INVESTIGATING THE BENEFITS OF USING SELECTED LEAN TECHNIQUES AT A SOUTH AFRICAN EXHAUST MANUFACTURER - A CASE STUDY

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ABSTRACT
This study investigates the implementation of supermarket-based scheduling of parts at a South African exhaust manufacturing plant.
The study investigates the manufacturer who competes for a valuable contract. The nature of the contract is such that it warrants building a new facility. The design of the facility and the manufacturing processes is of importance as some Lean techniques are employed during these early stages.
The research takes the form of a case study and data are collected mainly through interviews with staff, but also from direct observations on the shop-floor.

Interviews were conducted with:

- key project leaders responsible for the design and commissioning of the facility;
- production managers and technical staff currently operating the plant; and
- shop-floor personnel involved in daily production and logistics operations.

The as-built facility and procedures are compared with the literature found on the topic of Lean manufacturing. Various findings are recorded, both on conforming to and not conforming to typical Lean theory.

Potential changes are suggested in the following areas:

- an appropriate Pull strategy is proposed;
- the use of a pacemaker is suggested to support production levelling;
- potential improvements to quality are still possible by introducing an ‘at source’ approach to reduce reworking.
1 INTRODUCTION

The Japanese Lean Manufacturing guru, Taiichi Ohno [1], explains how the Toyota production management team discovered a new application for the concept of a supermarket. In a supermarket the customer dictates the needs, based on personal situation and budget. The customer then draws this only and the shop-manager restocks the shelf. This method of shopping was foreign to the Japanese, yet Ohno recognised the supermarket as a low inventory strategy with cost-saving opportunities.

In contrast to the supermarket strategy, the MRPII strategy follows a more rigid approach with more rules and procedures. According to Stevenson [2], MRPII is dependent on certain data to be successful; these data include firm orders or good forecast information, accurate product structure data and up-to-date inventory data.

Ohno’s supermarket system signified the birth of the Pull system. Pull systems result in (almost) zero WIP (Gross & McInnes [3]), as every work-centre only produces what has been consumed. In a Pull system, work-centres only respond to signals received indicating what to produce and how many to produce (Vollman, Berry, Whybark [4]).

For many production managers the challenge lies in the transition from traditional to Lean manufacturing. Smalley [5] suggests a procedure to allow manufacturers make the transition from MRPII to a Pull strategy. He classifies all products within a given process into Runners (making up 60% of volume), Repeaters (20%) and Strangers (20%) for the purpose of production scheduling. He then suggests a choice of four different Pull strategies built around these classifications.

Similar thinking was implemented, intuitively, by a catalytic converter manufacturer in Rosslyn, outside Pretoria, South Africa, in 2005. The manufacturer was committed to supplying its customer with the correct parts and quantities in the sequence they needed them in. In addition to this, they also had to comply with specific quality and production requirements, such as minimum inventory levels, delivery frequency and presentation methods.

2 OBJECTIVES

2.1 Main Objective

The main objective was to determine if there are any benefits in the application of selected Lean manufacturing techniques to ensure effective scheduling results at a Rosslyn-based exhaust manufacturer.

2.2 Sub-Objectives of the study

- To investigate how this project was initiated and implemented at the Rosslyn factory.
- To establish how successful the implementation was, in terms of meeting the demands of the customer.
- To identify which barriers and obstacles were encountered and had to be overcome.
- To establish what was learnt as a result of implementing a supermarket approach.
- To find what recommendations can be proposed.

3 PRESENTATION OF RESEARCH RESULTS

3.1 Introduction and Company Background

ABC Manufacturing is an international organisation with several facilities in South Africa. Its manufacturing headquarters are located in Port Elizabeth. The Rosslyn facility is the most recent addition to their network of manufacturing facilities in South Africa. The plant is located in close proximity to their customer, allowing regular small deliveries.
Similar scenarios can be found in Brazil. Pires and Neto [6] write about a ‘condominium’ approach to supply chain management. Examples include Tier 1 suppliers situated inside the customer plant and Tier 1 and Tier 2 suppliers located close to the customer. Although the production strategies described by Pires and Neto differ from that of ABC Manufacturing, several supply similarities were found, such as:

- the use of EDI communications;
- regular, small quantity deliveries (milkruns);
- sequential parts delivery; and
- frequent face-to-face contact between professionals from both supplier and customer.

