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QUALITY CONTROL ON SHOPFLOOR LEVEL IN A HEAVY STEEL PROCESSING FACTORY

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1. BACKGROUND

ABB Transmission and Distribution, Powerlines division is a world leader in the design, manufacture and erection of overhead transmission lines. The company undertakes complete projects that include design, testing, manufacture, transport and erection of transmission lines for clients. The Managing Director of ABB Transmission and Distribution, Wanland (2000:08), said that the objective and purpose of the company is "to provide a complete solution to the customer, thus to transport energy from substation A to substation B rather than to supply steel towers and powerlines."

Other customers prefer to do their own erection and require ABB Powerlines to supply only the tower steelwork for their projects. These projects tend to be smaller and would typically be extensions or modification to existing powerlines. (Pazzi, 1996 – 2001)

Major clients of ABB Powerlines include:

- Various city councils of South Africa – Significant projects were recently (last 5 years) completed for Pretoria, Johannesburg, Bloemfontein, Durban, Port Elizabeth and Cape Town councils.
- Eskom – the power authority in South Africa. Most of the larger turnkey projects were successfully completed for Eskom. Historically ABB Powerlines’ biggest client
- Smaller erection companies – These companies specialise in the erection of transmission lines, but they don’t have any manufacturing capabilities. Typically ABB powerlines would supply the steelwork for a project and one of these smaller companies would erect powerlines for the end customers. The end customer would buy the steel from ABB and contract one of these erection companies to put the line up.
- Export project to foreign power authorities – Successful projects were completed for Malaysia, Philippines, Mozambique, Namibia, Lesotho, Mauritius, Cameroon and Nigeria. (Pazzi, 1996 – 2001)

Each of these clients has got its own requirements regarding the design, manufacture, packing and dispatch of the material.

Export projects would typically have special requirements regarding the steel grade used for the towers as well as project specific packaging and documentation requirements.

For larger projects (over 500 tons per month) timing of the delivery of the steelwork is of utmost importance in order to keep to the agreed timing schedule. These projects could run for a period of 2 years (and some even longer).
The factory will manufacture towers in logical batch sizes as per construction site requirements. A constant flow of tower steelwork (material) from the factory to the site is standard procedure with 50 to 100 ton deliveries taking place almost weekly.

Construction sites are concerned with the erection of the towers and the stringing of the powerlines. Normal procedure is to start erecting towers from point A and follow the line through to point B. As the construction takes place along the line, the camp will be moved along the line. It is therefore necessary for the factory to produce the towers in the sequence that they would be erected along the line. For extremely large contracts involving lines that stretch over thousands of kilometres, multiple camps and construction sites are used.

Heavy erection and construction equipment is used for the erection of the towers. Some typical equipment used includes 50 ton all terrain mobile cranes, various all terrain trucks, concrete mixing and concrete handling equipment as well as specialised stringing equipment. Powerlines are erected over rough terrain and ABB Powerlines is required to make the necessary roads for access to the construction sites with minimal impact on the environment.

Towers are manufactured from angle iron and plate sections. All the items are manufactured individually in the factory and then the pieces are bolted together on site during the construction of a tower. Holes are punched/drilled in the material to enable these items to be assembled with bolts and nuts. A single tower can have in excess of 2000 different pieces.

The Towers factory has a capacity to produce on average 2000 tons of tower steelwork per month. (Pazzi, 1996)

At any one time up to 60 different shop orders can be in production simultaneously on the factory shop floor. One order can exist out of 1 tower or be for a batch of up to 60 towers per order. (Pazzi, 2001)
An item manufactured incorrectly and sent to site can cost thousands of rands to rectify. Consequences of incorrect items sent to site are:

- Project completion delays as construction of towers are delayed (most turnkey projects do include a penalty clause regarding the completion date for the project.)
- Transport cost of incorrect items back to the factory
- Rework or re-manufacturing costs (labour, material and loss of potential profit)
- Transport cost of the rectified items to the construction site
- Increased construction cost. Construction equipment cannot wait at a specific tower should any problems be experienced, due to the high cost of running construction equipment. It is standard procedure that the equipment proceed to erect the following towers on the line and then move back to erect the tower with the problem as soon as the correct pieces arrive on site.

ABB Powerlines has existed for more than 40 years in South Africa and a large percentage of the workforce spent all adult lives working for the organisation. The “mother company” (ABB Sae Sadelmi Powerlines unit, Italy) recruited these individuals in Italy and send them down to South Africa some 20 – 30 years ago. (Coetzee, 2000)

Dramatic increases in customer complaints were received recently, compared to previous years, due to poor quality product supplied. (Graham, 1997 – 2001) Annexe 1 attached, is a summary of customer complaints received 1997 to 2001.

2. PROBLEM STATEMENT

The aim of this project is to investigate the cause for decrease in quality of product supplied, in order to propose corrective actions to be taken to ensure the sustainability of ABB Powerlines (Steel Carpentry department).

3. OBJECTIVES

In order to address the problem as mentioned above, relevant data must be gathered and analysed.

The underlying reasons and / or causes for the relevant problems must be determined in order to generate a proposal to prevent the recurrence of common problems experienced, thus improving the quality of product supplied by ABB Powerlines.
Data to be gathered and analysed include the following:

- Customer complaints received
- Non-conformance reports raised (NCR's)
- Manufacturing practices and procedures
- Manufacturing conditions

By understanding the root causes of problems experienced, corrective actions can be generated and proposed in order to prevent the recurrence of said problems. Analysing the above-mentioned data will help the researcher to gain a deeper understanding of the problems and will generate or lead to proposals to suggest in order to improve the situation.

