Application of Just In Time (JIT) Manufacturing Concept in Aluminium Foundry Industry in Zimbabwe

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Abstract: ***This research study investigates the use of Just in time (JIT) concept for the aluminium foundry 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.***

Keywords: 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 [1]. 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.

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.

2. Justification

The country faces 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.

Aluminium Foundry Co is facing stiff competition on the market from Asian 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 [4].

Upgrading of manufacturing system to quickly respond to rapid market demand changes and other issues such as the scarcity of financial resources and material resources is required. High breakdown frequency, non reliability in terms of products with consistent quality and reduced productivity militate against the supposed system efficiency [5]. Hence Just in Time as a management philosophy it advocates for a holistic approach to manufacturing whereby each activity in the production system is analyzed and improvements made that will ensure that efficiency is achieved in the manufacturing system.

The benefits that are associated with the implementation of a JIT system include the following [7]:

- better quality products
- quality the responsibility of every worker, not just quality control inspectors
- reduced scrap and rework
- reduced cycle times
- lower setup times
- smoother production flow
- less inventory, of raw materials, work-in-progress and finished goods
- cost savings
- higher productivity
- higher worker participation
- more skilled workforce, able and willing to switch roles

- reduced space requirements
- improved relationships with suppliers

3. Just in time concept

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 [8]:

- 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

Basics of the concept are that industries should produce what is needed, when it is needed and in the quantity that it is needed [7]. A company aims to produce what customers' need that is, producing against customer orders as opposed to producing against forecasts. JIT can also be defined as producing the necessary units, with the required quality, in the necessary quantities at the last safe moment. Customer demand triggers the production of goods and these goods feed into a buffer before they are delivered to the customers. Material movement is of great importance in the JIT concept as shown in Figure 1:

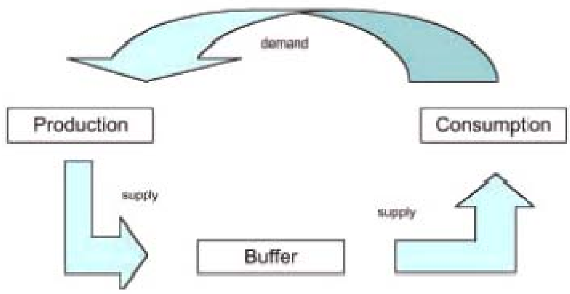

Figure.1: JIT concept [1]

JIT is more than just a production and inventory planning and control system analogous to the well-known material requirements planning (MRP) systems. 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.

3.1 JIT development

The present idea of JIT manufacturing can be traced to the Toyota motor company in Japan. However the concept was only adopted implemented and publicised by Toyota of Japan as part of its Toyota Production System (TPS). JIT was used by Toyota to deal with a problem of increasing and wasteful overstocking of cars they were producing around 1954[3].

Basically, it is manufacturing set up whereby the usage of parts determined the consumption rates of the parts. Materials were "pulled" through the plant by usage or consumption of parts in the final assembly. To obtain maximum benefit from this "pulling" system, it was also proposed the formation of manufacturing cells or bringing machines closer together in groups. The JIT system has continued to evolve and hence its applicability in a variety of industries. Also the notion that JIT is an inventory management system only has since been dispelled as it has come to be more than just an inventory management system. JIT has evolved into an operational philosophy that incorporates an improved inventory control system in conjunction with other systems such as [6].

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

3.2 Key elements of JIT manufacturing

3.2.1 JIT and the Kanban [4]

JIT primarily applied to repetitive forms of manufacturing in which the same products and components are produced over and over again. The general idea is to establish flow processes (even when the facility uses a jobbing or batch process layout) by linking work centres so that there is an even, balanced flow of materials throughout the entire production process, similar to that found in an assembly line. To accomplish this, an attempt is made to reach the goals of driving all inventory buffers toward zero and achieving the ideal lot size of one unit. One of the key features of a JIT system is the kanban which aids in this flow movement throughout the manufacturing system. 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. The conveyance kanban lets them know that parts need to be transported to another centre. The kanban system is classified as a "pull system" in production, which means that when parts are need they are pulled and sent to the work station in need of them. The starting point for a pull system is the customers and then it works its way backwards all the way to the raw material resources. Decisions regarding the number of kanban (and containers) at each stage of the process are carefully considered, because this number sets an upper bound on the work-in-process inventory at each stage.

