Application of JIT as a TQM Tool: The Case of an Aluminium Foundary Manufacturing

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This research work investigates the use of Just in time (JIT) as a TQM tool for the aluminium foundary industry. It explores the adaptation of the manufacturing approach to metal foundry, where raw materials are imported in a highly unstable economy. JIT is applied to improve cost effectiveness of operations, quality and to achieve world class benchmarks on all facets of the engineering entity as competitiveness in product delivery is getting to be mandatory for business survival.

Key words: just in time; foundry; aluminium; cost; effectiveness; world class

1. Introduction

Global manufacturing and trading industry continues to evolve and, most businesses are now faced with an ever increasing need to rapidly adapt to these changes. The changes include changes in market demand, product designs, product life cycles, changes in production and manufacturing technologies (Yusof, 2013). As markets gradually shift from mass markets into niche markets, it is becoming imperative that manufacturing entities respond with proactive strategies to ensure not only their continued survival but also facilitate for their own growth in a very competitive environment (Schonberger, 2003). Any organization needs to focus on quality of products, the cost of products, timely delivery of products and the flexibility of their internal business process to adapt to rapid changes [3]. The aspect of flexibility becomes very critical especially when an organization is trying to capture an immediate intermittent demand of a product (Talib *etal*, 2013).

There is a declining manufacturing production capacity due to a number of constraints. Companies are industry grappling with obsolete equipment, skills flight and depressed market activity. Most raw materials procurement involves importing. Major challenges remain the ability to supply products at the right time, in the right quantities, at the right level of quality and at a competitive price. The answer in which case lies with the effective implementation of TQM (Powell, 2014). Aluminium industry is facing stiff competition on the market from outside suppliers. One of the major obstacles to their ability to compete is the lack of transition from the traditional systems of manufacturing such as producing to stock to more modern systems such as Just In Time which are better suited to the current prevailing competitive conditions in the market (Karkahnis, 2010).

2. Just in time (JIT) concept review

JIT has been defined in a number of ways but the essential elements of JIT have remained the same. As a definition JIT is a manufacturing philosophy that aims to eliminate waste, as waste is or results from any activity that adds cost to the production process without necessarily adding value to the product, such as transporting inventories from one warehouse to the other or the simple act of storing them. Waste in the following areas or from the following identified sources need to be reduced or eliminated (Gyampah *etal*, 2006):

- Overproduction - waste from producing more than is needed
- Time spent waiting - waste such as that associated with a worker being idle whilst waiting for another worker to pass him an item he needs (e.g. such as may occur in a sequential line production process)
- Motion – waste associated with operator movements or employee movements on the shop-floor
- Transportation/movement - waste such as that associated with transporting/moving items around a factory
- Processing time - waste such as that associated with spending more time than is necessary processing an item on a machine
- Inventory - waste associated with keeping stocks or inventory
- Defects - waste associated with defective items

JIT is premised on customer demand triggering the production of goods in a way which minimises the above mentioned forms of waste (Ross, 2009). Hence material movement is of great importance in the JIT concept as shown in Figure 1:

