Chapter 7
How Toyota Shorten Production Lead Time

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CONTENTS

7.1 FOUR ADVANTAGES OF SHORTENING LEAD TIME

- *Production lead time* is the time interval from production dispatching to delivery of completed products.

- Having the flexibility to respond to market demand and the stability of smoothed production requires shortening the production lead time.

7.1 FOUR ADVANTAGES OF SHORTENING LEAD TIME

- Shortening lead time has four advantages.

- Toyota can achieve job-order oriented production that requires only a period to deliver a particular car to the customer.

- The company can adapt quickly to changes in demand in the middle of the month to minimize the inventory of finished products.

7.1 FOUR ADVANTAGES OF SHORTENING LEAD TIME

- Shortening lead time has four advantages (continued).

- Work-in-process inventory can be decreased by minimizing unbalanced production timing among the various processes and also by reducing the lot size.

- When a model change is introduced, the amount of "deadstock" on hand is minimal.

7.2 COMPONENTS OF PRODUCTION LEAD TIME IN A NARROW SENSE

- In a narrow sense, lead time consists of
  - queue time before processing
  - setup time
  - run time
  - wait time after processing
  - move time

7.2 COMPONENTS OF PRODUCTION LEAD TIME IN A NARROW SENSE

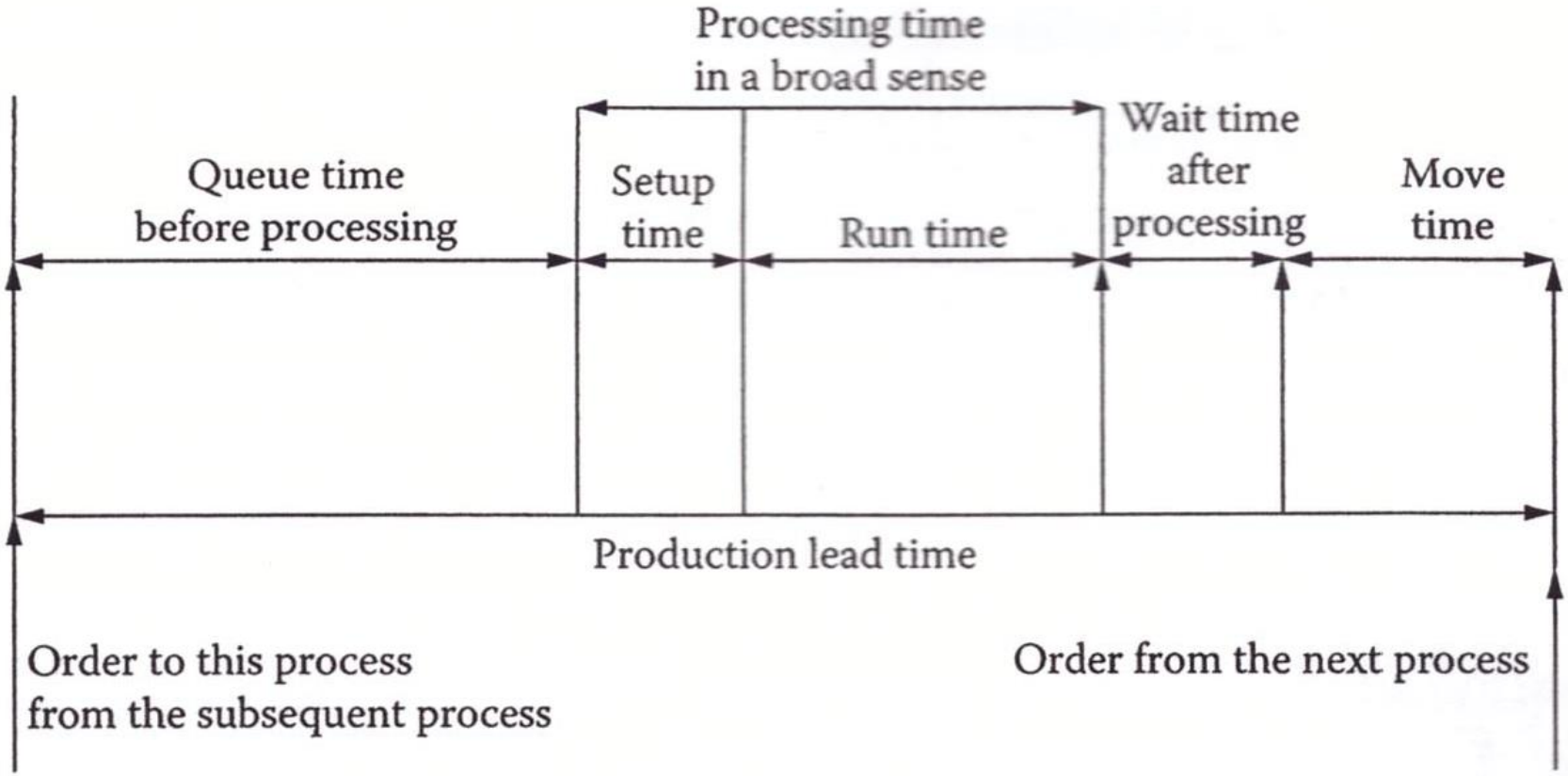
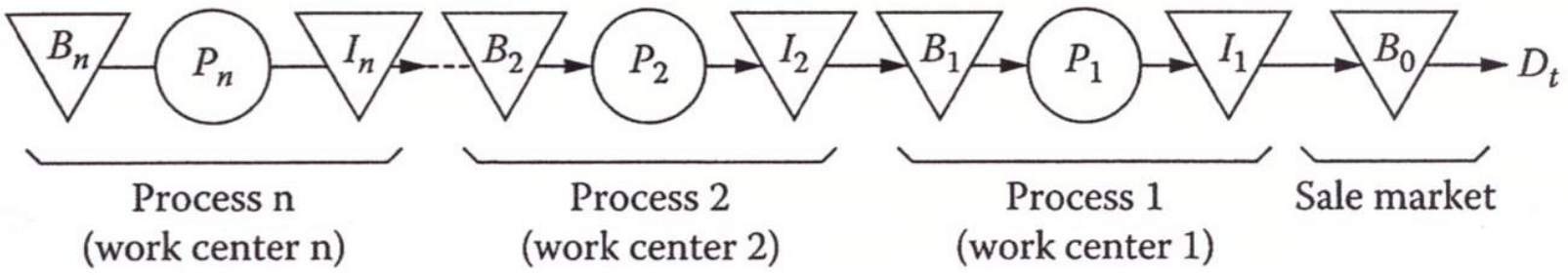


