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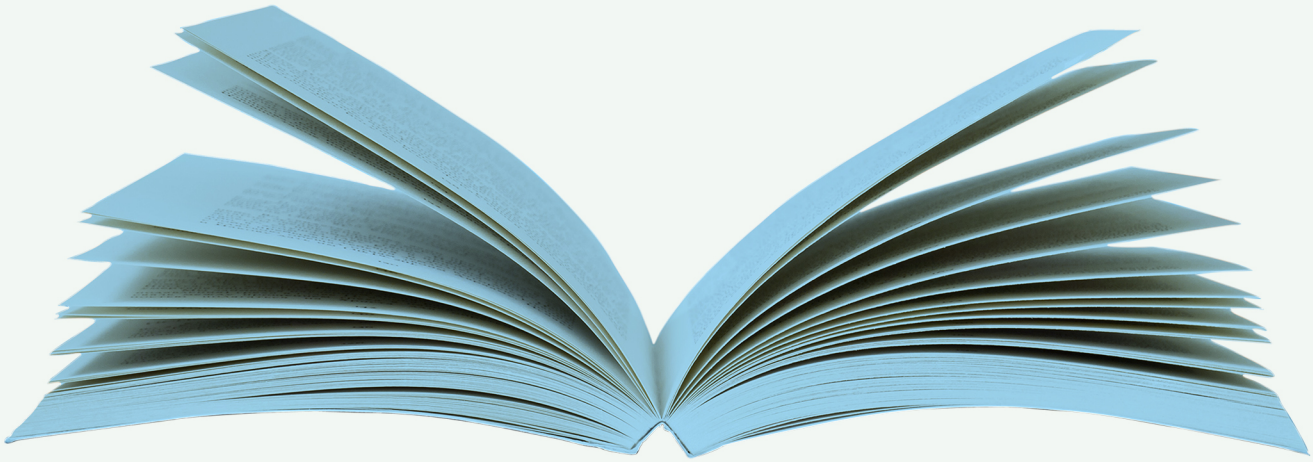
TC S362 Manufacturing and Inspection Technologies (Free Courseware)



香港公開大學
THE OPEN UNIVERSITY OF HONG KONG

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Chapter 1 Manufacturing systems

1.1 Introduction

Welcome to this free courseware topic, 'Manufacturing systems'!

This topic is taken from *Unit 1* of one of our OUHK distance learning courses, *TC S362 Manufacturing and Inspection Technologies*. *TC S362* is one of the core courses of the BSc/Bsc (Hons) in Product Design, Testing and Certification programme. The course provides comprehensive coverage of the technologies used in the manufacturing and inspection processes of goods. It is a one-semester, higher level course with a credit point value of 5.

Units in OUHK courses normally contain various elements to enhance the content, such as activities, self-tests, figures and assigned readings. You can find most of these elements in the courseware here so that you can have a taste of what an OUHK course is like. In addition to this topic on manufacturing systems, the original unit also contains topics on the major manufacturing processes and their management, manufacturing industry categories and quality assurance.

TC S362, like most OUHK courses, is presented in the distance learning mode using print-based materials. The materials for this free courseware have been specially adapted to make them more suitable for studying online.

In this module, we will look at how manufacturing systems have developed over the years, comparing and contrasting the various systems that have sprung up in different countries. We will then move into the present as we study four modern manufacturing systems that are commonly used: mass production, just-in-time manufacturing, lean manufacturing and flexible manufacturing.

The module should take around **4 hours** to complete, including time spent on activities and self-tests.

1.2 Manufacturing

Let's start by defining what we mean by manufacturing (http://en.wikipedia.org/wiki/Manufacturing). Manufacturing is not a new concept. As early as the Stone Age (http://en.wikipedia.org/wiki/Stone_Age), human beings used stones as tools to cut materials, such as tree branches, bamboo, and rattan and then connect different component parts to form simple products such as wooden sampans, tripods and huts. A sharp edged stone alone can cut soft things. When the stone is tied to a stick it becomes a hammer or an axe. The hammer or axe can be used for hunting and killing animals

and even cut them into pieces of meat for consumption. At this stage humans started making tools and using them in simple processes to create products for their own use.