The Rosslyn facility was designed to supply a single customer. Although the single customer plant is not a completely unique situation in the industry, it is unusual. Several Tier 1 suppliers in the industry apply a Kanban approach to supplying their customers in a Just-In-Time manner. However, many of these supply more than one and even many different OEM (Original Equipment Manufacturer) customers, as well as aftermarket customers.

ABC Manufacturing based its strategy on the supermarket approach. This would allow it to supply a single customer in a Just-In-Time manner, while still maintaining a batch manufacturing approach. This is significant as the manufacturer had to design an operation that would be profitable, flexible and robust.

Lean literature (Gross & McInnes [3]) would argue that batch manufacturing is required due to long set-up times and that these setup times need to be reduced at all costs. Even if this argument is valid, the supplier had managed to apply batch manufacturing to their benefit. While cost and operational improvements could still be realised through set-up time reduction (SMED), it is doubtful whether the supplier would stop its batch manufacturing.

### 3.2 Customer Requirements

ABC Manufacturing had to abide by certain obligations set out by the customer:

- Keep at least 3 days’ finished goods stock at all times to ensure continuity of supply to the customer.
- Maintain batch integrity by supplying according to engineering changes.
- Supply 10-15 units per hour in sequence based on a schedule supplied no more than 4 hours in advance.

### 3.3 Operational Objectives

The customer requirements stated above were translated into operational objectives to support the manufacturing strategy of ABC Manufacturing. The objectives were interpreted as follows:

1. The supplier had to hold no less than 3 days’ worth of finished goods stock or roughly 750 units on the premises. This was crucial to supply continuity in case of breakdowns and absenteeism. This had facility and inventory cost implications for ABC Manufacturing.
2. A low inventory strategy meant that upstream production had to be aligned with this aspect. It also meant that stock keeping had to be proportional to average demand.
3. Batch integrity is crucial at all times due to ongoing engineering changes and improvements. Clear identification of part numbers and change levels on every part was essential. As a result strict FIFO storage and withdrawal rules were to be implemented and maintained.
4. Parts had to be delivered hourly, in small quantities. This necessitated locating the plant within a 30-minute radius of the customer.
5. Parts had to be delivered directly to the customer’s assembly line and thus needed to conform to all quality standards imposed. Several quality checks had to be installed and all checks had to be relentless.
6. Parts call-off information would be sent from the customer four hours prior to the required delivery. As a result, stillages needed to be packed and sequenced according to this information. Parts have to be drawn from finished goods stock. This meant that all possible variants have to be available at all times.

The above requirements were further subjected to additional production complexities resulting from the product range, production mix and resource capacities. These aspects had to be taken into account in the design of the facility.

Some of the specific complexities were as follows:

1. The supplier, ABC Manufacturing, had to utilise a batch manufacturing strategy. This was due to the limitations of the production equipment. The equipment was constrained in several ways:
   a. in keeping with the low inventory strategy, batch sizes were limited;
   b. this further necessitated frequent change-overs of production equipment;
   c. it requires a change-over time of 30-60 minutes between batches;
   d. batch production necessitated accurate forecasting of average demand; and
   e. part demand and cycle times for various parts varied considerably (see Table 1).

<table>
<thead>
<tr>
<th>Product Variant</th>
<th>Percentage</th>
<th>Cycle Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Cyl, Petrol</td>
<td>30.71%</td>
<td>4.7min</td>
</tr>
<tr>
<td>6 Cyl, Petrol</td>
<td>37.39%</td>
<td>5.5</td>
</tr>
<tr>
<td>6 Cyl, Petrol (A)</td>
<td>18.46%</td>
<td>11</td>
</tr>
<tr>
<td>6 Cyl, Petrol (B)</td>
<td>7.56%</td>
<td>5.5</td>
</tr>
<tr>
<td>4 Cyl, Diesel</td>
<td>5.49%</td>
<td>5.1</td>
</tr>
<tr>
<td>6 Cyl, Diesel</td>
<td>0.39%</td>
<td>5.9</td>
</tr>
<tr>
<td><strong>100%</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 1: Part Demand and Cycle Times*

2. The low inventory strategy supported the batch integrity requirement, as this limited the likelihood of rejecting out-dated stock and the time-consuming process of ‘flushing’ of unusable parts from inventory.