4. DEFINING CONCEPTS AND CONSTRUCTS

The following definitions are applicable to this research project:

<table>
<thead>
<tr>
<th>Investigate</th>
<th>motions required to determine the cause of a state or a situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of product</td>
<td>Detail state of material supplied. Quality is measured in terms of:</td>
</tr>
<tr>
<td></td>
<td>• Conformance to dimensional requirements (drawings).</td>
</tr>
<tr>
<td></td>
<td>• Grade of material used.</td>
</tr>
<tr>
<td></td>
<td>• Conformance to quality and technical specifications.</td>
</tr>
<tr>
<td></td>
<td>• Tower material (steelwork) must be fit for purpose, thus fit together on site and be able to carry the designed loads.</td>
</tr>
<tr>
<td>Product</td>
<td>Various items manufactured from angle iron and plate sections. Holes are punched or drilled in the material and then bolted together on site to form a tower.</td>
</tr>
<tr>
<td>Steel carpentry</td>
<td>Towers factory, manufacturing transmission line towers. The galvanising and dispatch yard is viewed separately from Steel Carpentry. Steel Carpentry include the raw material store, various cutting punching, drilling and notching equipment, bending presses and forklifts. See factory layout attached in annexe 5.</td>
</tr>
</tbody>
</table>
5. LIMITATIONS

This dissertation will be limited in application to:

- The steel carpentry workshop of the ABB Powerlines Towers manufacturing unit in Nigel
- Operational activities of the South African manufacturing unit. This project excludes the financial data, analysis and impact of operational departments on the financial situation of the organisation in terms of cash flow and working capital. This project also excludes the marketing, present market analysis, construction and project management aspects of this organisation.

6. VALUE OF RESEARCH

This research project will identify factors leading to, or contributing to the decrease in quality of product supplied. The research will provide the researcher with a deeper understanding of the manufacturing process of tower steelwork.

As this research project will highlight areas to be improved in order to improve the overall product quality, corrective actions will be proposed for the ABB Powerlines management team in order to rectify the situation.

This research project will provide the opportunity for the researcher to gain a thorough understanding of the manufacturing methods and activities, daily problems experienced and flow of events in the manufacturing of transmission line towers. The detail understanding of the processes on the shop floor will be used to support future decision-making in the managing of the department.
Secondary benefits of this research project will include:

- Reduced rework cost (including associated transport, travel and erection cost)
- Improved customer relations that will secure future business as customers will be confident in the capabilities of the organisation. (Timeous deliveries and correct product supplied the first time)
- The current quality management system (based on, ISO 9001) highlight problem areas and require management to investigate and implement corrective actions to rectify the situation. This research project is the investigation into causes for the problem and will propose corrective actions.
- Improved morale of workers as the continuous rework lowers morale on the shop floor.
- Improved understanding and documentation of the manufacturing process for transmission line towers.
- Sustainability of the organisation as satisfied customers will have confidence in the capabilities of ABB powerlines.

7. RESEARCH DESIGN

In order to meet with the objective of this project, participatory research methods were used.

Participatory research methods are distinguished by two characteristics: the relationship between the people involved in the research, and the use of research as a tool for action. Participatory research encourages the active participation of the people whom the research is intended to assist. In this way, it empowers the people to be involved in all aspects of a project, including planning and implementation of the research and any solutions that emerge from the research. (Bless & Higson-Smith, 1995; 57)

Participatory research allowed the researcher to acknowledge the value of the opinions and thoughts of all people such as focus groups (for example CNC operators, Supervisors and other relevant parties that can contribute), through in depth interviews and participant observation.

Relevant data was collected through observation, interviews and historical data. Comparisons against historical data will identify the areas of difference, highlighting the causes for the decrease in quality of product supplied.

The researcher will compare a historical model ("picture") of the factory with the present model ("picture"). Differences will be identified that can be addressed in order to rectify the current quality problems.
Differences will be compared in terms of conditions, orientations and actions. See annexe 2 for a diagram of this presentation.

The aim is to identify the changes in the manufacturing environment from the past scenario to the present scenario. Understanding the impact of these factors will lead to propose corrective actions to be taken.

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Work load on the factory</td>
<td>• Production output (tons req’d per month), consistency of work</td>
</tr>
<tr>
<td>• Levels of supervision</td>
<td>• Responsibilities of various parties</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ORIENTATIONS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Workers beliefs about themselves</td>
<td>• Workers perceived importance of themselves to the organisation and role of themselves</td>
</tr>
<tr>
<td>• Workers beliefs about the future</td>
<td>• Secure working environment, sustainable organisation</td>
</tr>
<tr>
<td>• Level of morale of workers</td>
<td>• Willingness to execute work energetically</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACTIONS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Amount of enthusiasm on the shop floor</td>
<td>• Initiatives and improvements suggested from the workforce</td>
</tr>
<tr>
<td>• Willingness to participate</td>
<td>• Willingness to execute work energetically</td>
</tr>
</tbody>
</table>

8. DATA COLLECTION

The researcher elected to work on the factory floor for 6 months to fully understand the views of the factory workers better. Data were collected through participant observation and interviews (structured and informal) in order to understand the shop floor workers behaviours, feelings, attitudes and beliefs towards the daily routines on the shop floor better.

By working on the shop floor together with the blue-collar workers, the researcher gained a reasonable understanding of the natural flow of events on the factory floor for the production of transmission line towers. During the observation period, time were spend on the factory shop floor during normal working hours (07:00 to 16:30) as well as joining the shift teams working during night time.
Depending on the workload at the time, standard shift hours are:

- 06:00 to 14:00
- 14:00 to 22:00 and
- 22:00 to 06:00

The time spend on the shop floor allowed the researcher to obtain information through numerous informal interviews with supervisors and machine operators in the natural working environment. These interviews allowed for access and understanding of information that is not directly observable for an outsider in a short period of time. Through spending time with certain key individuals, one can gain their trust and access to their feelings, beliefs, attitudes and thoughts. By understanding employees' concerns, one can easily draw solutions from them, as some individuals experiencing the problems will propose solutions to a trusted colleague, but don't have the authority or courage to raise the solution to a senior manager or take the necessary actions.