3.2.2 Production scheduling within a JIT system

The need to stabilize and level the master production schedule (MPS) with uniform plant is emphasised within JIT manufacturing. To create a uniform load on all work centres through constant daily production and mixed model assembly are some of the techniques used to maintain a uniform plant loading. Demand fluctuations are met through end item inventory rather than through fluctuations in production level. Use of a stable production schedule also permits the use of back-flushing to manage inventory where an end item's bill of materials is periodically exploded to calculate the usage quantities of the various components that were used to make the item, eliminating the need to collect detailed usage information on the shop floor [2].

3.2.3 Set-up time reduction

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. A good example of the potential for improved setup times can be found in auto racing, where a NASCAR pit crew can change all four tires and put gas in the tank in under 20 seconds. The pit crew's efficiency is the result of a team effort using specialized equipment and a coordinated, well-rehearsed process. In a manufacturing system the single minute exchange of dies (SMED) has been an area that has received widespread attention in terms of research and application aimed at set up time reduction.

3.2.4 Reduction of lot sizes

Reducing lot sizes (whether manufacturing or purchase) is key in JIT production. 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.

3.2.5 Zero lead times

The reduction of lead times, which is the time it takes from the time a customer, places an order, to production and delivery enhances the principles upon which JIT manufacturing has been founded. Production lead times can be by moving work stations closer together, applying group technology and cellular manufacturing concepts, reducing queue length (reducing the number of jobs waiting to be processed at a given machine), and improving the coordination and cooperation between successive processes; whilst delivery lead times can be reduced through close cooperation with suppliers, possibly by inducing suppliers to locate closer to the factory.

3.2.6 Preventive maintenance

Preventive maintenance (PM) as a management system is of critical importance in the achievement of the objectives of JIT. Preventive maintenance involves the utilisation of machines' and workers' idle time to maintain equipment and prevent breakdowns. This tries to make sure that during production time no breakdowns are encountered so as to meet the deliveries to customers. Thus by utilising the idle time production can go on undisturbed. Introduction of fail-safe systems also greatly reduces the down time in a manufacturing operation and enhance JIT.

3.2.7 The workforce

Flexible work force: workers should be trained to operate several machines, to perform maintenance tasks, and to perform quality inspections. In general, JIT requires teams of competent, empowered employees who have more responsibility for their own work. The interdependence of the factors above can be summed in the diagram below:

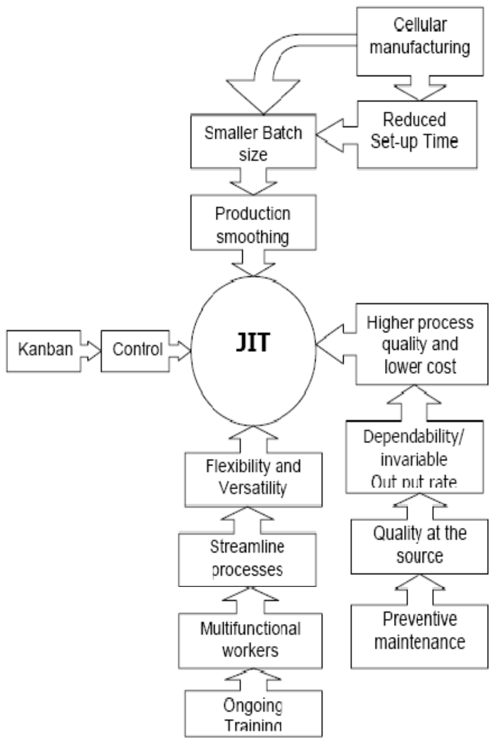

Figure 2: JIT system elements inter relationship [2]

3.3 Benefit of JIT in manufacturing

The ideal goal of JIT is that an enterprise's business cycle operates without interruptions and without non-value added time costs. Some of the more generic benefits in a manufacturing environment are [4]

- Reduced set up times
- Improved flow of materials throughout the manufacturing system
- Factory employees are multi-skilled
- Better consistency of production scheduling
- Improved supplier relationships
- Improved customer satisfaction levels

- Better quality products
- Improved productivity
- Eliminates the cost of storage facilities and associated costs
- A culture of continuous improvement
- Less capital tied up in inventories

The market is a strangely fluctuating phenomenon and for companies abiding by the approach of JIT, it is difficult for them to cope with those fluctuating cycles of customer demand. For instance, if the demand for a product goes suddenly up, companies using JIT won't be able to meet them from stocks held, since they are used to keeping small amounts of inventories. Such challenges can disturb the company's overall potential to supply goods in a timely manner or the capturing of that intermittent market.

