* + Just In Time (JIT)

# JIT Just-in-Time manufacturing

`Just-in-time' is a management philosophy and not a technique.

It originally referred to the production of goods to meet customer demand exactly, in time, quality and quantity, whether the `customer' is the final purchaser of the product or another process further along the production line.

It has now come to mean producing with minimum waste. "Waste" is taken in its most general sense and includes time and resources as well as materials. Elements of JIT include:

* Continuous improvement.
	+ Attacking fundamental problems - anything that does not add value to the product.
	+ Devising systems to identify problems.
	+ Striving for simplicity - simpler systems may be easier to understand, easier to manage and less likely to go wrong.
	+ A product oriented layout - produces less time spent moving of materials and parts.
	+ Quality control at source - each worker is responsible for the quality of their own output.
	+ Poka-yoke - `foolproof' tools, methods, jigs etc. prevent mistakes
	+ Preventative maintenance, Total productive maintenance - ensuring machinery and equipment functions perfectly when it is required, and continually improving it.
* Eliminating waste. There are seven types of waste:
	+ waste from overproduction.
	+ waste of waiting time.
	+ transportation waste.
	+ processing waste.
	+ inventory waste.
	+ waste of motion.
	+ waste from product defects.
* Good housekeeping - workplace cleanliness and organisation.
* Set-up time reduction - increases flexibility and allows smaller batches. Ideal batch size is 1item. Multi-process handling - a multi-skilled workforce has greater productivity, flexibility and job satisfaction.
* Levelled / mixed production - to smooth the flow of products through the factory.
* [Kanbans](http://www.ifm.eng.cam.ac.uk/dstools/process/kanban.html) - simple tools to `pull' products and components through the process.
* Jidoka (Autonomation) - providing machines with the autonomous capability to use judgement, so workers can do more useful things than standing watching them work.
* Andon (trouble lights) - to signal problems to initiate corrective action.

**History**

The technique was first used by the [Ford Motor Company](http://en.wikipedia.org/wiki/Ford_Motor_Company) as described explicitly by [Henry Ford](http://en.wikipedia.org/wiki/Henry_Ford)'s *My Life and Work* (1923): "We have found in buying materials that it is not worthwhile to buy for other than immediate needs. We buy only enough to fit into the plan of production, taking into consideration the state of transportation at the time. If transportation were perfect and an even flow of materials could be assured, it would not be necessary to carry any stock whatsoever. The carloads of [raw materials](http://en.wikipedia.org/wiki/Raw_material) would arrive on schedule and in the planned order and amounts, and go from the railway cars into production. That would save a great deal of money, for it would give a very rapid turnover and thus decrease the amount of money tied up in materials. With bad transportation one has to carry larger stocks." This statement also describes the concept of "dock to factory floor" in which incoming materials are not even stored or warehoused before going into production. The concept needed an effective freight management system (FMS); Ford's *Today and Tomorrow* (1926) describes one.

The technique was subsequently adopted and publicized by [Toyota Motor Corporation](http://en.wikipedia.org/wiki/Toyota) of [Japan](http://en.wikipedia.org/wiki/Japan) as part of its [Toyota Production System](http://en.wikipedia.org/wiki/Toyota_Production_System) (TPS). However, Toyota famously did not adopt the procedure from Ford, but from [Piggly Wiggly](http://en.wikipedia.org/wiki/Piggly_Wiggly). Although Toyota visited Ford as part of its tour of American businesses, Ford had not fully adopted the Just-In-Time system, and Toyota executives were appalled at the piles of inventory laying around and the uneven work schedule of the employees of Ford. Toyota also visited Piggly Wiggly, and it was there that Toyota executives first observed a fully functioning and successful Just-In-Time system, and modeled TPS after it.

The chief engineer at Toyota in the 1950s, [Taiichi Ohno](http://en.wikipedia.org/wiki/Taiichi_Ohno) ,examined accounting assumptions and realized that another method was possible. The factory could implement JIT which would require it to be made more flexible and reduce the overhead costs of retooling and thereby reduce the economic lot size to fit the available warehouse space. JIT is now regarded by Ohno as one of the two 'pillars' of the Toyota Production System.