FIGURE 7.1
Components of production lead time.

7.2 COMPONENTS OF PRODUCTION LEAD TIME IN A NARROW SENSE



where

P_i = Process i (or work-center i), which performs the production activity itself ($i = 1, ...,n$).

I_i = Inventory i, which was produced through the production activity of process i ($i = 1, ...,n$).

B_i = Line-side inventory i of parts to be processed in the Process i.

Consequently, all of B_i, P_i and l_i exist in the process i. Also, units are conveyed from I_{i+1} to B_i

D_t = Quantity of demand during the period t in the market.

B_o = Dealers' inventory in the market.

FIGURE 7.2

A chain of multi-process production.

7.2 COMPONENTS OF PRODUCTION LEAD TIME IN A NARROW SENSE

- The components of production lead time can be narrowed down into three categories

  - processing time
  - wait time
  - move time

To achieve JIT, each of these components should be shortened.

7.2 COMPONENTS OF PRODUCTION LEAD TIME IN A NARROW SENSE

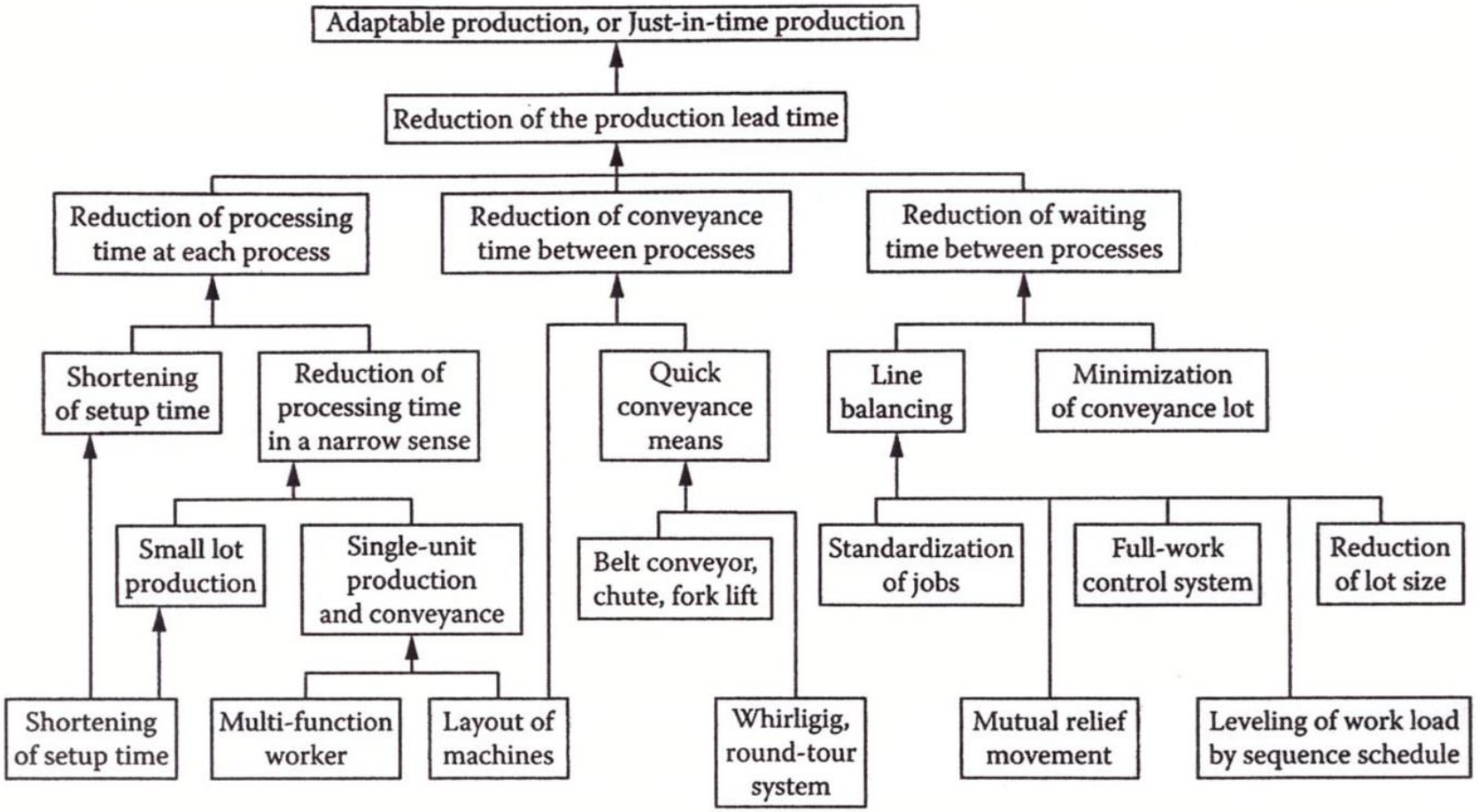


FIGURE 7.3

Framework for reducing lead time.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- Toyota refined the moving assembly concept of the conveyor system that characterizes the Ford System.

- The operation time and conveyance time of every process in the line must be equalized.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- In TPS, a unit of car can be produced in every cycle time.
- Meanwhile each unit of the output of any process will be sent to the next process.
- The cycle time consists of equalized operation time and conveyance time.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- In Toyota, such a production flow is called *single-unit production and conveyance* (*or one-piece production, Ikko-Nagashi*).
- All Toyota plants use an integrated single-unit flow of production, which is all connected to the assembly line.
- The operation is limited to small lot production.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- Consider a plant that uses Adam Smith's pin manufacturing (division of labour). 