3.4 Inventory in manufacturing

Inventory can be defined as all the raw materials, work-in-progress, finished goods, assemblies and sub-assemblies in a manufacturing organisation's production system. The goal of any manufacturing entity is to make money; stock held in an organisation represents money that is 'locked up' that might not necessarily translate to actually cash.

Hence the ultimate goal of JIT is to eliminate such activities so as to streamline all activities towards creating value in the product.

3.5 Perceived disadvantages of inventory [5]

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.

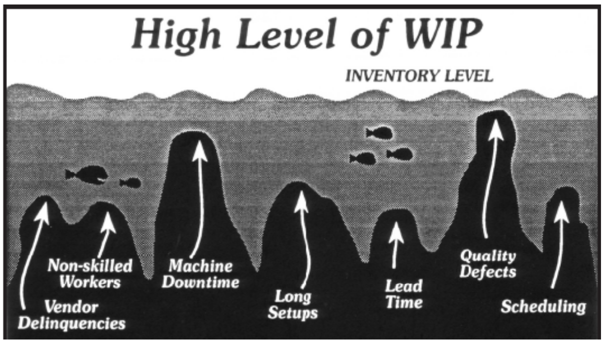

Figure 3: High levels of inventory [2]

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 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. However in very competitive markets reducing uncertainties by holding more inventories might prove not to be a valid remedy as inventory holding costs may become prohibitive. Too much or too little inventory leaves an organisation at a competitive (or cost) disadvantage to competitors.

Figure 4 shows that holding too little inventory will lead to an organisation not being able to meet customer requirements (low customer service level) and whilst too much inventory may lead to capital tie up and high storage costs that may affect the product price (or production cost) and possible loss or deterioration of the product whist it is in storage. JIT aims at obtaining the optimal mix of customer service level versus inventory that increases operational efficiency.

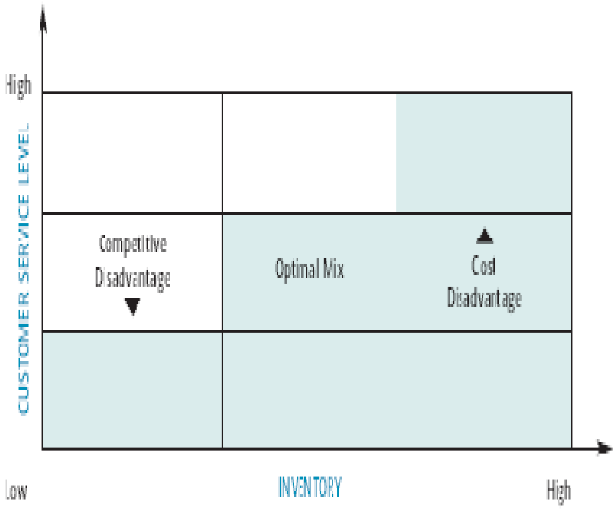

Figure 4: Inventory versus customer service level

3.6 JIT and quality management

A manufacturing company's survival in an increasingly competitive environment closely depends on its ability to produce highest quality products at the lowest possible cost and in timely manner with the shortest possible lead times. Thus quality management has also become an integral part of JIT systems. This has given rise to concepts such as JIT based quality management. Quality management can be defined as part of the overall management function that focuses on the achievement of results aimed at satisfying the needs, requirements and expectations of stakeholders in line with the organisation's quality policy and objectives. This includes the organisational practices, procedures, processes and resources for developing, implementing, achieving, reviewing, maintaining and improving the organisation's quality capabilities and performance (ISO 9000 standard, 2000). Thus an organisation in pursuance of JIT production will in essence be in line with some if not part of the requirements of a QMS. JIT based quality management has been defined as the combination of inventory control, quality control and production management functions that makes sincere efforts for quality improvements in two ways. Managers motivate workers to think quality first and then production rate second [7].