3. In-sequence delivery placed the following demands on the operation:
   a. parts of all variants had to be kept on hand;
   b. inspection and sequencing of parts prior to shipping; and
   c. provision for delivery delays and problems, such as traffic and breakdowns.

4. The supplier had to install multiple resources to contend with the OEM’s faster line-speed: OEM was running at four minutes per unit compared with the manufacturing cycle times of 4.7min and more (see Table 1).

5. The supplier operated on two 9-hour shifts, while the customer used two 8-hour shifts.
3.4 Facility Design

3.4.1 Project Initiative

The project coincided with the OEM upgrading its facility to launch a new range of vehicles. The OEM had selected ABC Manufacturing mainly on the basis of price and was willing to let ABC supply the entire exhaust system, where previously the systems were supplied by two separate suppliers as sectioned units.

The project involved finding a site within a 30-minute radius of the OEM, raising the required buildings, equipping the facility and producing the systems within 12 months.

Similar facilities have been designed and built by the parent company in Europe to supply the same OEM. The basic principle was thus not new but several unique elements differentiated this plant.

3.4.2 Design & Construction

For the construction of the storage system, managers decided to employ a mechanical design and construction contractor that was well known to and respected by the OEM. The final design was based on the principles of a stacked flow-rack, allowing ABC Manufacturing to reduce building costs. It has also made control of stock more effective than a floor-based system would have done.

The flow-rack design allowed for eight positions or “tubes”. Production was limited to six main product lines with some derivatives. The so-called runners and repeaters were each allocated one or two positions. This allowed for batch and design-change control. Strangers were kept in small quantities on the picking floor.

Each position resembles a “tube” with a capacity of nine stillages that each hold 10 to 15 parts. Stillages of each type are thus presented to the picker to withdraw parts of the appropriate type to prepare for each delivery to the customer (see Figure 1).

The facility was designed with future expansions in mind by allowing for mirroring phases. During phase one, one half of the layout could be built and, for phase two, that could be duplicated and mirrored to double capacity.
The guiding principle behind the design of the facility and the storage system was ultimately to ensure proper stock control. The design allowed for ease of electronic stock-keeping (not installed yet).

3.4.3 Logistics

ABC Manufacturing found local supplier and engineering/tooling organisations in the Rosslyn area unwilling to support them, due to the simultaneous work load required by the OEM. ABC Manufacturing turned to Port Elizabeth-based organisations for this support. This increased the risk and cost of the project.

Component supply became problematic, because of increased pressure to localise supply of components. Components were previously imported from Europe, but local content regulations were being imposed. Suppliers for pipes were found in the Gauteng area.

Scheduling was complex due to the need for batch production. This was, initially, further complicated by import delays. Raw materials stock keeping was targeted at about 14 days. However, the forecast window from the OEM was up to three months. While this allowed for orders to be placed, forecast accuracy was doubtful and import lead-times were highly variable.

3.4.4 Management

Senior and junior management personnel were originally drawn from within the group. Shopfloor personnel were taken over from the previous supplier and were found to be well trained, well motivated and productive. Technical staff availability was low and demand high, thus the cost of these skills was increasing.

Absenteeism presented a more long-term concern. The size of the operation required a very small staff complement, however this also served to amplify the effect of any absenteeism. Ongoing improvements and cost reductions have served to aggravate this amplification effect.

3.4.5 Lessons learnt

- The stock keeping time frames were found very limiting and would be increased where possible. This included raw materials and finished goods.
- Slight layout changes would be introduced at the sequencing/shipping area to improve efficiency of resources.
- Poka yoke (mistake proofing) devices and measures needed to be added to prevent delivery errors. Currently these errors are caught in an audit bay/dispatch area prior to leaving the plant.
- The customer had been too involved in the operation to the extent that it had almost become an interference in management issues.
- A single customer operation is highly susceptible and vulnerable to customer problems increasing overall risk to both the organisation and its employees.