So Toyota implemented a strategy now called [Single Minute Exchange of Die](http://en.wikipedia.org/wiki/Single_Minute_Exchange_of_Die) (SMED), developed with [Shigeo Shingo](http://en.wikipedia.org/wiki/Shigeo_Shingo),. With very simple fixtures, measurements were substituted for adjustments. Almost immediately, die change times fell to hours instead of days. At the same time, quality of the stampings became controlled by a written recipe, reducing the skill level required for the change. Further analysis showed that a lot of the remaining time was used to search for hand tools and move dies. Procedural changes (such as moving the new die in place with the line in operation) and dedicated tool-racks reduced the die-change times to as little as 40 seconds. Today dies are changed in a ripple through the factory as a new product begins flowing.

After SMED, economic lot sizes fell to as little as one vehicle in some Toyota plants.

**Philosophy**

The philosophy of JIT is simple - inventory is defined to be waste. JIT inventory systems expose the hidden causes of inventory keeping and are therefore not a simple solution a company can adopt; there is a whole new way of working the company must follow in order to manage its consequences. The ideas in this way of working come from many different disciplines including statistics, industrial engineering, production management and behavioral science. In the JIT inventory philosophy there are views with respect to how inventory is looked upon, what it says about the management within the company, and the main principle behind JIT.

In short, the just-in-time inventory system is all about having “the right material, at the right time, at the right place, and in the exact amount”, without the safety net of inventory. The JIT system has implications of which are broad for the implementers.

There are strong cultural aspects associated with the emergence of JIT in Japan. The Japanese work ethic involves the following concepts.

* Workers are highly motivated to seek constant improvement upon that which already exists. Although high standards are currently being met, there exist even higher standards to achieve.
* Companies focus on group effort which involves the combining of talents and sharing knowledge, problem-solving skills, ideas and the achievement of a common goal.
* Work itself takes precedence over leisure. It is not unusual for a Japanese employee to work 14-hour days.
* Employees tend to remain with one company throughout the course of their career span. This allows the opportunity for them to hone their skills and abilities at a constant rate while offering numerous benefits to the company.

These benefits manifest themselves in employee loyalty, low turnover costs and fulfillment of company **goals.**

**Stocks**

JIT emphasises inventory as one of the seven wastes (overproduction, waiting time, transportation, inventory, processing, motion and product defect), and as such its practice involves the philosophical aim of reducing input buffer inventory to zero. Zero buffer inventory means that production is not protected from exogenous (external) shocks. As a result, exogenous shocks reducing the supply of input can easily slow or stop production with significant negative consequences. For example, Toyota suffered a major supplier failure as a result of the 1997 Aisin fire which rendered one of its suppliers incapable of fulfilling Toyota's orders. In the U.S., the 1992 railway strikes resulted in General Motors having to idle a 75,000-worker plant because they had no supplies coming in.

**Transaction cost approach**

JIT reduces inventory in a firm. However, unless it is used throughout the supply chain, it can be hypothesized that firms are simply outsourcing their input inventory to suppliers (Naj 1993). This effect was investigated by Newman (1993), who found, on average, suppliers in Japan charged JIT customers a 5% price premium.

 **Environmental concerns**

During the birth of JIT, multiple daily deliveries were often made by bicycle; with increases in scale has come the adoption of vans and lorries (trucks) for these deliveries. Cusumano (1994) has highlighted the potential and actual problems this causes with regard to [gridlock](http://en.wikipedia.org/wiki/Gridlock) and the burning of [fossil fuels](http://en.wikipedia.org/wiki/Fossil_fuels). This violates three JIT wastes:

1. Time; wasted in traffic jams
2. Inventory; specifically pipeline (in transport) inventory and
3. Scrap; with respect to petrol or diesel burned while not physically moving.

**Price volatility**

JIT implicitly assumes a level of input price stability such that it is desirable to inventory inputs at today's prices. Where input prices are expected to rise storing inputs may be desirable.

 **Quality volatility**

JIT implicitly assumes the quality of available inputs remains constant over time. If not, firms may benefit from hoarding high quality inputs.

 **Demand stability**

Karmarker (1989) highlights the importance of relatively stable demand which can help ensure efficient capital utilisation rates. Karmarker argues without a significant stable component of demand, JIT becomes untenable in high capital cost production. In the U.S., the 1992 railway strikes resulted in General Motors having to idle a 75,000-worker plant because they had no supplies coming in.

**JIT Implementation Design**

Based on a diagram modeled after the one used by Hewlett-Packard’s Boise plant to accomplish its JIT program.