3.7 Lean management and JIT

Lean management is another concept very much similar to JIT and at times referred to interchangeably with JIT. Lean manufacturing or lean production, often simply, "Lean," is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for. Basically, lean is centred on preserving value with less work. Lean identifies five areas that are said to drive lean manufacturing and these are cost, quality, delivery, safety and morale. Lean also focuses on the elimination of waste while giving emphasis to the areas mentioned above.

3.8 Material requirements planning and JIT

Material requirements planning (MRP) is a production planning and inventory control system used to manage manufacturing processes. Most MRP systems are software or computer-based, while it is possible to conduct MRP by hand as well. An MRP system is intended to simultaneously meet three objectives:

- Ensure materials are available for production and products are available for delivery to customers.
- Maintain the lowest possible level of inventory.
- Plan manufacturing activities, delivery schedules and purchasing activities

MRP II brought master scheduling, rough-cut capacity planning, capacity requirements planning and other concepts to classical MRP. MRP systems in contrast to JIT systems have been defined as “push systems” as it is guided by forecasts to produce a Master Production Schedule (MPS) which then feeds into production and also that produced goods are moved to the next stage whether they are need or not whilst JIT relies on actual demand for a product [9]. The main advantage of MRP over JIT is that MRP takes forecasts for end product demand into account. While the main advantage of JIT over MRP is that JIT reduces inventories to a minimum. In addition to saving direct inventory carrying costs, there are substantial side benefits, such as improvement in quality and plant efficiency. MRP tends to produce excess inventories which JIT seeks to eliminate.

3.9 Supply chain management (SMC) and JIT

Supply chain management is the systemic coordination of the business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. As a consequence costs must be lowered throughout the chain by driving out unnecessary costs and focusing attention on adding value. Throughput efficiency must be increased, bottlenecks removed and performance measurement must focus on total systems efficiency and equitable reward distribution to those in the supply chain adding value [3]. The supply chain system must be responsive to customer requirement. From the above definitions it can be seen that to effectively adopt a JIT system that meets the customer requirements of timely delivery, the associated functions that feed into the production or manufacturing process that include procurement of materials, distribution or delivery of products and the production process management itself are key in meeting the customer requirements. This can then be summed up as the management of the system that delivers the product to the customer. Hence JIT and SCM are closely linked in terms of addressing the need to timely deliver a product to a customer.

3.10 Purchasing in a JIT environment

Purchasing is an act of acquiring goods and services that a company needs to operate or manufacture products. The process involves several steps; from requisition, soliciting bids, purchase order, shipping advice, invoice, payment and then delivery of goods ordered. In a highly competitive environment these processes can be found to be unacceptably slow, expensive and labour intensive. Each transaction generates its own paper trail, and the same process has to be followed whether the item being purchased is a box of paper clips or new equipment. In recent years and particularly in a JIT environment this has drastically changed [5]. This mainly due to increased competition on both the domestic and global levels that has led many companies to recognize that purchasing can actually have important strategic functions. It has been observed that in this new purchasing environment, a guideline known as the total cost of ownership (TCO) has come to be a paramount concern in purchasing decisions. Instead of buying the good or service that has the lowest price, the buyer instead weighs a series of additional factors when determining what the true cost of the good or service is to his or her company. These factors can include price, freight, duty, tax, engineering costs, tooling costs, letter of credit costs, payment terms, inventory carrying costs, storage requirements, scrap rates, packaging, rebates or special incentive values, warranty and disposal costs [6]. To lower TCO, companies are taking a number of steps to improve purchasing. These steps include strategic sourcing and building supplier relationships:

3.10.1 Strategic sourcing

Strategic sourcing seeks 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 [8]. 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.

3.10.2 Building supplier relationships

Supplier relationships are critical when an organisation intends to operate in a JIT set up. By looking at their key suppliers, an organisation can look at the ways key suppliers operate, study their business practices to see where the most money is added to the final cost of the product, and then work with the supplier to redesign processes and lower production costs [9]. This maximizes the contribution that suppliers make to the process. By knowing the market and knowing how much it costs for a supplier to do business, the purchasing department can set "target prices" on goods which they can negotiate with the supplier so to aid in cost reduction.