Structured interviews were also held with some of the more experienced senior members of the organisation. These individuals do have the experience of the past and will help in comparing the current situation with the past, in order to highlight differences and possible improvement areas.

The three methods of data collection used during this research was:

- Participant observation
- Interviews (structured and informal)
- Historical documents

Participant observation:
The researcher worked together with the employees on the factory shop floor in order to gain the relevant information and exposure from shop floor situations. Time spent on the shop floor allows the researcher to gain the trust of the workers and therefore the workers will accept the researcher into their environment. Workers that trust the researcher are more prone to provide insight into their view of the current situations, thus providing the researcher with a deeper insight into the current situation and attitudes of workers. The aim is to gain enough trust from the workers in order for them to act naturally on the shop floor when the researcher is present. The researcher spent more than 6 months on the shop floor exclusively to observe current methods of handling and addressing real life situations and current problems experienced.
Interviews:
During the time spend on the shop floor, numerous non-scheduled interviews were conducted with the employees. Interviews were conducted with operators, labourers as well as supervisors and foreman. These interviews gave insight to the current attitudes and views of the employees. More structured interviews were conducted with some senior individuals in the organisation. These individuals are currently not directly part of the production department, but were in the past and have considerable experience in the manufacturing practices of overhead transmission line towers. These interviews provided the researcher with information regarding the "past" picture of the organisation.

Historical data:
Records containing data from the past 5 years were analysed in order to identify trends and possible reasons for the sudden increase in poor quality product being supplied by ABB Powerlines. The data analysed includes the following:

- Number of customer complaints received per month
- Non conformance reports (NCR’s) raised per month
- Production volumes per month
- Structure of the factory (organisational chart)
- Documented Quality works instructions and procedures

9. DATA ANALYSIS

From the data collected as described in 8. Data collection, the following topics were identified as possible problem areas within the Powerlines factory, contributing to the quality problems presently experienced:

CONDITIONS:
- Complex operation
- Change in production requirements
- Lack of shop floor leadership and co-ordination
- Lack of responsibility and communication (every one feel that someone else is responsible to address the situation)

ORIENTATIONS:
- Lack of shop floor experience and knowledge
- Low morale of workforce
ACTIONS:

- Quality Control throughout the process
- Increase in NCR's, and customer complaints

Complex operation:

The manufacturing of various towers simultaneously is an extremely complex operation. Annex 5 attached is a layout diagram of the Steel carpentry workshop. The red lines (with arrows) indicate the flow of material from workstation to workstation through the factory.

Towers are manufactured to order and "job shop" manufacturing processes are being followed, in other words, a predetermined flow from one workstation to the next for every piece is not followed. The flow of each item through the factory is unique, based on the quantity of items required and operations required on the items. The workload at the time of processing a piece will also influence on which machine the piece is processed.

As stated in the 1. Background, up to 60 different shop orders can be in production simultaneously on the factory shop floor. One order can exist out of 1 tower or be for a batch of up to 60 towers per order. (Pazzi, 2001)

Towers are manufactured from various profiles of angle iron and plate sections.

Angle iron sections:

Standard angle iron steel sections ranging from A 45 x 45 x 3 up to A 200 x 200 x 20 are used for manufacturing towers. Holes are punched and/or drilled in the material. Most holes are punched into the material, but must be drilled when:

- Contractually required to do so for specified diameters
- Hole diameter are smaller than material thickness, this is an accepted rule in the industry as punches break when used in this situation. The forces required to punch through the steel are more than the punch can handle, as the punch diameter is smaller than the material thickness.

Towers are manufactured in economical and logical batch sizes. Towers are manufactured to order and cannot be produced to stock in a warehouse or yard. This is due to the fact that towers are designed for specific operating conditions, depending on the voltage requirements, wind speeds and physical location of each tower.

One tower consists out of thousands of items that will be bolted together on site. All holes must be punched/drilled accurately (a tolerance of ± 1mm is acceptable) in order for all the items to fit together on site. The factory manufactures all the items individually, bundle them in logical bundles and
dispatch them to site. The items are not assembled in the factory prior to despatch, but will be for the first time, on the construction site.

From the factory layout the following flow diagram for the manufacture of towers in the factory was drawn, see annexe 6 attached.

Material is requested from the raw material stores by means of a material requisition. 100% of material must be processed through an entry machine. An entry machine is defined as the machine that perform the first operations on the item, i.e. transfer a raw material (steel bar) into a piece cut to size, numbered and punched. Entry machines in steel carpentry are:

<table>
<thead>
<tr>
<th>MACHINE</th>
<th>MACHINE CAPABILITY (Material profile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT 200</td>
<td>A 80 x 80 x 6 up to A 200 x 200 x 18</td>
</tr>
<tr>
<td>PT 150</td>
<td>A 60 x 60 x 4 up to A 150 x 150 x 8</td>
</tr>
<tr>
<td>PTM 150</td>
<td>A 60 x 60 x 4 up to A 150 x 150 x 8</td>
</tr>
<tr>
<td>PTM120</td>
<td>A 45 x 45 x 3 up to A 120 x 120 x 8</td>
</tr>
</tbody>
</table>

The PT 200 and PT 150 can only perform the following operations:

- **Marking** (numbering of each item)
- **Punching holes**
- **Cutting**

The 2 PTM's (PTM 150 and PTM 120) can perform the functions as above and also do inline notching of material. This function is a benefit as it reduces the amount of material that have to be handled offline for manual chamfering.
The table below indicates the average amount of material (mix) to be processed at each operation, based on an average of 1500 tons production for the month.