1) **F** Design **F**low Process

 - **F** Redesign/relayout for **f**low

 - **L** Reduce **l**ot sizes

 - **O** Link **o**perations

 - **W** Balance **w**orkstation capacity

 - **M** Preventative **m**aintenance

 - **S** Reduce **S**etup Times

2) **Q** Total **q**uality control

 - **C** worker **c**ompliance

 - **I** Automatic *i*nspection

 - **M** quality **m**easures

 - **M** fail-safe **m**ethods

 - **W** Worker participation

3) **S** Stabilize **S**chedule

 - **S** Level **S**chedule

 - **W** establish freeze **w**indows

 - **UC** **U**nderutilize **C**apacity

4) **K** **K**anban Pull System

 - **D** **D**emand pull

 - **B** **B**ackflush

 - **L** Reduce **l**ot sizes

5) **V** Work with **v**endors

 - **L** Reduce **l**ead time

 - **D** Frequent **d**eliveries

 - **U** Project **u**sage requirements

 - **Q** **Q**uality Expectations

6) **I** Further reduce **i**nventory in other areas

 - **S** **S**tores

 - **T** **T**ransit

 - **C** Implement **C**arroussel to reduce motion waste

 - **C** Implement **C**onveyor belts to reduce motion waste

7) **P** Improve **P**roduct Design

 - **P** Standard **P**roduction Configuration

 - **P** Standardize and reduce the number of **p**arts

 - **P** **P**rocess design with **p**roduct design

 - **Q** **Q**uality Expectations

**Effects**

Some of the initial results at Toyota were horrible, but in contrast to that a huge amount of cash appeared, apparently from nowhere, as in-process inventory was built out and sold. This by itself generated tremendous enthusiasm in upper management.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed)]

Another surprising effect was that the response time of the factory fell to about a day. This improved customer satisfaction by providing vehicles usually within a day or two of the minimum economic shipping delay.

Also, many vehicles began to be [built to order](http://en.wikipedia.org/wiki/Build_to_Order), completely eliminating the risk they would not be sold. This dramatically improved the company's return on equity by eliminating a major source of risk.

Since assemblers no longer had a choice of which part to use, every part had to fit perfectly. The result was a severe quality assurance crisis, and a dramatic improvement in product quality. Eventually, Toyota redesigned every part of its vehicles to eliminate or widen tolerances, while simultaneously implementing careful [statistical controls](http://en.wikipedia.org/wiki/Statistical_process_control) for [quality control](http://en.wikipedia.org/wiki/Total_Quality_Management). Toyota had to test and train suppliers of parts in order to assure quality and delivery. In some cases, the company eliminated multiple suppliers.

When a process problem or bad parts surfaced on the production line, the entire production line had to be slowed or even stopped. No inventory meant that a line could not operate from in-process inventory while a production problem was fixed. Many people in Toyota confidently predicted that the initiative would be abandoned for this reason. In the first week, [line stops](http://en.wikipedia.org/w/index.php?title=Line_stop&action=edit&redlink=1) occurred almost hourly. But by the end of the first month, the rate had fallen to a few line stops per day. After six months, line stops had so little economic effect that Toyota installed an overhead pull-line, similar to a bus bell-pull, that permitted *any* worker on the production line to order a line stop for a process or quality problem. Even with this, line stops fell to a few per week.

The result was a factory that eventually became the envy of the industrialized world, and has since been widely emulated.

The just-in-time philosophy was also applied to other segments of the [supply chain](http://en.wikipedia.org/wiki/Supply_chain) in several types of industries. In the commercial sector, it meant eliminating one or all of the [warehouses](http://en.wikipedia.org/wiki/Warehouse) in the link between a factory and a retail establishment.

 **Benefits**

As most companies use an inventory system best suited for their company, the Just-In-Time Inventory System (JIT) can have many benefits resulting from it. The main benefits of JIT are listed below.