The alliances can sometimes register significant improvements in product quality as quality levels are clearly understood by the parties involved and their implications understood. The suppliers themselves have been found to be beneficiaries of this dynamic shift in purchasing in a JIT set up. These benefits include reduced paperwork, lower overhead costs, faster payment, long-term agreements that lead to more accurate business forecasts, access to new designs, and input into future materials and product needs.

3.11 World class manufacturing and JIT

With the need to produce high quality, low cost goods became 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 [6]. 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.

3.12 Organisational culture and JIT

Operational changes alone do not yield expected benefits if it is not accompanied with structural, managerial and cultural changes. Organisational culture remains one of the main challenges to a successful implementation of JIT in organisations [7]. The importance of aligning organisational culture with operational changes has been found to be a key in achieving the benefits of implementing any improvement related strategies in manufacturing. Organisational culture is also seen as an obstacle in sustaining the potential benefits of JIT as the tendency is to return to the traditional way of doing things if it is not adequately addressed. A Rational culture is driven by accomplishment and is task focused, efficient and prioritises quality and efficiency. In a developmental culture creativity and flexibility are necessary to sustain changes and growth. Both Rational and Developmental focus on the external environment in terms of competition and marketing. Thus organisational culture plays a crucial role in the success of any operational change or improvement effort.

3.13 Overview of JIT and technology [7]

JIT in itself does not dependent on technology since it is a philosophy upon which improvements can be achieved. However advances in manufacturing, equipment and systems technologies, information and communication technologies (ICT) has enabled the faster transformation of JIT from just a philosophy but into a real tool for changes in the manufacturing, technological and other industries. Recent technological developments such automation of process equipment have enhanced the scope of JIT and extended the possibilities of introducing JIT in new areas. This includes the use of robots on the shop floor helping to reduce set-up times and increasing productivity as well as product quality. The use of technology in a JIT system comes after process analysis and simplification. Effective use of the right technologies helps in informed decision making that shortens process time, reduces prototypes, cuts costs, and improves overall product and process quality.

The success of a JIT initiative depends on the smooth flow of communication and information within the organization. The emergence of the Internet and Intranet enhances the organization’s information processing and communicating capabilities.

Transmission of information through the internet and intranet facilitates availability of real-time information that enables making a large number of cross-functional interrelated decisions regarding the form, fit, function, cost, and quality of the product or process, contributing to reduced shipping, inventory and holding costs.

Computer-based Design and manufacturing systems such as computer-aided engineering (CAE), computer-aided design (CAD), computer-aided process planning (CAPP), MRP I and MRPII, and computer-aided manufacturing (CAM) rank amongst the major technological advances that support the goals of JIT. The application of such automated computer integrated manufacturing systems helps design, model and process products, simplifies and automates processes to achieve JIT goals in many ways, such as:

- ❖ eliminating labour intensive non-computerized process, saving time
- ❖ eliminating scope for mistakes all wasted time, effort and resources
- ❖ Eliminating scope of errors and contributing to quality assurance.
- ❖ identification and planning of the materials required for the product and each process
- ❖ attainment of greater shop floor control

3.14 JIT implementation

There is no standard to implementing JIT other than the inherent characteristic of the need of continuous progress towards the ultimate objectives of delivery of quality products in the right quantities as and when they are required, with a smooth synchronized continuous flow keyed to final demand.

JIT requires a modified approach to be taken by top management which may include significant modifications, such as designing an organisation that integrates strategy with people to achieve the basic premise of JIT, elimination of all waste, reducing specialisation or broadening employee skills, creation of project teams, ensuring responsibility for quality and operations to everyone, developing management and employee commitment to continuous improvement [7].

Secondly the modifications related to work space needed to addressed thus changing layouts of work centres, combining several related operations to minimize distance between them, grouping machines into cells, purchasing equipment with shorter set ups, responsibility for product design, quality and reliability, using TPM as part of the JIT system and analysing operations in order to identify areas where standardisation, simplification and automation are needed.

Thirdly JIT also requires that material flow processes be modified through the change in inventory holding, ordering and despatching processes. Stabilising production schedules on a regular basis, planning production from final assembly, developing methods for estimation of work in progress (or in process) and identifying why it's needed in the process and trying to reduce it gradually. Establishing new procedures to deal with suppliers such as defining the criteria upon which suppliers shall be chosen such as timely delivery, cost and quality of products supplied [5].