After years of development, human beings invented more tools and even machines that could provide higher power during operations and further assist workers to produce products in a faster manner and of better quality. The higher production rate gave rise to the concept of manufacturing with the use of machinery, tools and equipment through a series of planned activities, either by manual and/or automation systems operations, for producing goods on a large scale for use and/or sale.

Today, the term 'manufacturing (In some industries, instead of manufacturing, the term 'fabrication' is commonly used, such as the fabrication of semiconductors and steel.)' is commonly applied to large scale industrial production, by which raw materials are treated through various controlled processes, then different parts of materials are connected or joined together to form the finished goods with the desired appearance and purpose. For example, cloth in the weaving industry is produced from cotton which has to go through a series of processes and treatments. In the toy industry, different component parts are assembled and joined together to become a single unit product for entertaining children and adults. Another example is a television, which is also produced by assembling many components together. After testing and adjusting the various parts, audio signals and video images can be displayed to viewers.

In a market economy, mass production is the usual process in manufacturing. Products are produced under the consideration of cost effectiveness so that buyers and/or consumers receive the maximum benefit. A number of different manufacturing systems have been adopted to ensure the highest cost-effectiveness in production. In the global free market, there are also certain degrees of government regulation, such as labour, safety, quality, and environmental regulations. These regulations protect workers' rights to fair employment terms and, importantly, ensure that the goods produced and the waste generated are not harmful to human beings and the earth.

1.3 Development of manufacturing systems

In past centuries, manufacturing was usually performed by labourers or semi-skilled workers who used hand tools and very little machinery to produce goods. Productivity was low and the quality of products varied from factory to factory as well as from worker to worker even within the same production line and environment and using the same machinery and tools. Even the most skilful workers could not produce two completely identical goods with the same tools and procedures. In the last two decades, the manufacturing process has been transferred to semiautomatic or full automation with the result that productivity has become higher and more cost-effective, and products can be manufactured to much higher quality standards.

Indeed, in the last 20 years many manufacturing factories have moved from other regions in the world to manufacture or assemble their goods in China or countries in

South East Asia where cheap labour gives a cost advantage. This includes US and Japanese companies manufacturing famous brand goods. The use of cheap labour also means a certain degree of adjustment from full automation back to semi-automation in production.

In the 1970s and 1980s Hong Kong manufactured many popular goods such as watches and toys. After the opening up of economic policy in China in the early 1980s, many Hong Kong manufacturers started moving their manufacturing lines into China to gain the benefits of cheap labour and government support in terms of tax privileges and low factory rent. However, in recent years, rising remuneration, higher factory rents, and better benefits for workers through new government regulations have meant that manufacturers have had to upgrade their production lines with more automation systems or move to new provinces with lower labour and factory rental costs to reduce overall manufacturing costs.

1.3.1 English system of manufacturing

The early English system of manufacturing (http://en.wikipedia.org/wiki/English_system_of_manufacturing) began with skilful technicians who produced parts or products for a model or from a design. A skilful worker was responsible for producing all the different parts of the design from the beginning to the end product. Both the production quantity and production rate were low. Moreover, this manual production method could not produce exactly identical products when the ordered quantity was more than one. The dimensions of identical parts of the same design varied during the hand production process. As a result of deviations from the manual process, workers were grouped separately in order to produce a minimum number of parts. This minimized the size deviations induced from different workmanship. By using such a decentralized production process, the dimensions of each component part produced became more accurate and closely identical to each other. The fitting of a part to its counterpart was therefore more accurate and reliable so that every produced part was interchangeable with its similar part. Hence, the cost for reworking or material wastage could be minimized and the quality improved.