- with various machines for various processes

- multiple machines are required for each type of operation

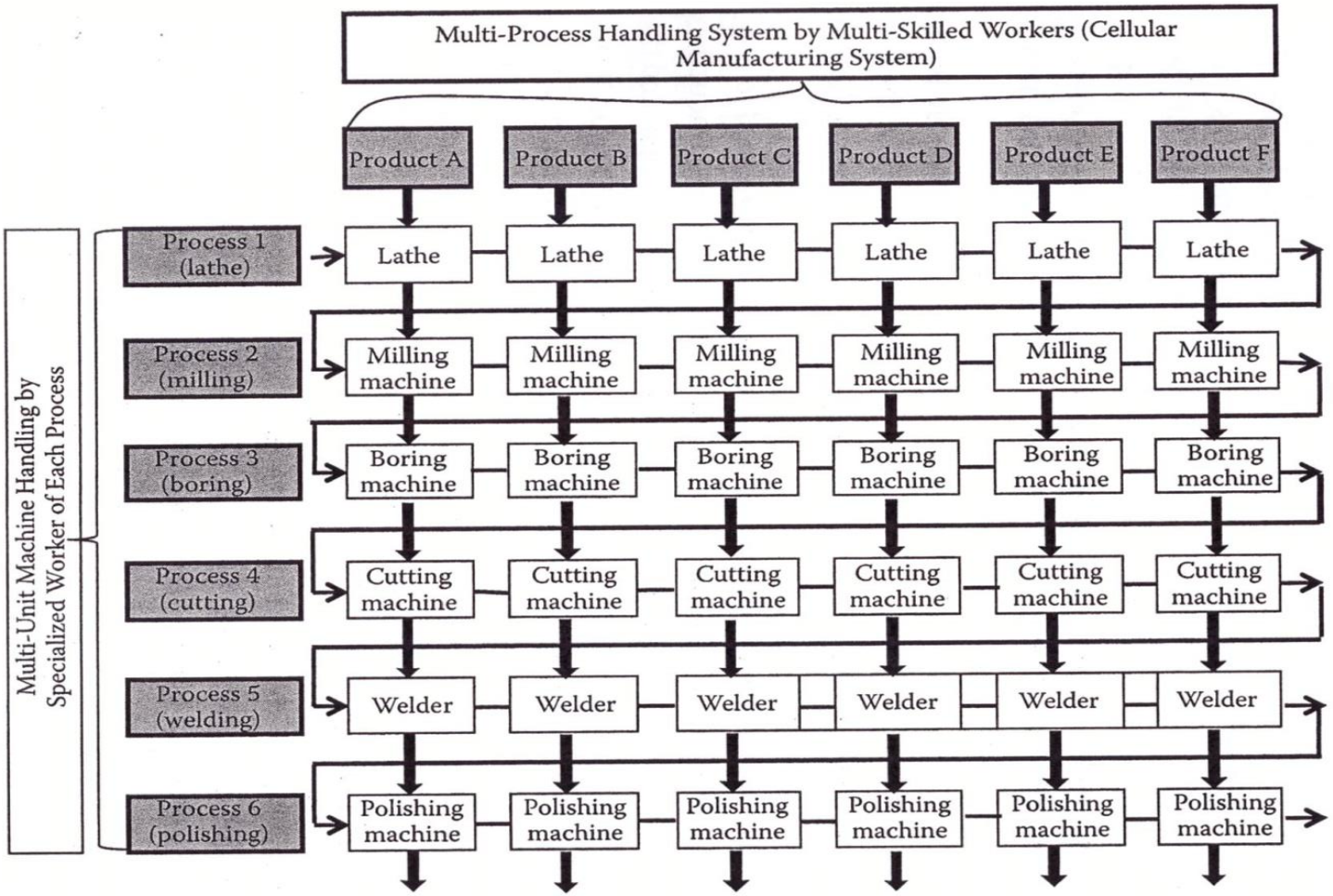


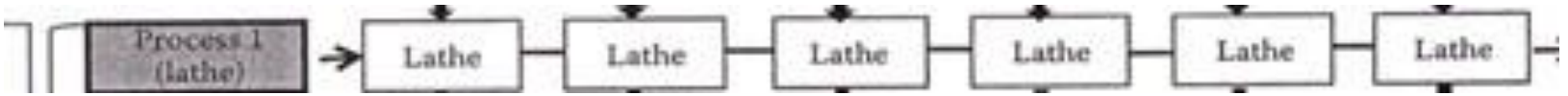
FIGURE 7.4
"Job-shop" manufacturing and "product-flow" manufacturing.

- Machines are grouped by type, and workers are assigned to each machine (*job-shop layout*).

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- If each worker handles only one machine, the worker will have waste of waiting time.

- If one worker handles all machines of the same type (e.g., lathe),

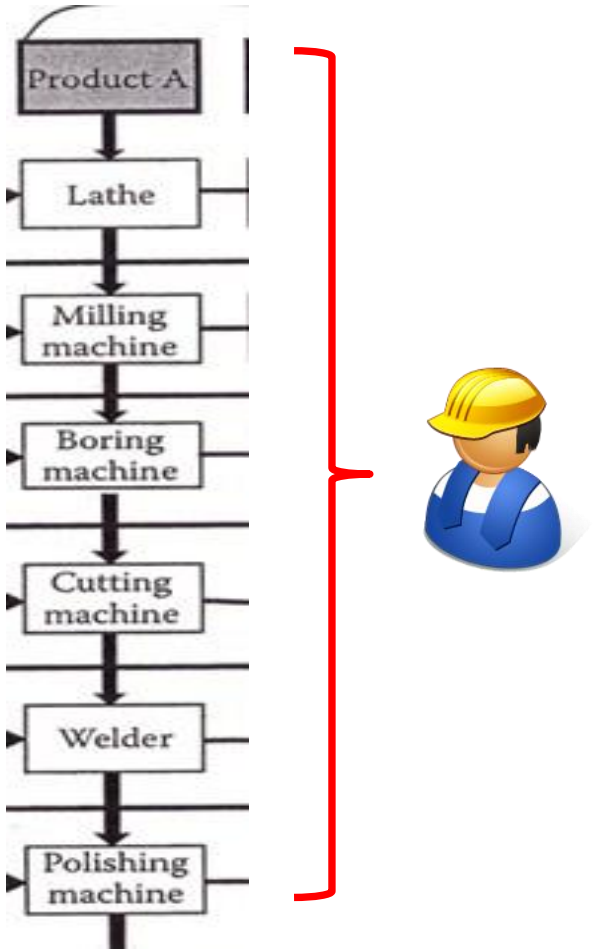


  - productivity will be increased

  - the stock of products or work-in-process will be large

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- In TPS, a multi-skilled worker handles a variety of machines.
- This machine layout is called *product-flow layout* or *flow-shop layout*.



7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

	Product Flow Layout	Job Shop Layout
Lot size	Small (usually one-piece)	Large
Lead time	Short	Long
Adaptability to demand changes	Speedy	Not speedy
Work-in-process inventory	Few	Many
Detectability of defects	Easy to find	Not easy to find
Skill of worker	Multi-skilled	Single-skilled
Machine	Small and less expensive	Big and expensive
Conveyance	Almost none	Much
Detectability of wastes	Easy to find wastes of conveyance, waiting, etc.	Hard to find wastes of conveyance, waiting, etc.
Productivity	Total optimization (productivity increase of the whole plant)	Sub-optimization (productivity increase of each machine)

FIGURE 7.5
Merits of product-flow layout compared to job-shop layout.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- To achieve smoothed production, all processes must ideally produce and convey only one piece corresponding to each car coming off the assembly line.