The final changes have to deal with the human resources training of personnel to improve and diversify their skills base, aligning the employees towards group work and incentives related thereof, increasing work flexibility, increasing worker participation in decision job related decision making and eliminating job boundaries or classifications. The training of management and employees to create an organisational culture that is consistent with the JIT philosophy plays also a pivotal role in ensuring a successful implementation.

4. Research design

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 can 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 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

5. Aluminium Foundry Co overview

Aluminium Foundry Co is an aluminium manufacturing company established in 1968, and it produces a wide range of aluminium products that include extruded profiles, bars and gravity die castings. The company produces 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 employees about 112 employees in 9 departments which are the Remelting plant, Extrusion plant, Foundry, Anodising and Powder coating, departments.

5.1 Production process route

At Aluminium Foundry Co, production is driven by a master production schedule derived from a production plan decided upon by the management. The following is a chart showing the company's production process routes.

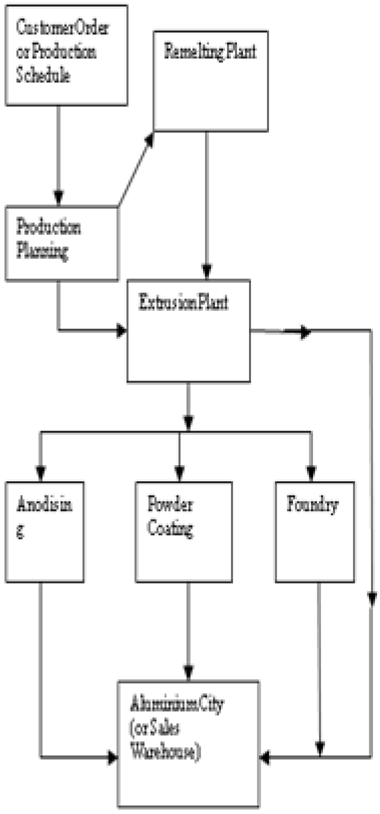

Figure 5: Production process route

5.2 Demand management and order processing

Aluminium Foundry Co uses a computerised ordering and production scheduling system known as CS3. This is system is based on a material requirements planning (MRP) system where manufacturing is done upon a certain plan or schedule. 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 Co 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. Once identified the list of dies so identified is put into a production schedule. Once the schedule is made out, production tickets known as direct sales orders (DSO) are generated. This ticket contains information pertaining to the quantity, finish, alloy and other relevant information for the production of the specified products. Once produced the material is stored in the warehouse awaiting customers. This is mainly done for the extrusions manufacturing. When a customer places an order the sales clerk generates a DSO. This ticket also contains information pertaining to the customer’s requirements such as product type, quantity, finish and expected delivery date (EDD). Normally Aluminium Foundry issues a predetermined 3 weeks delivery date on mill finish products and further days are added to the 3 weeks if the material has to go to either anodising or powder coating. Separate DSOs are raised for material that has to be anodised or powder coated. Once all information has been added to the DSO, the ticket is routed manually from the Sales office to the production planner for further processing. This processing includes the scheduling for production. The whole process from receipt of order to the actual production of the material may vary from a day to several days or weeks.

5.2.1 Remelting plant

The production process starts at the 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 melt 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 Co 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.

5.2.2 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. A small stretch is applied in order to remove any distortions and straighten the profile. The products or extrusions are then cut to the lengths specified by the customer and once cut the sections or bars are put in a furnace where they undergo another heat treatment process known as ageing at temperatures around 180 ºC for about 7 hours after which they are either sent to the Sales warehouse ready to be sold or delivered to the customer or they are sent to either of the finishing departments for anodizing or powder coating. The press at Aluminium Foundry Co has a rated capacity of 2500 tonnes. Productivity per hour of the press is rated at a nominal value of 900 kg/hr. Currently the press is operating at around 400 kg/hr. This leads to an average daily production of about 2.8 tonnes per day of extruded material.

5.2.3 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 Co 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.

5.2.4 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 Co. About 60 colours can be done. The cycle time for this process is about 90 minutes.

5.2.5 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 Co is basically the 'first in first out rule' (FIFO). The graph below shows the delivery statistics at the company for the period 2004 – 2010.