<table>
<thead>
<tr>
<th>AREA</th>
<th>OPERATION</th>
<th>TONS</th>
<th>%</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENTRY</td>
<td>PT 200</td>
<td>270</td>
<td>26%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PT 150</td>
<td>390</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PTM 120</td>
<td>330</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PTM 150</td>
<td>360</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PLATES</td>
<td>150</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>1500</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>OFF LINE</td>
<td>CHAMFER</td>
<td>360</td>
<td>24%</td>
<td>40% PTM 120 &amp; PTM 150 (144t)</td>
</tr>
<tr>
<td></td>
<td>BEND</td>
<td>135</td>
<td>9%</td>
<td>60% MANUALLY (216t)</td>
</tr>
<tr>
<td></td>
<td>HLS AFTER</td>
<td>30</td>
<td>2%</td>
<td>OF BENDED MATERIAL</td>
</tr>
<tr>
<td></td>
<td>MILLING</td>
<td>60</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPECIAL</td>
<td>45</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>630</td>
<td>41%</td>
<td></td>
</tr>
</tbody>
</table>

58% of the material produced, from the entry machines, do not need any offline operations and are sent to the galvanising department. The balance of the material (42%) must go through one or more of the offline operations.

Off line operations are secondary operations that cannot be done on the entry machines. These operations include chamfering (notching of material), bending, holes punched after bending and special operations. Special operations are defined as non-standard operations in the manufacturing of towers for example slotted holes, welding and profile cutting.

Each item on the shop floor is identifiable by means of a job card, indicating the shop order no, material profile, quality of material, amount of items required and operations required on the items.

Plate sections:
Standard plate profiles range in thickness from 3mm to 45mm. Occasionally thicker plates are required, but it is viewed as special requirements and is treated as such. Holes are punched or drilled into the plates after they are cut to size and numbered. The equipment installed in the factory can punch plates up to 12mm thick. Plate sections of 14mm and above are drilled on the CNC drilling machine. (Note that 13mm plate thickness is a non-standard profile.)

Annexe 7 is a flow diagram for the plate manufacturing section in the steel carpentry workshop.
Change in production requirements:
Annexe 3 attached indicates the production volumes per month for the previous 6 years.

From the graphs it is clear that the production volumes dropped significantly from 1996 to 1999. (From 17500 tons per year to 6500 tons per year) During 2000 a significant increase in volumes were experienced. It is also noticeable that the monthly volume requirements during 1996 to 1998 were relatively constant month to month. During 1999 and 2000 significant peaks and valleys are noticeable month on month.

The present production manager and the production planner (previous production manager in the steel carpentry department) indicated that the peaks and valleys are mostly due to the fact that the expected work doesn't materialise in time as planned. Reasons for the delays include:

- Shift in main customers from local to international customers. Timing of receiving expected orders is more difficult as most projects were started significantly later than planned. This is mainly due to the delays occurring in securing international work, down payments, clarification of technical queries etc. as the distance and language barriers needs to be bridged.

- Production of local projects can be planned according to erection requirements of the construction sites. Erection requirements are normally a constant supply of an agreed number of towers to the site. Normally a weekly supply of towers to the site is agreed to. The factory can then schedule production accordingly and it resulted in an even supply of material to site. For example the site would require on average 200 tons of tower steelwork per week to erect. Production for export projects requires that bigger amounts of material are produced and dispatched at once in order to meet with to shipping requirements (schedules). For export projects one shipment must be able to sustain the erection teams for at least on month at a time. One dispatch can be in access of 1000 tons at a time.

- Export projects tend to utilise special grade material and also special profiles. This material is non-standard in South Africa. This requires ABB Powerlines to place special orders on Iscor. Iscor has the monopoly of rolling and supplying steel in South Africa and ABB Powerlines are dependent on roll dates from Iscor. Although the amount of steel ordered from Iscor is "big" in terms of ABB Powerlines capacity, it is rather small in terms of Iscor capacity. This tends to be seen as a low priority from Iscor, resulting in unscheduled delays in availability of material.
Lack of shop floor leadership and co-ordination:
The observation period on the shop floor indicated that a leadership figure on the shop floor is lacking.

The following sequence of events occurred on a daily basis: The production manager identified the priority items for the supervisors. These items will be produced on the entry machines and then not followed through until complete. The operators at the offline operations work on the next batch of material without consulting a supervisor, thus ignoring the priorities.

During the past, the foreman went around each workstation and identified the priorities for the operators. The foreman co-ordinated and expedited the flow of material between the various workstations based on his experience and knowledge of the product. Based on this knowledge, the foreman identified potentially difficult items and ensured that all the offline operations are completed prior to sending them to galvanising or the dispatch yard.

Currently this function / responsibility is lacking because:

- The foreman position is vacant
- The current supervisors are not accepting the responsibility/duties previously carried by the foreman
- The current supervisors don't have the required experience and knowledge to perform this function as cases are recorded where items were send through galvanising without all the required operations being performed. These items were released for galvanising by the supervisors. (see the section on “Quality control throughout the process”)

The position for the foreman is vacant for the past 7 months. A Mr. M Belotti was the previously the foreman and retired during 1999. Mr. S Kekana were appointed as foreman to supersede Mr. Belotti. During his probation period Mr. Kekana requested the Powerlines management to be relieved of his responsibilities of foreman as the pressures and responsibilities of the position were too much for him and that he is battling to cope. Management acknowledged his request and he was re-appointed as supervisor in the plate section by the end of 2000.