- All workshops must ideally avoid lot production and lot conveyance.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

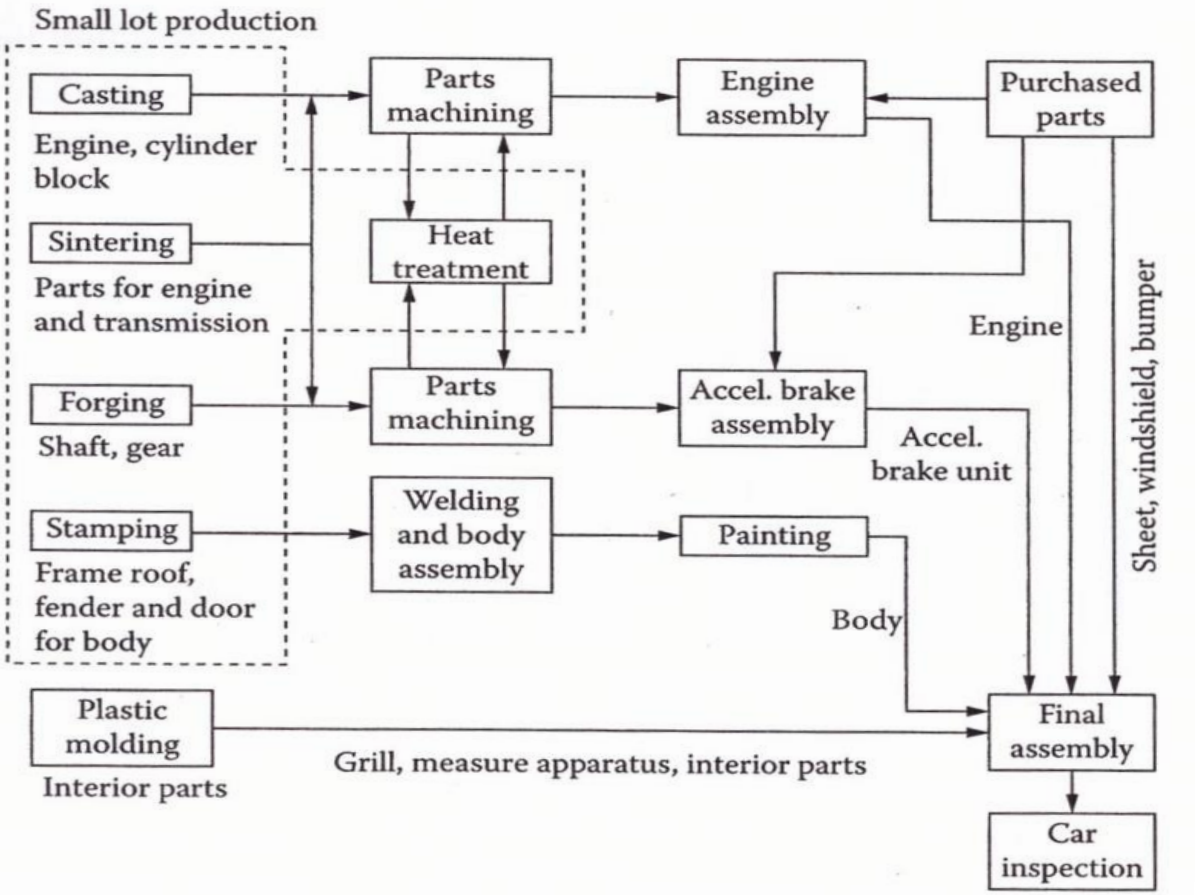
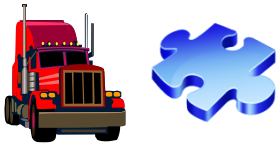


FIGURE 7.6
Toyota's production process.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- The processes in Toyota's plant can be classified into five categories.
  - casting and pressing 
  - parts machining 
  - parts assembling 
  - body welding 
  - final assembly line 

 Lot production

 Single-unit production

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- In lot production, lot size must be reduced to shorten processing time.

- Suppose that processing time for unit part A is 1 minute and the lot size is 3000.

Total processing time for each lot = 3000 minutes = 50 hours

- If the lot size is reduced to 300.

Total processing time for each lot = 300 minutes = 5 hours

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- If the setup time in changeover of the lots is kept constant, the total setup time will increase. Why?

- The setup time must also be shortened when lot sizes are reduced.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- If the setup time is 1 hour and the lot size is 3000,

Total production time = 1 hour + 1 minute ×3000 = 51 hours

- If the setup time is 6 minutes and the lot size is 300,

Total production time = (6 minutes + 1 minute ×300) × 10
= 51 hours

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- If the setup time was reduced to $1/N$ of the initial time, the lot size could be reduced to $1/N$ of its initial size without changing the loading rate of the process in question.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- Assume there are three types of parts: A, B, and C.
- Processing time of any part, per unit, is 1 minute and the setup time of alternating the lots is 1 hour.
- Lot size of any part is 3000.

Total production time for one lot of parts A, B, and C
= 51 hours ×3 = 153 hours

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- Consider that the lot sizes of parts A, B, and C were reduced to 300, and the setup time is reduced to 6 minutes.