1. *Set up times are significantly reduced in the factory.* Cutting down the set up time to be more productive will allow the company to improve their bottom line to look more efficient and focus time spent on other areas that may need improvement. This allows the reduction or elimination of the inventory held to cover the "changeover" time, the tool used here is [SMED](http://en.wikipedia.org/wiki/SMED).
2. *The flows of goods from warehouse to shelves are improved.* Having employees focused on specific areas of the system will allow them to process goods faster instead of having them vulnerable to fatigue from doing too many jobs at once and simplifies the tasks at hand. Small or individual piece lot sizes reduce lot delay inventories which simplifies inventory flow and its management.
3. *Employees who possess multiple skills are utilized more efficiently.* Having employees trained to work on different parts of the inventory cycle system will allow companies to use workers in situations where they are needed when there is a shortage of workers and a high demand for a particular product.
4. *Better consistency of scheduling and consistency of employee work hours.* If there is no demand for a product at the time, workers don’t have to be working. This can save the company money by not having to pay workers for a job not completed or could have them focus on other jobs around the warehouse that would not necessarily be done on a normal day.
5. *Increased emphasis on supplier relationships.* No company wants a break in their inventory system that would create a shortage of supplies while not having inventory sit on shelves. Having a trusting supplier relationship means that you can rely on goods being there when you need them in order to satisfy the company and keep the company name in good standing with the public.
6. *Supplies continue around the clock keeping workers productive and businesses focused on turnover.* Having management focused on meeting deadlines will make employees work hard to meet the company goals to see benefits in terms of job satisfaction, promotion or even higher pay.

**Problems**

**Within a JIT system**

The major problem with just-in-time operation is that it leaves the supplier and downstream consumers open to [supply shocks](http://en.wikipedia.org/wiki/Supply_shock) and large supply or demand changes. For internal reasons, this was seen as a feature rather than a bug by Ohno, who used the analogy of lowering the level of water in a river in order to expose the rocks to explain how removing inventory showed where flow of production was interrupted. Once the barriers were exposed, they could be removed; since one of the main barriers was rework, lowering inventory forced each shop to improve its own quality or cause a holdup in the next downstream area. One of the other key tools to manage this weakness is [production levelling](http://en.wikipedia.org/wiki/Production_levelling) to remove these variations. Just-in-time is a means to improving performance of the system, not an end.

With very low stock levels meaning that there are shipments of the same part coming in sometimes several times per day, Toyota is especially susceptible to an interruption in the flow. For that reason, Toyota is careful to use two suppliers for most assemblies. As noted in Liker (2003), there was an exception to this rule that put the entire company at risk by the [1997 Aisin fire](http://en.wikipedia.org/wiki/1997_Aisin_fire). However, since Toyota also makes a point of maintaining high quality relations with its entire supplier network, several other suppliers immediately took up production of the Aisin-built parts by using existing capability and documentation. Thus, a strong, long-term relationship with a few suppliers is preferred to short-term, price-based relationships with competing suppliers. This long-term relationship has also been used by Toyota to send Toyota staff into their suppliers to improve their suppliers' processes. These interventions have now been going on for twenty years and result in improved margins for Toyota and the supplier as well as lower final customer costs and a more reliable supply chain. Toyota encourages their suppliers to duplicate this work with their own suppliers.

 **Within a raw material stream**

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As noted by Liker (2003) and Womack and Jones (2003), it would ultimately be desirable to introduce synchronised flow and linked JIT all the way back through the supply stream. However, none followed this in detail all the way back through the processes to the raw materials. With present technology, for example, an ear of corn cannot be grown and delivered to order. The same is true of most raw materials, which must be discovered and/or grown through natural processes that require time and must account for natural variability in weather and discovery. The part of this currently viewed as impossible is the *synchronised* part of flow and the *linked* part of JIT. It is for the reasons stated raw materials companies decouple their supply chain from their clients' demand by carrying large 'finished goods' stocks. Both flow and JIT can be implemented in isolated process islands within the raw materials stream. The challenge then becomes to achieve that isolation by some means other than the huge stocks they carry to achieve it today.

It is because of this almost all value chains are split into a part which makes-to-forecast and a part which could, by using JIT, become make-to-order. Often, historically, the make-to-order part has been within the retailer portion of the value chain. Toyota's revolutionary step has been to take [Piggly Wiggly's](http://en.wikipedia.org/wiki/Piggly_Wiggly) supermarket replenishment system and drive it back to at least half way through their automobile factories. Their challenge today is to drive it all the way back to their goods-inwards dock. Of course, the mining of iron and making of steel is still not done specifically because somebody orders a particular car. Recognising JIT could be driven back up the supply chain has reaped Toyota huge benefits and a world dominating position in the auto industry.