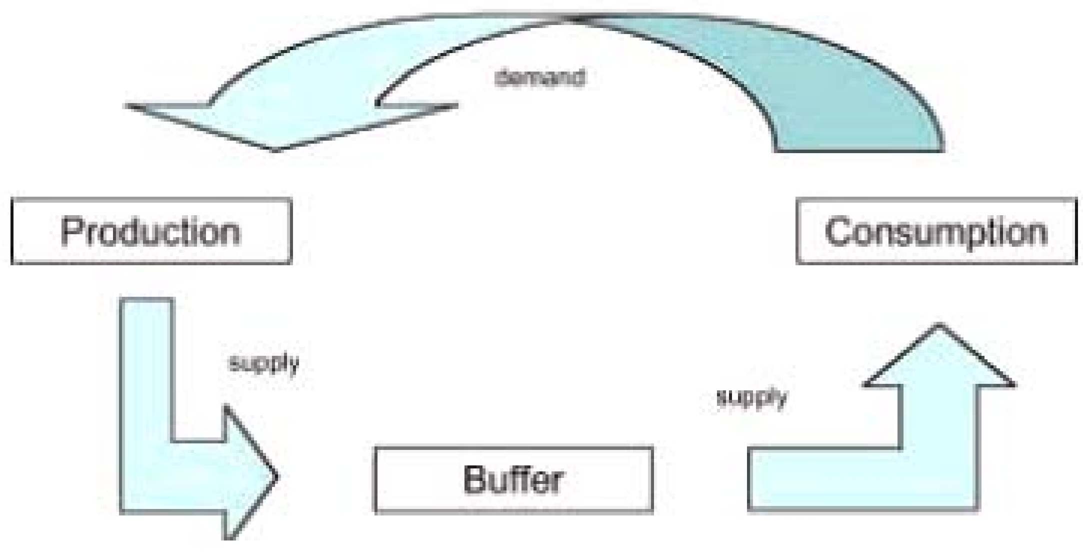

Figure 1 JIT concept (Ross, 2009)

As TQM is getting to be a global drive, to support this JIT pervades all aspects of the production and inventory flow process, covering not only the work-in-process (WIP) inventories (parts), but also the flow of finished goods from manufacturing to distribution centres in the forward direction and, in the backward direction, the flow from suppliers (Nayab, 2010).

JIT has evolved into an operational philosophy that incorporates an improved inventory control system in conjunction with other systems such as (Gyampah *etal*, 2006)

- A set-up time improvement system
- A maintenance improvement system
- A quality improvement system
- A productivity improvement system

JIT is primarily applied to repetitive forms of manufacturing in which the same products and components are produced over and over again. One of the key features of a JIT system is the kanban which aids in this flow movement throughout the manufacturing system (Baitler, 2010). There are two main types of kanban, the production kanban and the conveyance kanban. The production kanban lets the workers know that more of a certain part needs to be produced.

Reduction or elimination of setup times is one of the aims of JIT. JIT aims for single digit setup times (less than 10 minutes) or "one-touch" setup. This can be done through better planning, process redesign, and product redesign. Reducing setup times allows economical production of smaller lots and close cooperation with suppliers is necessary to achieve reductions in order lot sizes for purchased items, since this will require more frequent deliveries. The use of a control system such as a kanban system (or other signalling system) to convey parts between work stations in small quantities (ideally, one unit at a time) rather than in large complete batches helps to enhance JIT as materials move to the next work station without delay. These key elements of JIT are given in the Figure 2 below (Jha, 2013).