Since Mr Kekana's reappointment as supervisor, the position of foreman is vacant due to the fact that all appointments were frozen as present production volumes were low and future volumes were uncertain. A new foreman could not be appointed until further notice/approval.
The operators at the various stages were totally reliant on the foreman or supervisor to come and solve their problems for them. For example, an operator will stop a machine, wait for the foreman, production manager or a supervisor to decide whether the cutting blades should be changed or not.

Prioritising of work was also the responsibility of the foreman. The operators would start with the items that are the easiest to work with, continue to do so and ignore the set priorities completely. This would result in a backlog of more difficult items to process as all the “easier” items are completed.

From the above mentioned it is clear that the shop floor lack overall co-ordination and leadership. During the “participant observation” it was noted that some operators are ignorant regarding the work they are doing. Operators would for example carry on punching material with blunt punches. The supervisor, foreman or production manager will have to instruct the operators to change the punches. In some extreme instances, the operators didn’t realise that the punches were broken, resulting in batches of material to be reworked. It must also be noted that the levels of education are low on all workers except the CNC operators. A CNC operator is expected to have a minimum education level of Grade 12 (Matric)

Lack of responsibility and communication (every one feel that someone else is responsible to address the situation): The supervisors had different ideas as the production manager as to their responsibility in the workshop. The production manager expected the supervisors to assist in the off line operations and guide material through the offline operations. The supervisors spent the absolute minimum amount of time with offline operations. It was noted that the supervisors spent most of their time at the CNC machines (entry machines). A supervisor only visited the offline stations when an operator would call the supervisor, when the operator has some problem. The operator expected the supervisor to take the decision, but in most cases the decision were referred to the production manager.

During the non-scheduled interviews on the shop floor it was clear that the supervisors didn’t accept or comprehend the responsibility delegated to them.

The plate section is seen separate from the angle iron section in the factory. Mr. S Kekana (plate section supervisor) had his operation reasonably under control compared to the balance of the steel carpentry workshop. The production manager had to assist in identifying priorities and follow up regularly.

More serious problems were experienced on the angle iron side. The two supervisors (working alternating shifts) did not communicate between shifts with each other. There was no shift hand over time (overlapping period) or report in place. Secondly the two supervisors both indicated that according to them they are only responsible for the CNC machines. As mentioned previously, the
supervisors avoided the offline operations as far as possible. The CNC machines would produce material according to the agreed priorities, but the offline operations worked on material at random, normally starting with the "easiest" items, thus leaving the "difficult" items to pile up.

This caused unnecessary work in progress in steel carpentry as well as difficulty in keeping up with delivery dates. The cost effective manufacturing process of towers require a balancing act between "easy" items and "difficult" items. If the balancing between the two is correct, acceptable production levels can be maintained throughout the month. Should one do only the "easy" items, one will achieve good production levels, but dwindle all away when more time is required for the difficult items. This practice also causes situations for "rush jobs" in attempts to keep up with planned deliveries.

During the past the foreman instructed the offline operators on what items to work on and assisted with the difficult pieces.

Overall co-ordination of the manufacturing process are lacking as the supervisors only focus on their own sections.

**Lack of shop floor experience and knowledge:**

The operators at the various machines had very limited knowledge of the application of the product that they produce. During the past the supervisors and foreman were well experienced in the erection of towers, thus knowing the exact requirements of the items that they manufacture. Over years did these individuals work for experienced superiors who trained them "on the job". Experience was gained through many years of "on the job training".

During the recent past few years (1998), the management of ABB Powerlines was forced to execute a retrenchment program due to the fact that extremely low production volumes were realised, and that future plans didn't indicate a significant increase in the near future. Most of the "older" employees accepted voluntary retrenchment packages. These "older" employees were also more experienced. This also implied that most of the skills left the organisation with these employees. (Beltzig, 1998). See retrenchment report attached - annexe 4.

The powerlines manufacturing business is unique in South Africa (and the world) and there are not many experienced people available who understand the details of the business and the manufacturing techniques. Most of the skills are acquired over many years of in service training.
These individuals took informed decisions on shop floor level regarding the quality and acceptability of product that they produce. These individuals supervised and instructed the operators to ensure that only acceptable product is produced. During the retrenchment exercise most of these individuals accepted retrenchment packages. The two organisational charts attached in annexe 8 and annexe 9, show the structure of shop floor supervision up to 1998, and after the retrenchment.

Low morale of workforce:
During the time spent on the factory shop floor, the researcher observed that there is a strong feeling of mistrust from the workers in the management of the organisation. The workforce is strongly unionised and there are current disputes and conflict between the management and the union. This situation contributes to the workers doing the only absolute minimum that is required and extremely low levels of morale.

Symptoms contributing to low morale identified on the factory shop floor include:

- One of the current Supervisors is also a active union representative for the workforce. Although this is a individual's legal right, by definition a conflict of interest arise as the responsibilities of a Supervisor is also to discipline and supervise the workforce. The same individual can not initiate disciplinary actions and defend a worker at the same time.
- Negative attitude of workers toward organisational actions, for example the refusal of certain supervisors and operators to train new recruited employees as operators on CNC machines.
- Current "unofficial" ban on overtime imposed by the union.
- Workers don't trust management and seek approval of the union before engaging in any commitments, for example, workers request to consult with the union representatives before signing any safety training documents.
- Recent strike and marches organised by union representatives in the steel carpentry workshop.

During this research project, no scientific analysis was done to determine the level of morale, nor was any official morale measuring studies conducted. The comments regarding morale is based on observations made during the time spent on the factory shop floor.
Quality control throughout the process:
Presently a quality management system is implemented at the factory and is based on ISO 9001 system requirements. Although current accreditation with the SABS exists, serious quality problems are experienced as mentioned in the problem statement. Responsibility for quality of product manufactured is delegated to the operators and quality inspectors on the shop floor as per present documented procedures and work instructions.