It should be noted that the advent of the [mini mill](http://en.wikipedia.org/wiki/Steel_mills#Mini_mills) steelmaking facility is starting to challenge how far back JIT can be implemented, as the electric arc furnaces at the heart of many mini-mills can be started and stopped quickly, and steel grades changed rapidly.

 **Oil**

It has been frequently charged that the oil industry has been influenced by JIT.

The argument is presented as follows:

The number of refineries in the United States has fallen from 279 in 1975 to 205 in 1990 and further to 149 in 2004. As a result, the industry is susceptible to supply shocks, which cause spikes in prices and subsequently reduction in domestic manufacturing output. The GDP figures for the third and fourth quarters showed a slowdown from 3.5% to 1.2% growth. Similar arguments were made in earlier crises.

Beside the obvious point that prices went up because of the reduction in supply and not for anything to do with the practice of JIT, JIT students and even oil & gas industry analysts question whether JIT as it has been developed by Ohno, Goldratt, and others is used by the petroleum industry. Companies routinely shut down facilities for reasons other than the application of JIT. One of those reasons may be economic rationalization: when the benefits of operating no longer outweigh the costs, including opportunity costs, the plant may be economically inefficient. JIT has never subscribed to such considerations directly; following Waddel and Bodek (2005), this ROI-based thinking conforms more to [Brown](http://en.wikipedia.org/wiki/Donaldson_Brown)-style accounting and [Sloan](http://en.wikipedia.org/wiki/Alfred_P._Sloan) management. Further, and more significantly, JIT calls for a reduction in inventory capacity, not production capacity. From 1975 to 1990 to 2005, the annual average stocks of gasoline have fallen by only 8.5% from 228,331 to 222,903 bbls to 208,986 ([Energy Information Administration](http://en.wikipedia.org/wiki/Energy_Information_Administration) data). Stocks fluctuate seasonally by as much as 20,000 bbls. During the 2005 hurricane season, stocks never fell below 194,000 thousand bbls, while the low for the period 1990 to 2006 was 187,017 thousand bbls in 1997. This shows that while industry storage capacity has decreased in the last 30 years, it hasn't been drastically reduced as JIT practitioners would prefer.

**Business models following similar approach**

 **Vendor Managed Inventory**

[Vendor Managed Inventory](http://en.wikipedia.org/wiki/Vendor_Managed_Inventory) (VMI) employs the same principles as those of JIT inventory however the responsibilities of managing inventory is placed with the vendor in a vendor/customer relationship. Whether it’s a manufacturer who is managing inventory for a distributor, or a distributor managing inventory for their customers; the role of managing inventory is given to the vendor.

The primary advantage of this business model is that the vendor has industry experience and expertise which enables them to better anticipate demand and inventory needs. The inventory planning and controlling is facilitated by the use of applications that allow vendors to have access to the inventory picture of its customer.

Third party applications offer vendors the benefit afforded by a quick implementation time. Further, such companies hold valuable inventory management knowledge and expertise that helps organizations immensely.

 **Customer Managed Inventory**

With [Customer Managed Inventory](http://en.wikipedia.org/w/index.php?title=Customer_Managed_Inventory&action=edit&redlink=1) (CMI), the customer as opposed to the vendor in a VMI model is given the responsibility of making all inventory decisions. This is similar to the concepts employed by JIT inventory. With a clear picture of their inventory and that of their supplier’s, the customer is able to anticipate fluctuations in demand and make inventory replenishment decisions accordingly.

 **See also**

* [Theory of Constraints](http://en.wikipedia.org/wiki/Theory_of_Constraints)
* [Lean Manufacturing](http://en.wikipedia.org/wiki/Lean_Manufacturing)
* [CONWIP](http://en.wikipedia.org/wiki/CONWIP)
* [Just in case](http://en.wikipedia.org/wiki/Just_in_case) Manufacturing
* [Just in Sequence](http://en.wikipedia.org/wiki/Just_in_Sequence)
* [Industrial Engineering](http://en.wikipedia.org/wiki/Industrial_Engineering)
* [Liquid Logistics](http://en.wikipedia.org/wiki/Liquid_Logistics)
* [Statistical process control](http://en.wikipedia.org/wiki/Statistical_process_control)
* [Total Quality Management](http://en.wikipedia.org/wiki/Total_Quality_Management)
* [Vendor Managed Inventory](http://en.wikipedia.org/wiki/Vendor_Managed_Inventory)

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