3.4.6 Production Planning and Control Design

Production control was based on traditional Push scheduling. Orders were released by a centralised production plan based on the demand requirements for the following two weeks. Batch sizes vary, but would typically be one to two shifts worth of production.

Production planning was conducted by Master Production Schedule (MPS) and by a Manufacturing Requirements Planning (MRP II) approach. This was based on a demand forecast received from the OEM. Figure 2 shows a Value Stream Map of the current production process.

Intermediate and final assembly operations were disconnected by means of an on-site WIP warehouse. Sub-assemblies were returned to the production floor for final assembly.
Sub-assemblies were released to final assembly in container quantities. Final assembly consists of three automated assembly stations. These were manned by two or three operators doing loading, unloading and rework as needed. As soon as a stillage was full (10 to 15 units) it was sent to finished goods storage.

Production Control Considerations

For ABC Manufacturing this system is currently successful for three main reasons:

1. Stable forecast: The forecast received from the OEM has been stabilised to some degree, as the product was a dependent part in the OEM’s production process.
2. Simple Manufacturing Process: The production process was limited to three stages. (See Figure 6) This allowed for ease of and more accurate inventory (WIP) control and MPS runs.
3. Product Standardisation: Item numbers of sub-assemblies were limited as much product standardisation had been implemented in the design phase. This limited production complexity, reduced WIP and improved data integrity.

Change Control Considerations

An important qualification by the OEM is the need to observe engineering changes. The manufacturer has been able to do this effectively by combining four aspects of the environment.

1. Forecast window: ABC Manufacturing normally has a three to six-month warning period. This is sufficient to ensure tooling gets updated and/or the component or material orders are placed or updated.
2. Finished Goods Stock: The three-day finished goods stock limitation allows them to run out any ‘old’ parts quickly and leads to potentially very low numbers being scrapped, should it come to that.
3. Limited Product Range: The product range of ABC Manufacturing comprises about six variants while the storage system allows for eight locations. This leaves at least one location per variant thus limiting potential errors in supply.

4. Flow-rack design: The flow-rack has been designed in such a way as to physically prevent the insertion of stillages in amongst other older parts. This enforces the first-in-first-out (FIFO) principle.

3.5 Measures and Results

The success of the facility and operational designs was confirmed by means of interviews with staff and management. These results were triangulated with actual counts and time studies.

In terms of the following measures, no reports indicating serious problems could be found:

- Delivery Accuracy
- Sequencing of parts
- Returns from OEM
- Engineering Change Integrity (Change Control)

In terms of the following measures actual measurements were conducted on the shop floor and all stated conditions were verified:

- Availability of Stock
- Cycle Times
- Daily Production Targets
- Work in Process

Down time data for 2009 indicate that change-over related down time was the second largest contributor during November 2009 (Figure 2). This superseded part shortage and breakdown delays. Other contributors were not clearly defined or had little impact on the total figure.

It was also found that change-overs doubled in count (Figure 3) in the months October ’09 and November ’09. This contributed to the increasing trend in total monthly down time over the second half of 2009 (Figure 4).
4 COMPARISON OF ACTUAL DESIGN WITH LITERATURE

4.1 Current State of Production

Production control is forecast based. Historical demand distribution is shown in Table 2, while daily demand could differ dramatically from this.
Table 2: Demand Distribution and Setup Times

<table>
<thead>
<tr>
<th>Product Variant</th>
<th>Demand Percentage</th>
<th>Setup Time</th>
<th>Cycle Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Cyl, Petrol</td>
<td>37.39</td>
<td>30</td>
<td>5.5</td>
</tr>
<tr>
<td>4 Cyl, Petrol</td>
<td>30.71</td>
<td>30</td>
<td>4.7</td>
</tr>
<tr>
<td>6 Cyl, Petrol (A)</td>
<td>18.46</td>
<td>30</td>
<td>11</td>
</tr>
<tr>
<td>6 Cyl, Petrol (B)</td>
<td>7.56</td>
<td>30</td>
<td>5.5</td>
</tr>
<tr>
<td>4 Cyl, Diesel</td>
<td>5.49</td>
<td>30</td>
<td>5.1</td>
</tr>
<tr>
<td>6 Cyl, Diesel</td>
<td>0.39</td>
<td>30</td>
<td>5.9</td>
</tr>
<tr>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2 Comparison of Actual Design with Definitions Found in the Literature

The system in place cannot be deemed a Pull system, for a few simple reasons:

1. It is not governed by the downstream process, but rather by a central production planning (MRPII) system.
2. It produces large batch quantities of parts.