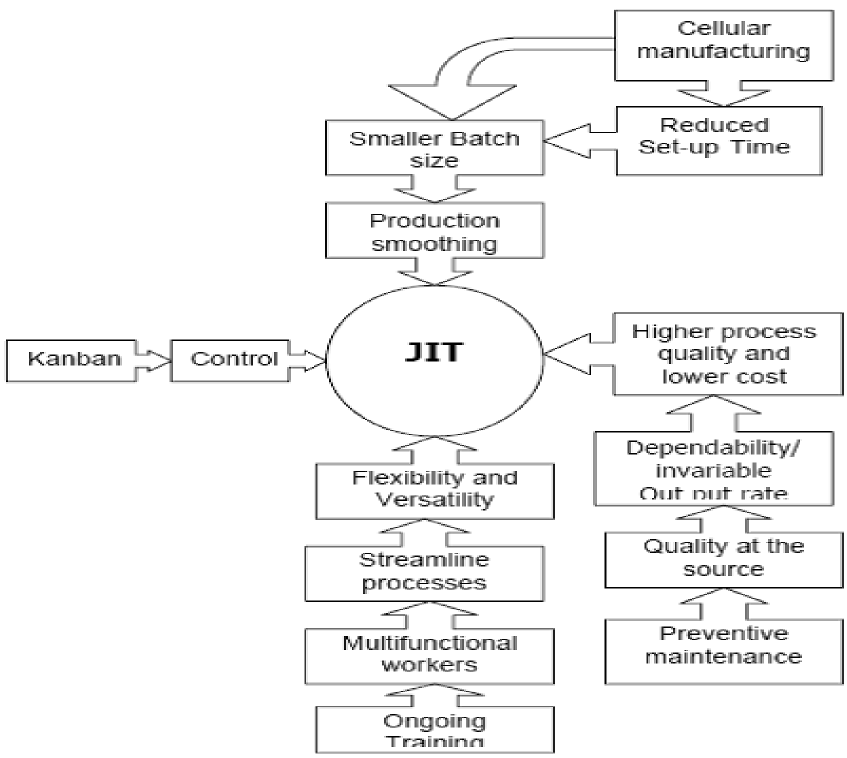

Figure 2 JIT system elements inter relationship

JIT as a TQM tool also addresses the tendency with most organisations that have to keep some level of inventory is to keep more than what is enough or a high level of inventory. Figure 3 below gives an insight into the dangers associated with high levels of inventory.

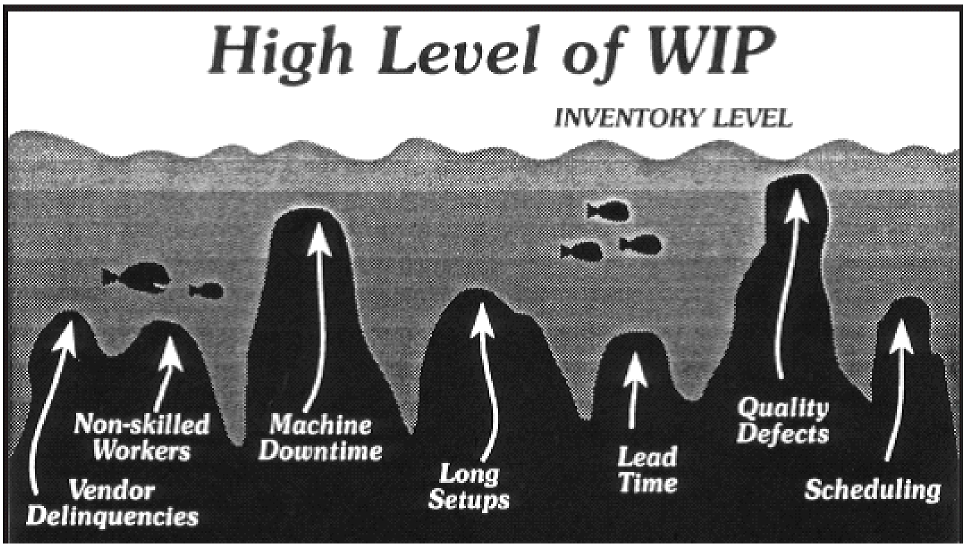

Figure 3 High levels of inventory (McNair, 2006)]

Inventory can mask or cover a lot of problems within a manufacturing system. These problems may include machine breakdowns, long set-up times, long lead times, quality defects, problems associated with scheduling and even problems associated with the selling and marketing of products. With a high level of inventory such TQM problems are not immediately recognised and at times these later can manifest in a number of ways such as tied up capital, storage space problems and loss or deterioration whilst in storage.

As a TQM tool, JIT advocates for strategic sourcing a means to lower costs and improve quality. It analyzes what products the company buys in the highest volume, reviewing the marketplace for those products, understanding the economics and usage of the supplier of those products, developing a procurement strategy, and establishing working relationships with the suppliers that are much more integrated than such relationships were in the past (Jha, 2013). The products that are purchased in the highest volume will be the best candidates for cost reductions. This is because once those products are identified, the company can then justify the time and expense needed to closely study the industry that supplies that product. This bring in the relevance of TQM in Enterprise resource planning(ERP) in establishing relationship with key suppliers.

With the need to produce high quality, low cost goods came the need to streamline manufacturing organisations such that all activities were geared towards the achievement of cost effectiveness. Four key aspects are identified in world class manufacturing are product quality, delivery time, cost and flexibility. This led to the development of various process improvement and management theories and concepts that were aimed at achieving just that (Lam *etal*, 2012). Therefore JIT can be described as one of the way by which an organisation can achieve the status of world class manufacturer. Common amongst world class manufacturing based companies is the need to continuously improve operations whilst adding value for the customer.