- Production of parts B and C are inserted into the 10 production runs for part A.

Total production time for one lot of parts A, B, and C
= (6 minutes + 1 minute ×300) ×3 = 15 hours and 18 minutes

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

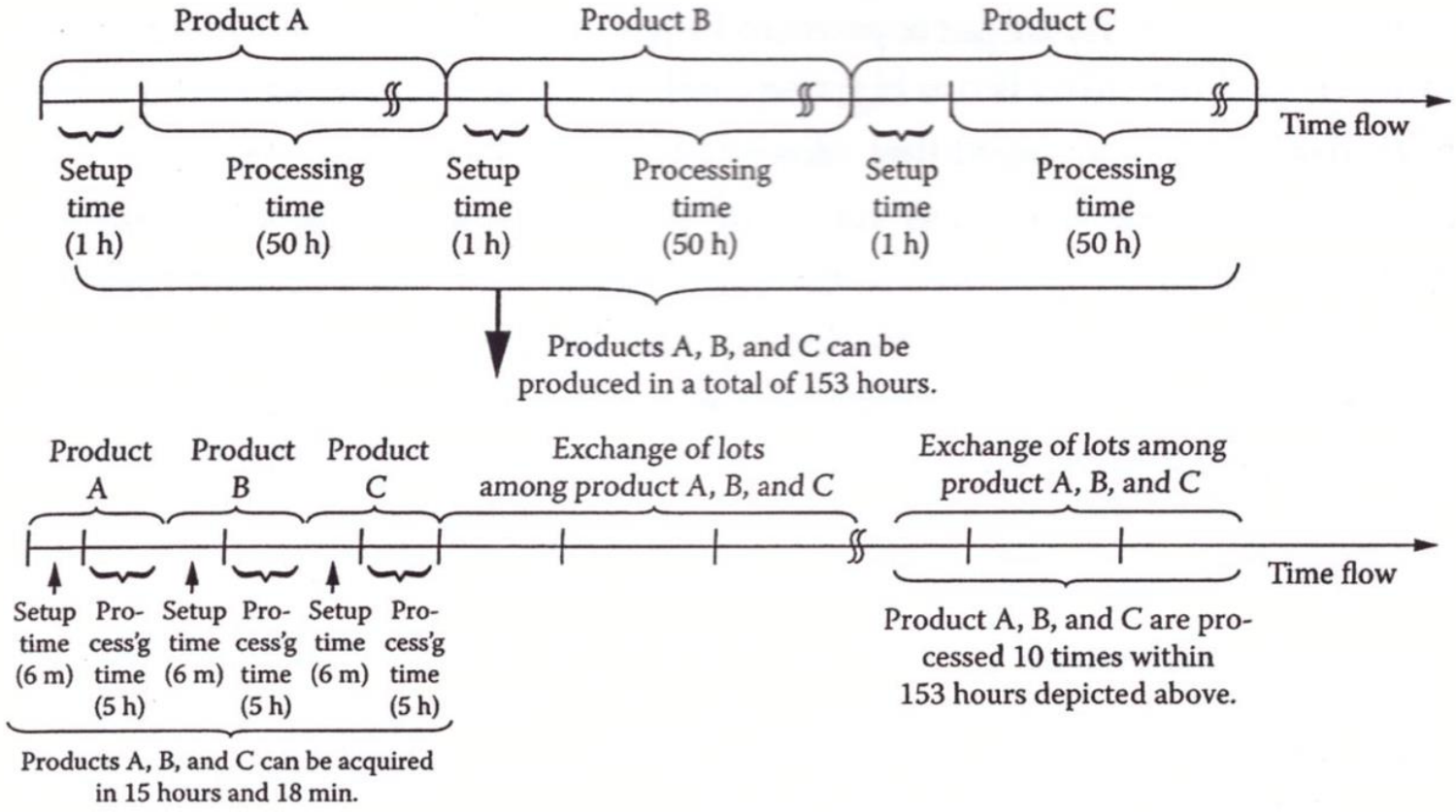


FIGURE 7.7

Shortening processing time for a variety of products through small-lot production.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- Because the lot size of stamped parts of a car is fairly big, a lot size reduction control chart is proposed.

