tr>
</tbody>
</table>

**OCAP and responsibilities identified in case of out-of-control process**
## Stakeholders involvement in Control Phase

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Area</th>
<th>Role in control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top management</td>
<td></td>
<td>Reviewing performance.</td>
</tr>
<tr>
<td>Dr Maryam Mohamed AlJallaf</td>
<td>Process Control potroom and Cell Relining</td>
<td>- Setting dynamic buffer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- physical stock taking, monitoring and reporting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Monitoring and communicating consumption.</td>
</tr>
<tr>
<td>Najm Alwadahi</td>
<td>Purchase Strategic Materials</td>
<td>Implementing MRP recommendation with supplier.</td>
</tr>
<tr>
<td>Asim Hassan</td>
<td>Warehouse</td>
<td>MRP control based on data from all sources.</td>
</tr>
<tr>
<td>Ibrahim Baggash</td>
<td>Smelter services</td>
<td>Reporting consumption in SAP.</td>
</tr>
</tbody>
</table>
Results Achieved & Financial Benefits

WORKING CAPITAL REDUCTION

- Working capital reduction by 11.3 million AED audited by finance.

OTHER BENEFITS:
- Reduced greatly fire fighting situations.
- Reduced greatly expiry of shelf life items.
- Improved storage space utilization.

Avg 20.8 excess pot sets

Avg 2 excess pot sets

Working capital reduction by 11.3 million AED audited by finance.
Project Closure

• **Learning from the project**
  – Enhanced understanding of the process through Value Stream Mapping.
  – Lean and Six Sigma integrated project a unique case study.
  – Cross functional team involvement.

• **Horizontal deployment**
  – Learning from the project applied to other process materials.

• **Further refinement**
  – Automated MRP project in SAP 2013.

• **Team recognition**
  – Team was recognized monetarily through performance enhancement project (PEP) program.
  – Presented in quarterly review meeting and appreciation from VP smelter operation.
Why this project is an excellent improvement example

- **Impacted Dubal’s cash flow positively** and reduced it by 11.3 mAED.
- **Complex project involving multiple functions**, having specialized and customized high value materials (minimum 51 Million AED at 2009).
- **Achieved reduction** in inventory **in spite of limitation of 6 months lead time**.
- **Transformation in inter department relationship** and team work *(namely Smelter operation, warehouse and purchase)*.
- **Great success story in service area** (not only technical).
- This project is a live example of how **lean application with six sigma** can provides a **unique blend of results**.
Q & A
Thank You
Lining Mat. inventory before power outage (Oct 2008)

- High inventory Vs min Required
- High Variation (not usable)
- Not considering ready shells
Lining Mat. inventory after power outage
(March-April 2009)

NOT ONLY TO COMULATE INVENTORY TO COVER THE RISK, BUT LOWERING RISK BY IMPROVING DELIVERY CONTROLS.