3. Materials and methods

The study was based on data from the actual manufacturing operations at Aluminium Foundry Co. It looked at the current manufacturing system and its merits under the existing market and economic conditions. Effort was made to investigate how JIT could be implemented in a manufacturing system. This was done by looking at how the manufacturing system implements demand management, supply chain management and inventory management which are strategic goals in a JIT system. In this research most of the data used was from archival sources such as company annual reports, daily and monthly manufacturing production reports and other manufacturing management information. Information on suppliers' lead times, delivery times, customers' satisfaction and production lead times was gathered in this study

4. Aluminium foundry overview

Aluminium Foundry is an establishment which produces a wide range of aluminium products that include extruded profiles, bars and gravity die castings. Also included in the production range are: aluminium sections for engineering and other purposes in anodized or powder coated finishes, irrigations pipes and their fittings, as well as various castings that includes cookware. Presently, the organization employs about 112 employees in nine (9) main departments which are: Re-melting Plant, Extrusion Plant, Foundry, Anodising and Powder Coating departments. Major flow process routes are given by Figure 4 below:

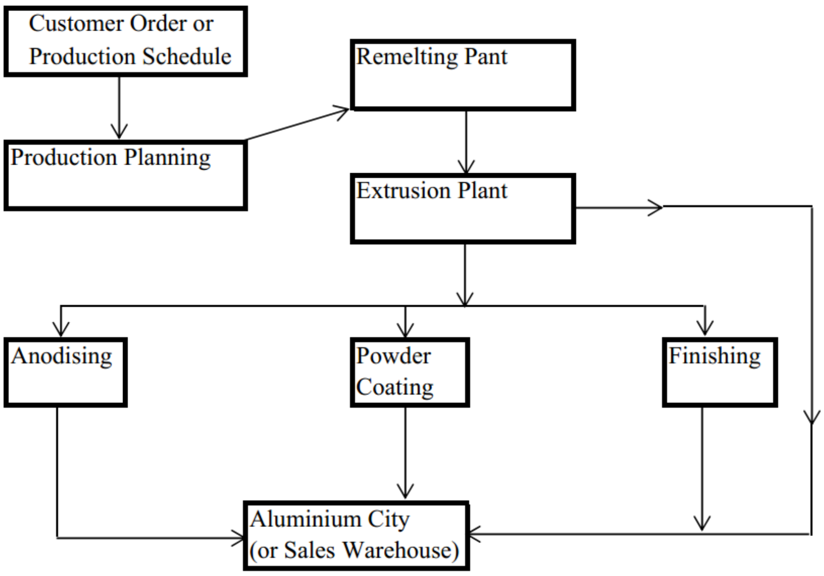

Figure 4 Production process route

A demand or sales forecast is used to drive the production departments. Products are produced for both stock and on customer orders. Special dies are kept for customers who require specific products and also tolling production is also a part of manufacturing system. For stocking purposes, Aluminium Foundry relies on an internal prioritisation system that is called 'fast moving dies' system. This is whereby the company analyses its purchases from stock and identify which products are on demand over a certain period.

Re-melting plant: Aluminium scrap from various sources and aluminium high purity (HP) ingots (at a ratio of 65:35) are charged into a reverberatory furnace with a capacity of 5.5 tonnes. Other additions are made in smaller quantities (normally less than 20 kgs each) which include magnesium, silicon and titanium (in the form of titanium-boron rod). Aluminium and its alloys melts around 630 ºC. Once these materials have melted and the melt analysed for consistency in terms of the elemental constituents a casting process is then done. The casting that is done at Aluminium Foundry is known as direct-chill (DC) casting and from this cylindrical logs are produced. The logs produced go through a heat treatment process called homogenization and cooling after which they are then cut into smaller sections known as billets to lengths of 420, 525 and 630mm depending on the requirements of the next stage of extrusion of which the billets are the feedstock. The capacity of the furnace at is 5.5 tonnes and the production rate is currently at 4.8 tonnes per day of logs.