1.3.2 American system of manufacturing

The American system of manufacturing (http://en.wikipedia.org/wiki/American_system_of_manufacturing) evolved over the 19th century. The system featured a set of manufacturing methods that involved semi-skilled workers using machine tools (http://en.wikipedia.org/wiki/Machine_tool) and jigs (http://en.wikipedia.org/wiki/Jig_%28tool%29) to produce standardized and identical interchangeable parts for achieving better specified tolerances. These methods produced parts that could be assembled and fitted together with minimal mismatches and reworked within a limited time, and with limited skills and labour. This system introduced the concept of

quality assurance (http://en.wikipedia.org/wiki/Quality_assurance) in manufacturing. Because it was American companies that first successfully adopted the system, it was called the American system of manufacturing.

The demand for the manufacturing of interchangeable identical parts initiated the development of parts production by semi-skilled labour with the assistance of accurate precision machines and tools. As a result, there was reduced demand for fully skilled workers. Such manufacturing process development became the dominant management strategy and resulted in the division of labour for higher productivity and product quality standards.

The use of machinery in operations and machine tools brought about quality benefits such as consistency in interchangeability of parts and higher productivity. This then led to the concept of a quality assurance system. Such advantages encouraged manufacturers to come up with more ideas for innovations. These same advantages also led to the development of new machine tools, jigs and fixtures for producing more accurate and higher quality products.

1.3.3 Soviet collectivism of manufacturing

The economy of the former Union of Soviet Socialist Republics (USSR) was characterized by a system of state owned production. The government applied a system of collective farming (https://en.wikipedia.org/wiki/Collective_farming) and used centralized administrative planning for manufacturing. The government planned and controlled the economy and investment, while industrial assets were publicly owned. Under the centralized policy, individual citizens lacked initiative for production; as a result socioeconomics was hindered by lack of progress for a number of decades.

From 1928 to 1991 the entire USSR economy was based on a series of Five-Year Plans. For a period of around 40 years during this period, the USSR was one of the world's three top manufacturers of many capital goods. The country could manufacture heavy industrial products, especially military weaponry, extremely efficiently. However, the country fell behind in light industrial production and consumer products. This was because the economic planning committee only focused on the development of heavy goods and ignored the market needs of light products.

1.3.4 China's system of manufacturing

China has been an agricultural country since the establishment of the People's Republic of China (PRC) in 1949. In 1978 China promoted and implemented the Four Modernizations (1979–82) (http://en.wikipedia.org/wiki/Four_Modernizations) in the fields of agriculture, industry, national defense, and science and technology. It also introduced a market-based economy to reform China. Since then its economy has

grown very quickly. China has maintained stable annual growth, even during the financial turmoil in 2008.

Before the 1980s, the manufacturing policy in China was quite similar to that of the USSR. It was characterized by state ownership in production, collective farming, and centralized administrative planning. China's production policy involved heavy industry such as steel and automotive manufacturing. However, this was of rather low quality and mainly for national use only. The manufacturing system relied greatly on manual labour with low product quality. The opening up of Special Economic Zones (http://en.wikipedia.org/wiki/Special_Economic_Zones_of_the_People%27s_Republic_of_China) after 1980 introduced new technology and management skills to increase productivity and product quality.

After the return of Hong Kong to China in 1997, many Hong Kong manufacturers started to invest in low-tech and high-tech machinery in China. This stimulated the fast evolution of the manufacturing economy. China began to offset its economic policy, modifying state ownership of production and collective farming as well. This new policy provided a greater degree of freedom to the public in production and economic activities, while centralized administrative planning remained under the control of the national government. Manufacturing activities involved many heavy industries, including domestic and military products. Moreover, China frequently gave incentives and privileges to investors to push the development of production in Special Economic Zones. Today, China has been called the 'world's factory' with goods from light industry (such as electronic products) to heavy industry (including automotives, train and planes) being manufactured in many provinces. However, despite the introduction of automation technologies, many semi- or manual-manufacturing systems are still being used in remote villages and provinces. This provides a cheaper labour force and a simple assembly process.

By now you should have some idea of the development of manufacturing systems in several major countries. Now have a go at Self-test 1 (Page 5) to check how well you have followed the stages of the development of manufacturing systems.