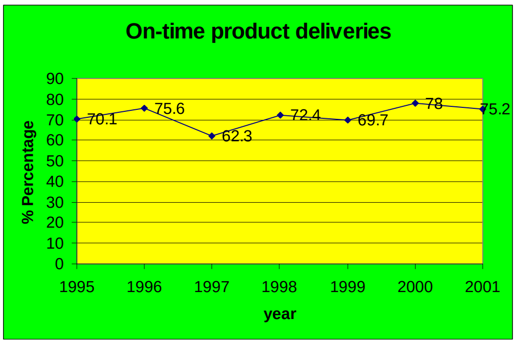

Figure 6: Delivery statistics

5.3 Supply chain management

Purchasing at Aluminium Foundry Co begins by the person (termed requisitioned) requiring an item filling out a requisition form. The requisition form then has to be signed by the requisitioner themselves; the departmental approves it and sends it to the buying office. The buying office then has to get the finance and general managers' approval before the purchasing can be done. Normally on the requisition form 3 supplier of the items required have to be put down on the form. Once the finance and general managers' approval has been sought then the buying office can then purchase the products. With the QMS in place an approved supplier's list used to be in place and hence the purchasing was normally from suppliers on this list. But due to the economic downturn of the past decade, this had been disregarded and purchases were now being done from any supplier who could supply the items at the lowest price. Table 1 below shows the lead times for some of the critical items that Aluminium Foundry Co purchases on a frequent basis:

Table 1: Lead times

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

5.4 Inventory management

The inventory holding position for Aluminium Foundry Co's main warehouse is determined mainly by the information gathered using the 'fast moving dies' systems. This is to say 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.

5.5 Scrap rates

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 swa or cut to length sections of the plant

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

Although the system at Aluminium Foundry Co seeks to eliminate defects, issues to do with cycle times are not explicitly managed currently. While, JIT always seeks to deliver defect free products on time to the customers.

6. JIT implementation at Aluminium Foundry Co

6.1 Kanban system

Currently at Aluminium Foundry Co, 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.

Movement of DSOs currently is being transferred physically by people to relevant departments, as production planners literally move out of their offices to leave DSOs at various departments for production to start. Thus lead time is greatly affected as time to deliver the DSOs varies each time an order is to be processed. Delivery time to take DSOs is not standardized.

6.2 Production scheduling

The production at Aluminium Foundry Co 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 unsuitable to use this in a jobbing shop producing configure to order products with high set up and long lead times. But for success 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.

6.3 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 Aluminium Foundry Co

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.

6.4 Lot sizes analysis

The batch sizes in each department can be considered small. At the re melt department, with 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 without much effect to the manufacturing system or the products.

6.5 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.

6.6 Preventive maintenance analysis

Aluminium Foundry Co 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 2012.

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 C.

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 total number of stoppages across the departments. Hence preventive maintenance has been identified here and in the literature to be a 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.

6.7 Workforce and organisational culture

The workforce was trained in ISO 9001 and 14 000 quality management and environmental management systems. Though no formal JIT training was done, these other training efforts point to how well JIT may be received if implemented correctly. The organisation has over the years also invested in multi-skilling of the workforce during the restructuring that saw workforce reduced from 350 to the current 112 employees. Thus the remaining workers could now do more than one job. This again is an element of a JIT manufacturing system.

6.8 Demand management analysis

The Table 9 below shows on-time deliveries for the company from 2005 to December 2012. Thus there is a decline of on-time deliveries of products to customers from 72.4% in 2005 to only 31.4% in 2012. 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 (%)
2005	72.4
2006	55.6
2007	46.4
2008	41.0
2009	35.6
2010	34.9
2011	33.2
2012	31.4

The Table 10 below shows also that between 2005 and 2012 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.

Inventory	Target holding tonnage (tonnes)	Actual annual average 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	48	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 reduces 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.