Extrusion plant: In the extrusion plant the billets are then forced under pressure through a die to form the various sections, bars, profiles and tubes. Before extrusion begins, the die is heated in a furnace. The die is a steel disk containing one or more cavities through which the aluminium is extruded. The die assembly is lowered into a holder and transferred into position within the press. The aluminium billets are heated to 320 – 500 ºC   in order to make them soft. The billets are often heated so that the front end is hotter than the rear (taper heating). This is because as the billet progressively deforms in the press, it also heats up due to friction and deformation. The main extrusion cycle begins and as the profile emerges, it is cooled using air or water sprays in order to develop its metallurgical properties. This process is known as direct extrusion and the products so produced have what is known as a mill surface finish. At the end of extrusion, there is still a small length of billet remaining. This 'butt end' is sheared off in order to present a flat face for the subsequent billet to join onto. The extrusion is sawn off just past the cooling zone and then transferred to the stretcher.

Anodising plant : Anodising is an electrochemical reaction which is used to protect and give a coloured finished to an aluminium section. The reaction is based on the fact that pure aluminium when exposed to the atmosphere it reacts to give a thin oxide layer on the aluminium which is very resistant to most chemical attacks. The anodising process is used to enhance the formation of this oxide layer and also to give the aluminium some colour. At Aluminium Foundry the anodising process is done as a batch operation where sections are first assembled on a jig. This jig takes the form of a rectangular shape formed by bars onto which the aluminium sections are tied using aluminium wire. The cycle time for the process from jigging to the last stage known as sealing is about 150minutes. The target per day for the department is 400 m2 of anodised sections.

Powder coating plant: Powder coating is a process used to put a coloured finish to an aluminium section. Powder coating is an electrostatic deposition process where a powder is energised and sprayed onto a pre-treated aluminium section. Various colours depending on the customer specification can be done at Aluminium Foundry. About 60 colours can be done. The cycle time for this process is about 90 minutes.

Despatch process: Once processing of the material is complete, the ticket is completed and sent to the production controller for the department. The production planner then issues transfer notes for the material to be moved to the relevant next section or to the customer. It is envisaged that the whole process from customer order to the despatching of the material to the customer takes between 3 to 6 weeks. The despatch rule at Aluminium Foundry is basically the 'first in first out rule' (FIFO).

With the QMS in place an approved supplier's list is used for input purchases. Table 1 below shows the lead times for some of the critical items that are purchased on a frequent basis:

Table 1. Input purchase lead times

Item	**Lead time (in days)**	
	Min	Max
Paraffin (kerosene)	2	10
Safety Clothing	3	21
High purity ingot	21	90
Production consumables	1	21
Scrap	1	5
Lubricants	1	5

The inventory holding position varies periodically due to the demand pattern prevailing at the particular time. Due to the economic conditions that have prevailed over the past year inventories of raw materials have largely been ignored with the general approach being to purchase whatever was necessary at any given time.

Table 2 below shows scrap rates that have been incorporated into the production system. Figures have been predetermined considering the process design and inherent recoveries from each department.

Table 2. Predetermined scrap rates per department

Department	Scrap Rates (%)		
	Planned Scrap	Non-performance scrap	Total

Remelt	20	10	30
Extrusion	20	10	30
Anodising	10	5	15
Powder coating	10	5	15
Foundry	20	15	35
Average	**16**	**9**	**25**

Key

Planned scrap – is scrapped material due to process design such as runners on foundry products, off cuts from the billet swap or cut to length sections of the plant

Non-performance – is scrap produced during production say due to poor product quality

The major observation at the organisation, in its quest to achieve TQM and eliminate defects, issues to do with cycle times are not explicitly managed currently. Hence need to take on board JIT as a philosophy to deliver defect free products on time to the customer always (Thamizhamani *etal*, 2010).