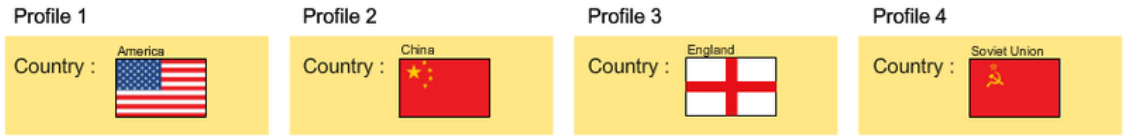
1.3.5 Self-test 1

Profile 1	Profile 2	Profile 3	Profile 4
Country:	Country:	Country:	Country:

Profile 1	Profile 2	Profile 3	Profile 4
Manufacturing policy:			
Privately owned production	Mainly state owned but gradually become privatized	Privately owned production	Mainly state owned
Automation:			
Early adoption of modernized automation systems	Started adopting machinery from about 1980s and then encouraged full automation	Early adoption of modernized automation systems	Early use of automation systems
Type of industry:			
High technology, IT, computers, electrical appliances, military weaponry	From 1949 to 1979 mainly light industry and collective farming; low quality heavy industry such as steel and vehicles, toys, telecommunications, food, aerospace, railway and energy, etc	Steel, vehicles, railway, energy, machinery and tools, electrical appliances	Heavy industry and specialized in military weaponry
Product:			
High-tech products such as PCs, mobile phones, and military weaponry	Domestic electronics and electrical appliances, toys, textiles, food and beverage	Heavy industry , such as energy, construction machinery vehicles	Military weaponry
Development:			
Decentralization in production highly improved the production	Energy, transportation, telecommunications, finance, PCs, and food	Decentralization in production highly improved the production	Slow progress

Profile 1	Profile 2	Profile 3	Profile 4
rate and quality of products		rate and quality of products	
Trend:			
Low end products and light industry are outsourced to countries with low labour cost	Full range from light to heavy industry with high technologies	Low end products and light industry are outsourced to countries with low labour cost	Slow progress

1.3.5.1 Self-test 1 feedback



1.4 Modern manufacturing systems

You now have a general idea about the past and modern development of manufacturing. Today, manufacturers are adopting quite a number of manufacturing systems, with some manufacturers even adopting more than one system in their business. This section will introduce four common manufacturing systems.

1.4.1 Mass production

Mass production (https://en.wikipedia.org/wiki/Mass_production) is a method of producing standardized goods in large quantities so that the goods can be produced at the lowest cost per unit, while the quality of the goods can also be maintained at specified standards. The standardization and/or quality of products can be achieved through precision-manufacturing. The mass production process normally adopts automated equipment for transferring parts and materials; as well as using automated systems of machinery to achieve high volume production. The parts and

materials flowing through different stages in the manufacturing process are well organized. Quality control (http://en.wikipedia.org/wiki/Quality_control) of various production parts takes place by programming automated precision machinery and the division of labour to ensure the high quality of products. This mass production system can be applied to many kinds of products, from fluids to particulates, and discrete solid parts. Some examples are: fuel, chemicals, minerals, foodstuffs and discrete solid parts for assembly of larger products (such as household appliances and machinery).

Mass production relies on the use of machinery and system automation with the smallest possible labour force. It is therefore important and necessary to invent and develop modernized and intelligent machines. Nowadays, mass production systems use a lot of precision machines and equipment to produce large numbers of identical parts at very low cost with the minimum labour.

A mass production system affects the organization of work in many ways:

- Tasks can be subdivided and performed by unskilled workers or semi-skilled workers.
- Most operation skills are built into and operated by precision machines.
- The manufacturing process is more complicated so many of the management and operation controls are performed by supervisory and managerial staff.
- The increasing complexity of operations demands more skilful technical staff.
- A labour force can be divided into national and international regions. A factory can have different production lines for the production of various parts in different countries.