However, on the exit side of the supermarket, parts are assembled into delivery stillages, exactly as the downstream process (the OEM) calls for it. In addition the parts are sequenced to the customer’s requirements; Svensson [7] refers to this as Just-In-Sequence (JIS) production as opposed to Just-In-Time (JIT) production.

In this case it is still possible to push JIT manufacturing further up the supply chain by converting the operation of ABC Manufacturing into Pull production. In so doing, further savings are possible.

4.2.1 Conversion Example

Such a conversion would see ABC manufacturing using Smalleys’ [5] Runners, Repeaters and Strangers as follows:

A Items: (60% of demand)
- 6 Cylinder Petrol
- 4 Cylinder Petrol

B Items: (next 20% of demand)
- 6 Cylinder Petrol (A)

C Items: (Last 20%)
- 6 Cylinder Petrol (B)
- 4 Cylinder Diesel
- 6 Cylinder Diesel
Based on these categories, Table 3 offers an example breakdown of stock keeping quantities per part type. This shows the allocation of locations to part demand. The part density per stillage leads to additional pressure on available space as high demand parts can only be packing 10 to a stillage rather than 15 in other cases.

**Table 3: Stock Keeping Quantities**

<table>
<thead>
<tr>
<th>Product Variant</th>
<th>Percentage</th>
<th>Minimum Quantity</th>
<th>Locations Used</th>
<th>Actual Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Cyl, Petrol</td>
<td>37.39</td>
<td>280</td>
<td>2</td>
<td>240</td>
</tr>
<tr>
<td>4 Cyl, Petrol</td>
<td>30.71</td>
<td>230</td>
<td>2</td>
<td>240</td>
</tr>
<tr>
<td>6 Cyl, Petrol (A)</td>
<td>18.46</td>
<td>138</td>
<td>2</td>
<td>160</td>
</tr>
<tr>
<td>6 Cyl, Petrol (B)</td>
<td>7.56</td>
<td>57</td>
<td>1</td>
<td>120</td>
</tr>
<tr>
<td>4 Cyl, Diesel</td>
<td>5.49</td>
<td>41</td>
<td>1</td>
<td>120</td>
</tr>
<tr>
<td>6 Cyl, Diesel</td>
<td>0.39</td>
<td>3</td>
<td>Kept Separate</td>
<td>15</td>
</tr>
<tr>
<td><strong>100%</strong></td>
<td><strong>750</strong></td>
<td></td>
<td><strong>8</strong></td>
<td></td>
</tr>
</tbody>
</table>

In order to implement Pull into the production area, Smalley [5] lists three crucial requirements:

- **matched cycle times for the different parts** - well-matched cycle times will allow for similar sized packs (a pack is a small batch quantity - often enough to run production for 10-30 minutes only)

- **reduced set-up times for all parts** - for such small batches, the setup time between packs needs to be minimal. According to Shingo [8], the implementation of SMED, or change-over time reduction, is one of the first tasks in implementing the Toyota Production System (TPS). Shingo points out that
  
  “..no transition to Toyota Production System can occur without drastic reductions in setup times”.

- **a suitable pitch interval** - the Pitch can be described as the time taken to manufacture a small quantity of parts called a ‘pack’. This should, however, be a repeatable timeframe for all part types, although the quantity per pack might differ from type to type. This is described by Rother & Shook [9] as a load leveling technique.

The existing system is flexible, as locations can be re-assigned to items as the demand vary. The main weakness of the existing system lies in the cost of expansion. Should the product range increase rapidly, the number of locations will need to increase too. Such a scenario would be much harder to support under the current production control strategy, while Smalley’s [5] small quantity production would be more supportive of such situations. Small quantities would make it easier to follow the call-off of parts, especially for larger product ranges.