5. Results

TQM seeks for reduced waste and costs in the manufacturing operation, JIT as a TQM tool with have to reviewed for each and every critical aspect of the organisation.

A. Kanban system

Currently production lot tickets or draft sales order tickets (DSOs) are used in the manufacturing operations and stock bin cards. DSOs are used to drive production and distributed to all plants prior to production with each process having its own type of DSO. The system has to be configured that the DSOs are put in the kanban format without much change to the information currently carried by the DSOs. Instead of triggering production, the kanban will facilitate for the pulling effect through the manufacturing system.

B. Production scheduling

The production uses a computerized based system (SAGE 500/CS3), which is basically an MRP I software. At any given time the MRP gives quantities ordered, order date, delivery date and other information relevant for production. The challenge remains that it is unsuitable to use in this jobbing shop hence need to re-configure to order products with high set up and long lead times. But for success, it has been realized in high volume, more repetitive make to demand product lines. Thus JIT principles can be easily implemented in production scheduling at the company.

C. Set-up times

The set up times represent maximum amount of time that it takes to prepare before production can start in each department .Table 3 gives the set-up times for each plant.

Table 3. Set up time for each department at the Foundry

Department	**Maximum set-up time**
Remelt	40 hours
Extrusion	2 hours
Anodising	1 hour
Powder coating	1 hour

This time includes starting the machines, heating up and up to being ready to start production. With the exception of re-melt department whose set up time can be reduced 20 hours as currently prevailing, all other set ups times cannot be reduced significantly without changing the equipment that is currently in use.

D. LOT SIZES ANALYSIS

The batch sizes in each department averages 3 tonnes in mass. The re-melt department has a furnace of maximum capacity of 5.5 tonnes which is more than what one customer can order at any given time. Also varying tonnages can be handled well by the production capacity available. Other departments are also able to operate with very small batches of 0.5 tonnes without any adverse effect to the manufacturing system or the products.

E. LEAD TIME ANALYSIS

The lead time on all orders is an average of 21 days, however due to inconsistent supply of raw materials this lead time is adversely affected by mostly delayed delivery of DSOs to the relevant plants. Although a computerized system of order entry is available, it is not linked to all departments except of the extrusion department. Order tracking was undertaken and Table 4 gives the resultant trend of this exercise.

Table 4. Order processing lead times

Department	**Total No. Of tracked orders**	**Lead times**			
		0 – 21 days		**More than 21 days**	
		No.	**%**	**No.**	**%**
Remelt	50	15	30	35	70
Extrusion	50	27	54	23	46

Anodising	50	11	22	39	78
Powder coating	50	40	80	10	20

It was observed that the extrusion plant and the powder coating departments had more than a 50% success rate in meeting the 21 days lead time set by the company at 54% and 80% respectively. Anodizing and re-melt were found not to be so effective in timeous handling of DSOs.

F. Preventive maintenance analysis

The organisation uses reliability-centred maintenance (RCM) to enhance plant availability and reliability. This augurs well for JIT as preventive maintenance and plant availability (ideally 100%) are key to achieving the overall goal of JIT of timely delivery of quality goods. However frequent breakdowns are quite common at this plant. Table 5 gives re-melt stoppages over 6 month period from June to December 2013.

Table 5. Re-melt department stoppages

Nature of stoppage	**Frequency**	**Percentage (%)**
Raw material related	6	16.7
Production related	15	41.7
Equipment related	11	30.6
Other	4	11.0
Total	**36**	**100**

With 30.6% of the stoppages at Re-melt department attributed to equipment it becomes difficult to achieve timely delivery to customers. Other production challenges include inadequate manpower. Thus to avoid unnecessary down time, effective maintenance system has to be put in place. For the Extrusion plant the distribution of stoppages is given by Table 6 below:

Table 6. Extrusion plant stoppages

Nature of stoppage	**Frequency**	**Percentage (%)**
Raw material related	3	9.7
Production related	7	22.6