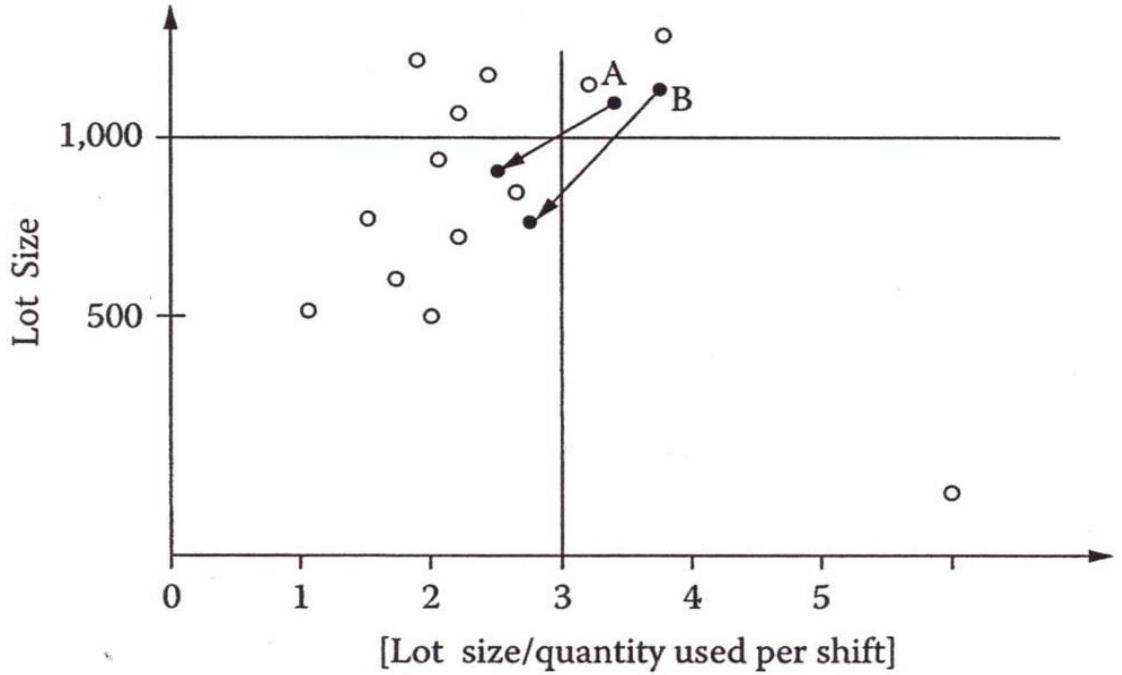


FIGURE 7.8
Lot size reduction control chart.

7.4 SHORTENING WAITING TIME AND CONVEYANCE TIME

- Waiting time is the time spent by parts-in-process waiting to be processed and assembled, or by completed products waiting to be withdrawn by a subsequent process.

- It excludes the conveyance time.

7.4 SHORTENING WAITING TIME AND CONVEYANCE TIME

- In Toyota, the *mutual relief movement* should be applied to make up for delays in some processes.

- The point connecting two workers or two processes is designed so that the workers can help each other.

  =>similar to the baton touch zone in relay races of track events

7.4 SHORTENING WAITING TIME AND CONVEYANCE TIME

- Line balancing problem <= capacity differences
  =>solve using the full-work control system

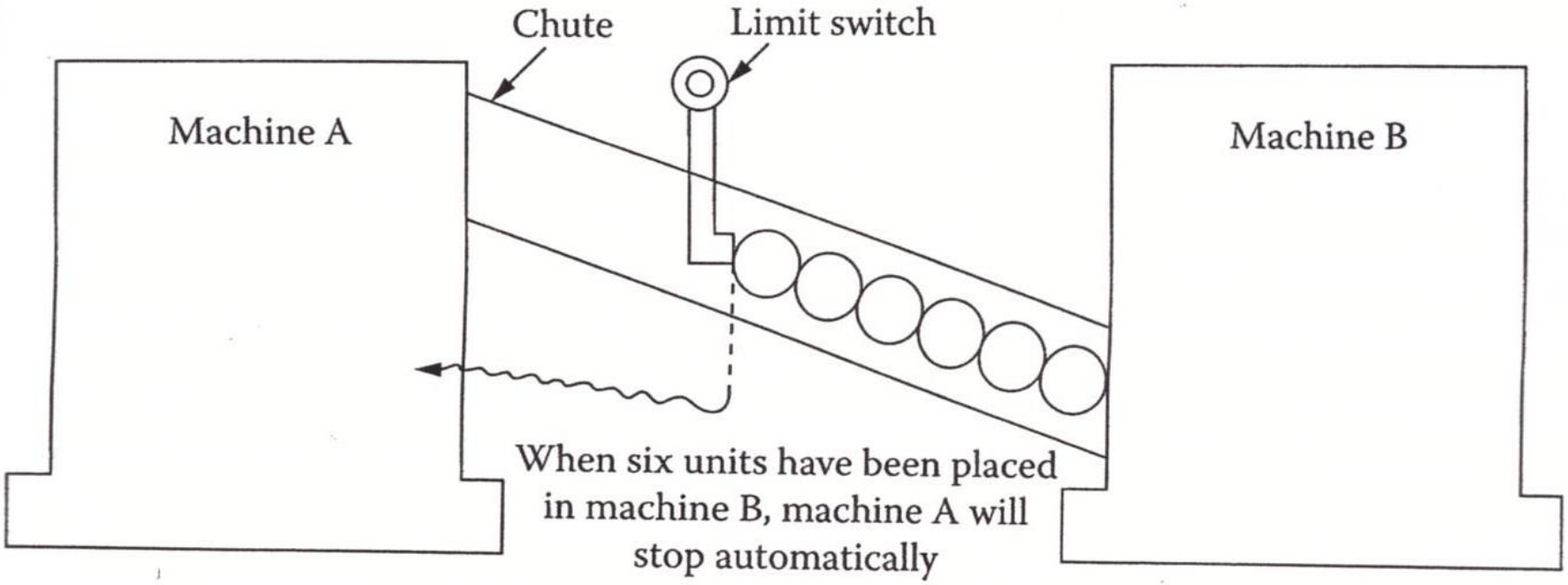


FIGURE 3.18
Full-work system.