This project forms part of the quality investigation into the problem, and this document are compiled in co-operation with the quality department.

According to the quality procedures and works-instructions the following process must be followed.

The store man is responsible to check and issue the material, as stated on the material requisition, in terms of

- Grade of material (copies of material certificates are stored in the quality department)
- Dimensional check
- Visual inspection on general appearance of material.

The following responsibilities are described for the shop floor:

- Dimensional check on material received (sampling)
- After production of the first item the supervisor must be notified to check and release the item for production.
- Once the batch is complete on the specific operation, the supervisor must perform a full dimensional check and sign the job card to document the approval of the items. A quality inspector is also allowed to sign items off.
- After all the offline operations are also completed, a supervisor or the quality inspector must sign off the batch prior to galvanising.

The supervisors agreed to the above-mentioned procedure, but on inspection of job cards submitted to the production office it was clear that the system is not fully functioning. Job cards were found without any signature on them, thus the items were not inspected prior to galvanising and despatch. Items returned from site (incorrect) were tracked backwards to the operator and supervisor who manufactured it. The job cards were signed off although the item is incorrect, indicating that the items were either never inspected or the supervisor is incapable to release items after production.
Increase in NCR's, and customer complaints:
The average amount of NCR's raised per year increased from approximately 80 to approximately 150 over the period from 1996 to 2000. A NCR is raised for every customer complaint received as well to ensure that corrective action is taken.

The NCR's raised mainly by the supervisors, quality personnel and the production manager. The cost associated with each NCR is calculated by the production manager and comprises off:

- Standard administration cost of R50.00 per NCR.
- Investigation cost including the hourly rate of the investigator(s) x hours spent investigating the incident, travel and accommodation cost (if applicable).
- Production cost including rework hours, rework material and loss of profit due to time spent on rework.
- Transport cost of material to and back from the construction site (if applicable)

An analysis of the NCR's raised are summarised as follows:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Human error</td>
<td>19</td>
<td>23</td>
<td>20</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>Tape error</td>
<td>24</td>
<td>31</td>
<td>21</td>
<td>29</td>
<td>39</td>
</tr>
<tr>
<td>Machine error</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Incorrect quantity</td>
<td>7</td>
<td>5</td>
<td>0</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Drawing incorrect</td>
<td>17</td>
<td>24</td>
<td>28</td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td>Operator negligence</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Not checked/released</td>
<td>10</td>
<td>12</td>
<td>19</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>TOTAL</td>
<td>79</td>
<td>100</td>
<td>91</td>
<td>137</td>
<td>151</td>
</tr>
</tbody>
</table>

The categories are defined as follows:

- Human error
  The relevant individuals on the shop floor who had worked on the mentioned items failed to produce the item according to specification (made an honest mistake)
- Tape error
  Data input error by the person entering the information into the computer system for the CNC machines to be able to produce the item
- Machine error
  The CNC machine produces the item incorrectly, mainly due to wear of a mechanical part, or due to failure of an electronic part.
- Incorrect quantity
  Operator/human error in producing the required amount of items
  Normally items are short produced for example, 107 is required but
  only 102 are delivered/produced
- Operator negligence
  Operator produces an incorrect item as a result of negligence, for
  example the first off inspection on the item are omitted and the
  operator proceeds to produce the complete batch quantity and it is
  found that the item is incorrect.
- Drawing incorrect
  Items are produced according to the drawing, but the drawing is
  incorrect resulting in items not to fit.
- Not checked / released
  A supervisor or a quality inspector did not check items prior to
  galvanising as per the quality procedure.

The following table indicates generalised positions responsible for the type of
error recorded on the NCR.

<table>
<thead>
<tr>
<th>TYPE OF ERROR</th>
<th>OPERATORS</th>
<th>FOREMAN / MANAGER</th>
<th>PROD. ENGINEER</th>
<th>QA INSPECTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUMAN ERROR</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAPE ERROR</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MACHINE ERROR</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INCORRECT QTY</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRG ERROR</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>OPERATOR NEGLIGENCE</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOT CHECKED</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

From the attached summary of customer complaints annexe 1 it is clear that the
amount of customer complaints received are on the increase taken the period
from 1996 to 2000.
The complaints were summarised and categorised as follows:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material not to drawing</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Drawing error</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Poor quality (physical appearance)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Material shortages</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>4</strong></td>
<td><strong>5</strong></td>
<td><strong>8</strong></td>
<td><strong>14</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

See graphical presentation attached – annex 10

The categories can be defined as follows:

- **Material not to drawing** - one or more of the physical dimensions of the items produced do not correspond with the drawing requirements.
- **Drawing error** – Items produced are according to drawing, but the drawing is not correct. Although the end product produced is incorrect, the cause of these complaints can be traced back to the drawing office.
- **Poor quality (physical appearance)** – Physical dimensions of the Items produced conform to drawing requirements, but the items are of a poor physical quality. For example excessive burrs on material or galvanising not cleaned properly.
- **Material shortages** – The construction site claim that items are missing inside the bundles, therefore they cannot complete the erection towers. This complaints are the responsibility of the dispatch yard as the produced items are packed in the yard and therefore counted prior to dispatch. It is expected of the yard to inform the production manager when material shortages are experienced during the packing stages.
- **Other** – Any other complaints received from customers, for example late delivery or delivery to the wrong construction camp.

From the table above the amount of “material not to drawing” increased from 1 up to 8 per year. Investigation and analysing these complaints indicated that:

- 62% of the complaints were items manufactured incorrectly
- 34% of the complaints were items not completed
- 4% of the complaints – insufficient data recorded
The reasons for the errors are defined as follows:

Items manufactured incorrectly are for example:
- Incorrect diameter holes used
- Holes don’t align
- Dimensions of item incorrect
- Bend the wrong way
- Bend incorrect degrees

Items not completed are when offline operations are omitted on the items, for example:
- Chamfering not done
- Bending not done
- Holes after bending not done
- Milling not done

10. FINDINGS

From the data analysis the following items were identified for contributing to the supply of poor quality of product.