6. 10 Inventory turn over

Inventory turnover is calculated as:
Inventory turnover = (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 10: Customer complaints from 2005 t0 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**
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**
2012	52	7	**13.5**	44	**84.6**	1	**1.9**
Average	60	9	**15.0**	44	**72.6**	7	**12.4**

6.9 Inventory management analysis

Stock holding positions at Aluminium Foundry Co were considered for its major raw materials and scrap is given in Table 11:

Table 11: Inventory holding from 2007 to 2012

Table 12: Inventory turnover 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 survivals and collapse for a business in competitive markets. Inventories where possible should be kept to a minimum with a view to eliminate them and have a system that delivers only the required products without holding stock as what JIT advocates for.

6.11 Suppliers' delivery performance analysis

Table 13 show the delivery performance by suppliers. This was randomly selected for Aluminium Foundry'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, which puts 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.

6.13 Implementation analysis

The Japanese 5-S system was adopted as the basis of the JIT implementation at Aluminium Foundry Co for this case study.

Sorting the work place (Seiri): This JIT implementation involves classifying tools, equipment and materials to where they are really needed and unnecessary materials removed.

Straightening up (Seiton): Label have to be put on the production departments and work place to enhance plant organization. Alarms have to be also incorporated to signal for various activities in the plant.

Sweeping (Seisou): Housekeeping has to be taken seriously in the plant for both orderliness and employees safety. This JIT concept has to enhance the ISO 14 001 and OSHAS 18 000 for integrated occupational health, environmental and health management systems.

Standardising (Seiketsu): This JIT aspect needs all processes to be having operating procedures put in place for all the plants and department.

Sustaining (Shitsuke): The organisation has to adopt a learning culture for continuous improvement through training and top management involvement as part of it culture for JIT to be a success for desired results and benefits.

6.14 Communication resources

Although JIT does not require state of art computer infrastructure, the use of computers improves accuracy of data and handling the large volume of information with the system. The company has a total of 27 computers all connected to intranet and internet.

Computers can be classified as P1, P2, P3 or P4 depending on processing speed, with P1 being the slowest and P4 the fastest. Table 14 shows the distribution of computers within the department at Aluminium Foundry Co.

Table 14: Distribution of computer resources

Department	Number of machines per department				Total
	P1	P2	P3	P4	
Remelt	0	0	0	0	0
Extrusion	0	0	2	1	3
Powder coating	1	0	0	0	1
Anodising	0	0	0	0	0
Sales & marketing	0	0	0	6	6
Purchasing	0	0	0	2	2
Finance & IT	0	0	0	3	3
Human resources	0	0	0	2	2
Process engineering	0	0	0	1	1
Maintenance	1	0	0	0	1
Production planning	1	0	1	1	3
Total	3	0	3	16	22

From the table it can be seen that the company can implement JIT without additional computer resources. To improve on movement of lead times, all computers can be linked to SAGE 500, so that DSOs can be replaced by computer communication, instead of production delivering the DSOs physically wasting time. Thus the cycle times are reduced in the manufacturing system.

7. Research recommendations

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 total management and employees' commitment.

8. 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 Zimbabwe. The major challenge revealed by the study was the foreign based supplier whom the company cannot engage mutually for timeous deliveries.

9. Further research

More work is needed especially on how best to build and maintain supplier relationships to enhance JIT and organisational culture's influence on JIT implementation. Gyampah and Gargeya (2001) conducted a study on the implementation of JIT in manufacturing companies in Ghana. They concluded that firms that used JIT practices had better systems in place to control and management the manufacturing operations and also their efforts towards set-up time reduction, continuous improvements, quality related improvements, supplier partnerships and employees' training.

References

[1] Schonberger, R (2003), World Class Manufacturing Casebook: Implementing JIT and TQC. New York. The Free Press

[2] Baitler, J (2010), The Power of effective procurement and strategic suppliers, Strategic Finance (Aug): 36 -40

[3] Ross, G (2009), The JIT world can't be run by layers of supervision and control.

[4] Karkahnis, S (2010), Steps in implementing JIT manufacturing, Harvard Business Review (Mrc): 12-16

[5]McIntosh, R (2008), Becoming Lean and Responsive Manufacturer, Butterworth Heinemann

[6] Prabir J (2007), Measuring the efficiency of a supply chain, University of Trent

[7] Nayab, N (2010), Technological advances that support the goals of JIT (source: www.brighthub/members/nayab.)

[8] Gyampah, K. Gargeta (2006), Just-in-time manufacturing in Ghana: Industrial Management and Data systems 101(3): 106 -113

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