Equipment related	18	58.0
Other	3	9.7
Total	31	100

For extrusion plant, equipment related stoppages are at 58% contributing significantly to stoppages in this plant in the period under review. This is mainly due non-functioning of RCM at Aluminium Foundry. For the Anodising plant the distribution of stoppages is given below by Table 7:

Table 7.Anodising plant stoppages

Nature of stoppage	Frequency	Percentage (%)
Raw materials related	1	4
Production related	5	20
Equipment related	17	68
Other	2	8
Total	25	100

The anodising plant equipment related stoppages was 68%. This was due to the breakdown of one of the key machines (chiller unit) that is used in this department. The machine required to be replaced and it took over 6 months to replace. It became very clear that that without effective maintenance and replacement system of equipment the goals of JIT remain far off from being realised.

In the Powder coating plant the distribution of stoppages are given in Table 8 below. Here stoppages are caused by non availability of raw materials.

Table 8.Powder coating plant stoppages

Nature of stoppage	Frequency	Percentage (%)
Raw material related	15	45.5
Production related	6	18.2
Equipment related	8	24.2

Other	4	12.1
Total	33	100

On average equipment related stoppages contributed significantly to total number of stoppages across the departments. Hence preventive maintenance has been identified here and in the literature to be key in facilitating the achievement of goals of JIT. It is noted that other causes of stoppages identified need to be addressed so as to have a functional system that aggregates towards the goals of JIT manufacturing.

G. DEMAND MANAGEMENT ANALYSIS

The Table 9 below shows on-time deliveries for the company from 2006 to December 2013. Thus there is a decline of on-time deliveries of products to customers from 72.4% in 2006 to only 31.4% in 2013. It implies that the bulk of the customers did not receive the products within the set delivery target time for the company.

Table 9. On-time delivery percentages

Year	**On-time deliveries (%)**
2006	72.4
2007	55.6
2008	46.4
2009	41.0
2010	35.6
2011	34.9
2012	33.2
2013	31.4

The Table 10 below shows also that between 2006 and 2013 customer complaints were 15% product quality, 72.6% due to late delivery and 12.4% due to other reasons. The number of complaints due to late delivery rose during the period under review.

Table 10.Customer complaints 2005 to 2012

Year	Total (No.)	Nature of complaint					
		Product Quality		Late Delivery		Other	
		No.	%	No.	%	No.	%
2005	32	4	12.5	20	62.5	8	25.0
2006	45	8	17.8	30	66.7	7	15.5
2007	67	14	20.9	42	62.7	11	16.4
2008	56	9	16.1	41	73.2	6	10.7
2009	67	8	11.9	55	82.1	4	6.0
2010	73	11	15.1	57	78.1	5	6.8
2011	88	11	12.5	62	70.5	15	17.0
2012	52	7	13.5	44	84.6	1	1.9
Average	60	9	15.0	44	72.6	7	12.4

H. INVENTORY MANAGEMENT ANALYSIS

Sock holding positiona at Aluminium Foundry were considered for its major raw material and scrap and are given in Table 11:

Table 11: Inventory holding from 2006 to 2012

Inventory	Target Holding Tonnage (tons)	Actual annual tonnages (tons)						
		2006	2007	2008	2009	2010	2011	2012
Scrap	39	43	44	50	45	42	39	34
Aluminium ingot	19	18	20	15	19	21	18	15
Finished Products	27	35	34	37	45	45	35	32

For scrap inventories the holding was above the set target of 35 tons. Thus about USD 10 was locked in scrap. Aluminium ingot holding was below the target of 20 tons. Also here USD190 000 was locked in excess finished goods inventory. The current level of inventory holding position reduce the organization's competitiveness. Since the costs considered here do not include storage space, deterioration in storage and possible pilferage, the actual value of holding may be even higher.