Responsibility
The foreman’s responsibility is currently vacant and no one on the shop floor accepted this responsibility. The previous foreman used to control the flow of product through the factory, with major concentration on offline operations. Through his experience, the foreman could identify potentially difficult pieces and ensured that only completed items are sent out of the workshop. This function is delegated to the supervisors by the production manager, but they didn’t accept the responsibility and the researcher is also of the opinion that they lack the knowledge to do so.

During the past responsibility on the shop floor was delegated to a number of supervisors who can then focus (concentrate) their attention to a relatively small production area. This level was eliminated during the restructuring and the amount of work expected from the supervisors in the present structure allows for errors to go through unseen.

The discipline of adhering to set procedures and work instructions can be improved on as numerous NCR’s indicated that standard procedures were not followed. A possible reason for this can be that the supervisors are not able to look at the complete workshop, thus neglecting certain expectations. This problem is also aggravated by the fact that the level of morale is low on the shop floor and even the supervisors are negative regarding the organisation.
Knowledge
Loss of knowledge regarding to product manufactured is adding to the fact that incorrect items are being supplied. During the past the foreman and his various supervisors (plate, angle iron and ending) had the experience of erecting towers and could instruct operators on how to their tasks correctly. All these individuals left the organisation during the retrenchment exercises resulting in the operators doing work at random and not knowing what to look for in order to produce correct material. (Not knowing the obvious pitfalls)

Human resource issues
The workforce is not motivated and the morale on the shop floor is low. According to the workers a lot of their complaints must still be resolved. Unresolved issues include hours of work, rate of pay and training of newly recruited employees. There are feelings of distrust between the management and union representatives. The supervisor that is also a union representative are focusing on union matters and neglecting the production responsibilities are contributing to the problem rather than assisting in finding solutions.

Market situation
An extremely fluctuating market and increased customer demands are forcing the suppliers of towers to supply the material in shorter times. Export logistics are contributing to put more pressure on the organisation, as the factory will be overloaded for one or two months just to be under-utilised for the following two months.

All the above-mentioned factors are contributing to the current factory to supply an unacceptably high amount of poor quality product to its customers.

11. DISCUSSION OF RESULTS

The following differences were identified in comparing the past scenario with the present one.

The fact that the manufacturing of towers is a complex operation remains unchanged. It was a difficult process before the volume declined and the restructuring took place, and it still remains so today. During the investigation no major differences were identified that could contribute to the decline in quality of product supplied. The fact that the process is complex could be argued as a contributing factor, but it is not the view of the researcher as acceptable product were delivered from the same processes in the past.

The past production requirements were noted to have changed in comparison with the present regarding continuity of work. The historical picture revealed that a constant volume of work was produced month on month.
During 1999 to 2001 major peaks and valleys can be observed in the production volume graph, indicating that the factory produced for a period and were idle for the next period. This "start - stop, start - stop" manufacturing cycle bring about pressure on the shop floor that don’t exist with a constant workload.

All the problems noted regarding lack of leadership, co-ordination, responsibility, communication, experience and knowledge can be contributed to the restructuring exercise. This was the single most evident item that changed in comparing the past with the present situation. In comparing the organisational charts of the past vs. present, one can see that the level of supervision has been reduced. To contribute to this fact is the lack of knowledge of the supervisors, the vacant foreman position and the negative attitude of the supervisors and the workforce.

The powerlines factory use to be managed and controlled on the shop floor level by a team of well-experienced and knowledgeable individuals. These individuals knew how to identify potentially difficult items and controlling and monitoring these difficult items, ensured that acceptable quality levels were maintained in supplying to its customers. This team of experts existed out of:

- Foreman
- Plate supervisor
- Angle iron supervisor (assisted by 2 shift supervisors)
- Bending supervisor

The shift supervisors were trained internally and had no experience in erecting towers. Most of this team of key individuals left the organisation and took their knowledge with them. The shift supervisors were promoted to manage the shop floor, but due to a lack of product and process knowledge, are unsuccessful. During 1998 and 1999 the Powerlines factory managed to produce reasonable quality product because the required volumes were low compared to maximum capacity of the factory. The lower volumes indicate that there were less items on the shop floor, thus more controllable and easier to identify priorities and items that are incorrect.

During 2000 and 2001 the production volumes increased to 1500 tons per month, but the structure of the shop floor weren't increased accordingly to support the required volumes.
12. CONCLUSION

From the previous discussions it is clear that the ABB Powerlines factory lost key personnel (knowledge) during a period of low volumes, but never filled these positions when the volumes increased. There was also no follow up or back up training for these individuals when they left. Currently the factory staff is capable to produce the required work, but lack the overall shop floor management and supervision.

13. RECOMMENDATION

The change in manufacturing requirements is assumed to be a result of a change in the market place, presumably due to the shift from local projects to export projects. It is not within the scope of this project to analyse the market situation and to identify solutions to ensure a constant flow of work for the factory. It is noted that a constant supply of work to the factory will contribute to less "production disruptions & priority changes" and consequent inaccuracies in product supplied.

As the most obvious change in production procedures is the restructured shop floor supervision and the fact the flaws with the present structure can be identified, it is recommended that the supervision levels on the shop floor be reinstated to the original structure. The original structure has proven to be successful in the past and allows for individuals to concentrate on a small area of responsibility. The responsibilities for the supervision levels should be clearly defined and documented.

As most of the skills were lost during the restructuring, it is recommended that the foreman be employed as a consultant on a contractual basis to assist and train the supervisors in their responsibilities.