Finally, Pull systems require that only acceptable parts are passed onto the next station. Daugherty, Rodgers and Spencer [10] have found empirical proof of the need for improved quality and the implementation of quality management programmes to ensure the success of similar Pull systems.
Evidence of such quality awareness was found at ABC Manufacturing. Each cell does its own inspection and rework. However, if information about rework was recorded and feedback given, welding programmes could be changed to improve quality and cycle times.

5 REVISITING RESEARCH OBJECTIVES

5.1 Have the operational objectives been met?
It was demonstrated that the manufacturer aligned its process and facility to serve the needs of the customer. This focus on customer needs is typical of Lean and followers of the Toyota production system (Dennis [11]).
All the customer requirements were met; limiting the amount of stock keeping, delivering parts in sequence and on time and engineering change control.
Although the objective of the manufacturer was not to actively pursue Lean initiatives, it did apply some Lean principles and techniques. These have been practical and applicable to the situation.

5.2 What barriers and obstacles were encountered?
The first barrier was the distance and newness to the region. This was overcome by relocating a senior staff member as project leader to the area. His objectives included managing and implementing the project as well as appointing contractors and other staff to assist in bringing the project to completion.
Possibly the most important barrier was the ability to build a network of support in the area. This could be ascribed to availability, micro-cultures, mutual lack of history and confidence among customer and support suppliers.
The simultaneous upgrade of the customer’s facility to introduce a new vehicle left a support vacuum. This was unexpected and left the manufacturer to find alternative sources, adding cost and risk.
The time-frame to complete the project presented an important barrier. ABC Manufacturing effectively had twelve months to design, build and commission a fully functional plant.
Finally, staffing issues presented various problems and in some cases internal policies added to the complications.

5.3 Lessons learnt by ABC Manufacturing

5.3.1 Problems
The risks involved in running a single customer operation are high. However, additional and unforeseen operational problems included the following:
• The inability to use production resources flexibly. Once the finished goods quota was full, production staff was forcibly idle. Policies prevented more flexible arrangements.
• Production speed at the customer dictated that of ABC Manufacturing. During the 2009 recession, the customer opted for short-time production, which had a direct effect on the manufacturer.
• The involvement of the customer in the business was at times interfering and directive rather than assisting and supportive.

5.3.2 Successes
The use of respected and trusted support made the design and construction of the storage system not only possible but also successful.
The close-knit and contractual relationship between the customer and ABC Manufacturing proved to ensure a highly successful partnership to date. This case shows that it is possible and essential to create a basis of understanding on which to build the partnership.

5.4 What changes could be recommended?

The following changes have been recommended:

1. Reduction of change-over times will save some production time and will open opportunities to introduce Pull production.
2. The introduction of a TPM programme and even a 5S programme will allow for smoother production, better ergonomics and better flow with less interruption and downtime.
3. Specific policy and union agreement changes were identified that would further allow more flexibility in dealing with the pressure of a single customer supplier.

6 CONCLUSION

The case emphasises the need for careful planning, design and consideration of Lean techniques to effectively meet the very high standards and demanding delivery requirements of the customer.

A pure Lean facility will practice ‘Pull production’ for various reasons, but mainly to achieve flexibility and reduce waste. This was one of the main ‘deficiencies’ identified by this study. Reasons are offered and the resulting complications and compensations are discussed. Yet, even though Pull was not achieved, the plant has managed a good flow and definitely managed to satisfy their customer.

The normal evidence for continuous improvement was strikingly absent from the plant. Yet, shop-floor staff members who were interviewed showed some dedication to process ownership.

At a more technical level, relatively long change-over times have not been rigorously targeted as improvement opportunities. If this had been done, production planning would have been a simpler and more routine exercise with less dependency on forecasts. Reducing cycle times and grouping of parts into families present further opportunities.

The findings of this study point to the success of the facility in meeting the demands of the customer. These demands have been conflicting in some ways and challenging in others. The solutions that were found and implemented have been unconventional and creative in many ways. Certain challenges are, however, still to be resolved.

7 REFERENCES