Honda Motor Co. (http://www.honda.com/) uses mass production of cars in China. In March 1999, the Japanese carmaker announced that it would invest in and produce 10,000 cars in China in that year, and the manufactured cars would be sold to the US. Output would also be increased to 30,000 by 2001, and the quantity could be raised to 50,000 in the future. However, the company felt that China might not have adequate or good quality parts for manufacturing the cars, so parts and components would be imported from Japan, the US, Thailand and Malaysia (*Asian Economic News*,1999).

The following video clip (http://www.youtube.com/watch?v=5-eVjxCO-OE) shows the Motor Honda Mass Production Line in the application of machineries and automation systems with minimal workers.

1.4.2 Just-in-time manufacturing

Just-in-time (JIT) production (http://en.wikipedia.org/wiki/Just_in_time_%28business%29), also called the Toyota Production System (http://en.wikipedia.org/wiki/Toyota_Production_System), is a production strategy for reducing in-process inventory and production costs. In the JIT system a signal (also called a *kanban (https://en.wikipedia.org/wiki/Kanban)*) is generated between different points in the production process. The signal, designed to be visually observed easily by supervisory staff, tells the production staff when to request the next part so that materials can be delivered

to the production line at just the right time without delay or too early. The signal may indicate the presence or absence of a part on a shelf. JIT also gives an indication of stock depletion so that replenishment orders for new stock can be placed at the right time. When products are completed on time, they are delivered to customers as soon as possible. This method ensures the calculation of the most exact quantity of parts in the assembly line and thus minimizes the storage of excess parts during the production process. This reduces the storage space and costs of the parts. The finished goods are moved out to customers to reduce the need for large storage spaces. An excess supply of parts may need to be returned to storage afterwards. Therefore, JIT helps improve efficiency, cost-effectiveness, production time and productivity.

However, in the production line there should be a sequence of workstations operating together to produce products. This means that failure or interruption to any workstation will affect the operation of the whole production line.

Advantages of JIT production are as follows:

- It helps calculate the exact quantity of parts in a production line; hence reducing excess storage of parts/materials (or zero inventory) on the production line.
- It gives signals for the next part/material to be delivered to the production line to avoid interruption of production.
- It provides signals for parts/materials delivery to the production line at the right time without delay or early delivery.
- It gives a notice on stock depletion and alerts re-ordering of parts/materials.
- It improves production efficiency, costs-effectiveness, production time, and productivity.
- It helps to manufacture high quality products at low cost.

The Toyota Motor Corporation (http://www.toyota-global.com) uses the just-in-time manufacturing system. Find out what difference JIT manufacturing has made to Toyota's productivity by completing Activity 1 (Page 9).

1.4.2.1 Activity 1

Read about the Toyota production system concept (http://www.toyota-global.com/company/vision_philosophy/toyota_production_system).

How has Toyota achieved 'productivity improvement' through the implementation of JIT?

1.4.2.1.1 Activity 1 feedback

Toyota has adopted the slogan 'Making only what is needed, when it is needed and in the amount needed!' To achieve this, as soon as an order for a vehicle is received, an

instruction is immediately issued to the beginning of the production line to start the production process. The production line is kept stocked with all the necessary parts for assembling any kind of vehicle. Whenever parts are used, the assembly line retrieves an equivalent number of those parts to replace them. A small number of all types of parts are kept in the parts-producing process, and new parts are produced only to replace those parts just used. This JIT production method eliminates wastage and production of unnecessary parts and makes the production process more efficient.

1.4.3 Lean manufacturing

Lean manufacturing (http://en.wikipedia.org/wiki/Lean_manufacturing) is a management philosophy derived mostly from the Toyota Production System. Lean manufacturing is a production practice which aims to reduce wastage of expenditure of resources. The system aims to reduce the expense of product design or resources that may not create value to customers in a customer's view. Manufacturers should understand and know what customers need and what they would like to pay for in terms of the actions or processes for the products. Suppliers have to be responsive to customers' needs as well as ensuring market competitiveness so they have to focus on the customer's view of product value and avoid valueless work. Hence, lean manufacturing can decrease waste and improve efficiency in manufacturing.