With the proposed supervision structure it can be expected of all relevant individuals to adhere to the existing procedures and work instructions as described in the quality manual.
14. BIBLIOGRAPHY

ANNEX 1
CUSTOMER COMPLAINT REPORT
CUSTOMER COMPLAINTS 1997 TO 2001

NUMBER OF COMPLAINTS

YEAR

ANNEX 2
RESEARCH DESIGN MODEL
RESEARCH DESIGN MODEL

PRESENT AND HISTORICAL FACTORS ARE IDENTIFIED IN TERMS OF THE FOLLOWING:

CONDITIONS:
- Workload
- Supervision

ORIENTATIONS:
- Workers beliefs in themselves
- Workers beliefs in the future
- Level of morale

PRESENT FACTORS:
Existing conditions and production environment (poor quality product supply)

HISTORICAL FACTORS:
Historical conditions and environments during the past production periods when towers were supplied successfully (acceptable quality product supplied)

IDENTIFIED DIFFERENCES:
Identify factors (conditions and environments) that have changed - this will identify possible causes for the decline in quality of product supplied

UNDERSTAND IMPACT OF FACTORS ON QUALITY

IDENTIFY AND PROPOSE CORRECTIVE ACTIONS TO MANAGEMENT
ANNEX3
PRODUCTION VOLUMES PER MONTH
### Production Volumes 1996 to 2001

#### ABB T&D

**Powerlines Division**

<table>
<thead>
<tr>
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<td>465</td>
<td>312</td>
<td>213</td>
<td>389</td>
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<td>996</td>
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<td>446</td>
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<td>503</td>
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<td>353</td>
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<td>513</td>
<td>446</td>
<td>263</td>
<td>162</td>
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**Total** 17444 16213 11297 6538 7186 12949

![Production Volumes Graph](image-url)
ANNEX 4
EMPLOYEE RETRENCHMENT LIST
## ABB Transmission and Distribution
### Powerlines division

**Retrenchment 1998 - Towers and Galvanising**

<table>
<thead>
<tr>
<th>Company number</th>
<th>Surname</th>
<th>Initials</th>
<th>Position held</th>
<th>Years service</th>
</tr>
</thead>
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<tr>
<td>086</td>
<td>Nuchibella</td>
<td>E</td>
<td>CNC supervisor</td>
<td>5</td>
</tr>
<tr>
<td>589</td>
<td>Tunini</td>
<td>P.M</td>
<td>Plate section supervisor</td>
<td>25</td>
</tr>
<tr>
<td>911</td>
<td>Ts'mang</td>
<td>T.P</td>
<td>Operator</td>
<td>2</td>
</tr>
<tr>
<td>678</td>
<td>Monamodi</td>
<td>R.J</td>
<td>Operator</td>
<td>6</td>
</tr>
<tr>
<td>631</td>
<td>Zungu</td>
<td>L</td>
<td>CNC operator - angle punching</td>
<td>10</td>
</tr>
<tr>
<td>008</td>
<td>Meinardi</td>
<td>M</td>
<td>Bending section supervisor</td>
<td>31</td>
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<tr>
<td>588</td>
<td>Belotti</td>
<td>M.L</td>
<td>Foreman - Towers</td>
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<tr>
<td>385</td>
<td>Tshongo</td>
<td>E</td>
<td>CNC operator - angle punching</td>
<td>20</td>
</tr>
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<td>374</td>
<td>Travella</td>
<td>D</td>
<td>Supervisor Galvanising</td>
<td>27</td>
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<tr>
<td>813</td>
<td>Pavan</td>
<td>C</td>
<td>Maintenance foreman</td>
<td>18</td>
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<tr>
<td>088</td>
<td>Simelane</td>
<td>S</td>
<td>Bending press operator</td>
<td>23</td>
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<tr>
<td>314</td>
<td>Vusi</td>
<td>J</td>
<td>Supervisor - Low tech shop</td>
<td>16</td>
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<tr>
<td>108</td>
<td>Janse van Rensburg</td>
<td>P.M</td>
<td>CNC operator - angle punching</td>
<td>8</td>
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<tr>
<td>634</td>
<td>Nkosi</td>
<td>P</td>
<td>CNC operator - angle punching</td>
<td>2</td>
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<tr>
<td>518</td>
<td>Mashimiate</td>
<td>L</td>
<td>Production office clerk</td>
<td>14</td>
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ANNEX 5
STEEL CARPENTRY WORKSHOP LAYOUT
ANNEX 6
FLOW DIAGRAM TOWERS MANUFACTURING
(Angle iron sections)
ANNEX 7
FLOW DIAGRAM TOWERS MANUFACTURING
(Plate sections)
TOWERS PRODUCTION FLOW CHART (PLATE SECTIONS)

- CNC DRILL
  - Thickness >12mm
  - Thickness <12mm
    - MARKING
      - Guilotine
        - Raw Material Store
    - PROFILE CUTTING
      - GUILLOTINE
        - RAW MATERIAL STORE
  - CHAMF REQ'D
    - YES
      - CNI (punch)
        - CHAMFERING
          - GALVANISING
            - PACKING
              - DESPATCH
    - NO
ANNEX 8
SHOPFLOOR STRUCTURE (before restructuring)
ORGANISATIONAL CHART - EFFECTIVE UNTIL 1998

Foreman

CNC supervisor
- Shift supervisor
  - Operators
- Shift supervisor
  - Operators

Plate supervisor
- Operators

Bending supervisor
- Operators

Chamfering operators
- Milling operator
- Special operations operators
ANNEX 9
SHOPFLOOR STRUCTURE (after restructuring)
ANNEX 10
CUSTOMER COMPLAINTS (Categorised)