I. INVENTORY TURN OVER

Inventory turn over is calculated as:

Inventory turn over = (cost of sales)/(inventory)

Inventory holding is calculated as :

Inventory holding (in weeks) = 52/ (inventory turns)
Inventory turns for period 2006 t0 2012 is given by Table 12:

Table 12. Inventory turn over for period 2006 to 2012

Year	2006	2007	2008	2009	2010	2011	2012
Inventory turns	6.2	5.8	6.4	5.2	4.8	4.7	4.5
Inventory holding (in weeks)	8.4	9	8.1	10	10.8	11	11.6

Inventory turns decrease from a high of 6.2 in 2007 to 4.5 in 2012. Although inventory is current asset, but at times the rate it is converted into cash is a decisive factor between survival and collapse fo a business in competitive markets. Inventories where possible should be kept to a minimum with aview to eliminate them and have a system that delivers only the required products without holding stock as what JIT advocates for.

J. SUPPLIERS' DELIVERY PERFORMANCE ANALYSIS

Table 13 show the delivery performance by suppliers. This was randomly selected for organization's main raw material consumables.

Table 13. Supplier's deliver performance on critical raw materials

Performance	**Frequency**	**Percentage(%)**
Early deliveries	20	20
On time	23	23
Late	57	57
Total	100	100

With JIT seeking to provide products on time every time (100% on-time deliveries), the performance of suppliers is only 43% on time , 57% of purchase are late. Putting a lot of pressure on the company to deliver on time.

JIT heavily relies on supply chain effectiveness, thus supplier relationships help to reduce late product deliveries. In some instances suppliers have to adopt JIT practices themselves to be able to meet their customer's needs.

5. Discussion

Several factors appeared to be important in successful JIT implementation. These factors included close geographical proximity of suppliers and customers, the existence of a highly competitive market, a broad product range, small to medium company size, the existence of flexible manufacturing technology and a low degree of vertical integration in the organisation. JIT was found to be particularly useful in batch manufacturing companies to reduce throughput times and conversion (or production) cost. It was also found to be non-capital intensive and required the company's top management and employees' commitment.

Draft sales order (DSO) tickets: The DSO tickets formed the basis of initiation of jobbing activity, just like the Kanban. All the required materials sourcing were triggered to timeous production of finished products.

Production scheduling: The high set up and resulting lead times persisted with limited improvement, and this attributed to the old equipment currently in use. The way forward to redress this may be a major retooling of the plant to modern and efficient standards. This was despite the improved communication flow which had now been taken on board.

Work stoppages: These were reduced by JIT as adoption of TPM and multi-skilling of various operators initiatives managed to increase the availability of the plant in all the departments. This also meant a flexible deployment of idle resources to busy stations in the plant.

Scrap level: Scrap level remained above the target of 35 tonnes, although gradually coming done. JIT implementation, despite seeking to minimize waste, the age of the equipment hindered the possible improvements. Hence recommendations were given to improve key equipment in phases to significantly reduce scrap wastage. As reworking, collecting and storage of scrap is a cost to be eliminated.

Supplier delays: JIT relies on supply chain effectiveness for its success. The outcome on implementation was that 57% of the input purchases were late due to import logistics factor. Effort was also made to stock key imported raw materials in just enough quantities to avoid stock outs.

Customer complaints: These were marginally going down on product quality and remained significantly high on late delivery. This was attributed to obsolete equipment in current use.

JIT philosophy and as a tool for TQM has to be embraced as a culture. Its effectiveness is embodied in self-respect for employees, small gradual and continuous system improvement for the plant where it is in application.

6. Conclusion

JIT implementation is recommended for organisations that are willing to simplify their systems at the same time building a network of all processes (supply chain) involved in converting raw materials to finished products to satisfy the complicated customer of today on time. As JIT is based on small and permanent adjustment or improvement to manufacturing, these valuable changes are lasting for the company. The study found out that JIT basic elements can be integrated into manufacturing system without major changes to the system. The gap between the company's internal manufacturing processes and requirements of JIT was found not to be as wide as might be expected for a company in a developing country. The major challenge

revealed by the study was the foreign based suppliers whom the company cannot engage mutually for timeous deliveries.
Organisations adopting TQM philosophies of which JIT is one as part of their grand corporate strategy will reduce costs and achieve solid foundation to enhance human capability, conducive organisation and optimal utilisation of all resources as well as improved processes to gain competitive advantage in the market place.

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