Lean manufacturing steps:

- Identify customer wants.
- Identify actions to add value to products, such as design, development, and production tasks.
- Manage information on ordering, service schedule, and delivery.
- Establish pull manufacturing so that products produced are on customer orders.
- Establish continual improvement approaches to reduce wastage.

The Toyota Motor Corporation also uses the lean manufacturing system to deploy manufacturing processes that address customers' needs and wants in terms of five expectations: safety, quality, delivery and production, cost, and technological capabilities.

1.4.4 Flexible manufacturing

A flexible manufacturing system (FMS) (http://en.wikipedia.org/wiki/Flexible_manufacturing_system) has a certain flexibility level that allows the manufacturing system to react to changes, predicted or unpredicted, to improve productivity. It is an integration of manufacturing processes, operations, and management that gives a built-in flexibility of online changes to machines, tooling, and operations. The flexibility can be divided into two categories:

1. Machine flexibility — the ability to change for producing new product types, and changes to orders.
2. Routing flexibility — the ability of multiple machines to perform the same operation on a part, and adapt to changes in volume and capacity.

Advantages of FMS include:

- time efficiency and better effort for manufacturing a new product;
- flexible and suitable for the production of small sets of products in mass production;
- flexible manufacturing cells can be highly automated and unmanned;
- variable production size that can be small and at lower unit cost;
- reduced direct labour and inventories; and
- short lead time for product changes.

Now test your understanding of the four manufacturing systems we have discussed in this section by completing Self-test 2 (Page 11).

1.4.4.1 Activity 2

Watch the following promotional video (http://www.youtube.com/watch?feature=endscreen&v=hNGzFJqUnjE&NR=1) which demonstrates the advantages of a particular flexible manufacturing system.

1. Think about the system abilities and state whether they belong to machine flexibility or routing flexibility.

2. What production advantages of FMC are highlighted in the video?

1.4.4.1.1 Activity 2 feedback

The video introduces multiple milling processes working simultaneously, and other processes such as washing the workpiece, which can also be integrated into the system. See if there are any benefits in cost effectiveness to customers; optimization of resources and time saving; and space requirements in operations.

1.4.5 Self-test 2

List at least four differences and four similarities of the four systems above (mass production, just-in-time manufacturing, lean manufacturing and flexible manufacturing) and give examples of manufacturing products that are produced under these systems by completing the following table.

Hint: one difference is that customers' focus is different; one similarity is the ability to reduce manufacturing costs; and one product example that applies to the four systems can be car manufacturing.

	Possible differences	Possible similarities	Examples of products
1. Mass production			
2. Just-in-time			
3. Lean manufacturing			
4. Flexible manufacturing			

1.4.5.1 Self-test 2 feedback

	Possible differences	Possible similarities	Examples of products
1. Mass production	Different customers	Reduce costs	Different vehicle models
2. Just-in-time	Applications of technologies	Improve product quality	Variety of food types
3. Lean manufacturing	Manual to automation	Reduce labour requirements and factory space	Furniture either tailor-made or made according to standard design

	Possible differences	Possible similarities	Examples of products
4. Flexible manufacturing	Complexity of product design	Reduce waste	Building construction

1.5 Conclusion

In this module we have covered the history and development of manufacturing and production, from hand tools and machines to applications of semi-automatic machines to computer-aided systems into full automation in manufacturing. We've looked at how manufacturing has developed in four areas of the world in particular: England, America, Russia and China. You've also been given an overview of four commonly used manufacturing systems and have compared their respective advantages.

The development of manufacturing systems tells us that under a competitive market, manufacturers and their engineers need to continually improve their productivity and product quality with more efficient systems and processes. The adoption of computer-aided manufacturing systems can definitely help to improve productivity and product quality. Having studied this module, you should now have a general idea of where manufacturing systems have come from, how they are implemented in the present, and where they may be heading in the future.