7.4 SHORTENING WAITING TIME AND CONVEYANCE TIME

- To shorten the waiting time, the conveyance lot size needs to be minimized.

- Suppose there are 3 processes and each takes 1 minute to produce one unit.

7.4 SHORTENING WAITING TIME AND CONVEYANCE TIME

- If 600 units must be produced and the units are conveyed to the subsequent process when all units are finished

Total production time = 1 minute × 600 × 3 = 1800 minutes

- If each unit is conveyed to the subsequent process as soon as it has been processed by the preceding process,

Total production time = 1 minute × 600 + 1 minute +1 minute
= 602 minutes

7.4 SHORTENING WAITING TIME AND CONVEYANCE TIME

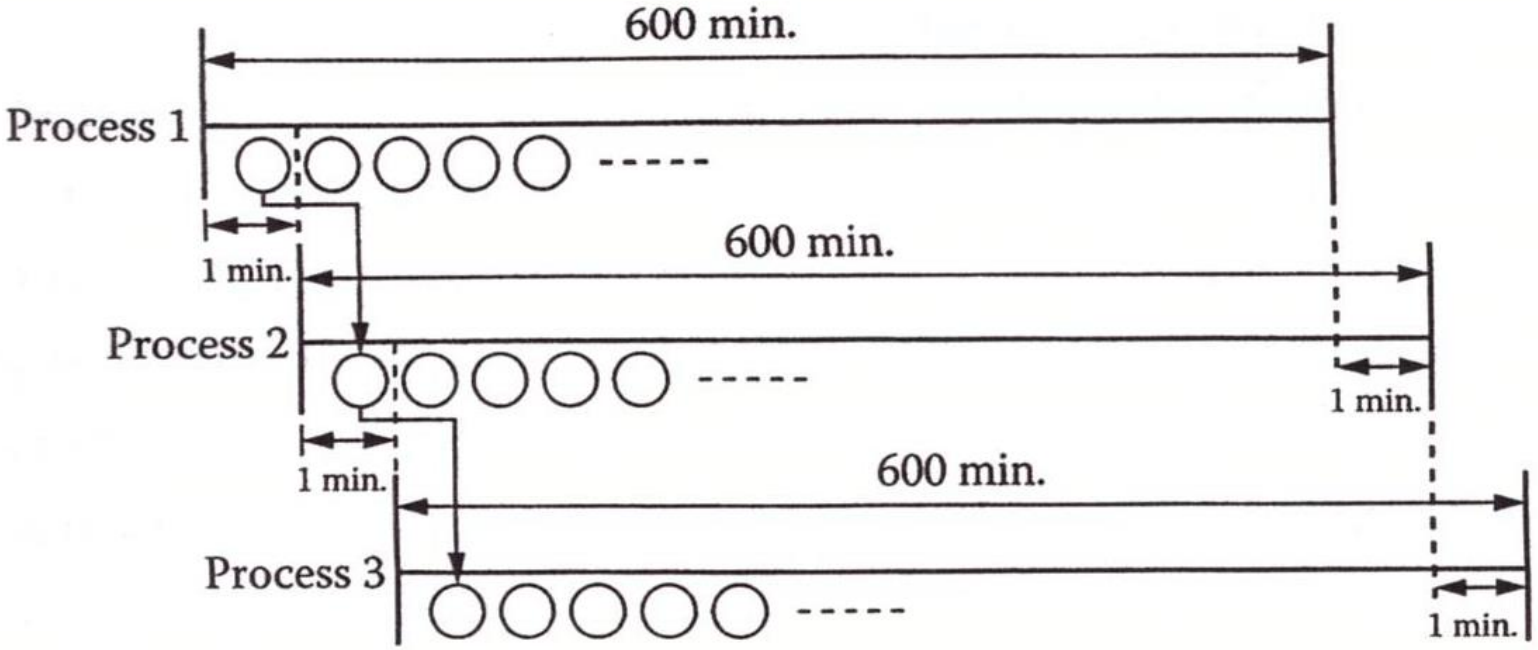


FIGURE 7.9
Relationship between processes and processing times.

7.4 SHORTENING WAITING TIME AND CONVEYANCE TIME

- Improvement of the conveyance operation can be achieved in two steps.
  - The layout of different machines should be in accordance with the flow of processes instead of by machine type.
  - Quick means of conveyance such as the belt conveyor, chute, or forklift should be used to connect the processes

One chute conveyor

7.5 A BROAD APPROACH TO REDUCING PRODUCTION LEAD TIME

- JIT production system is aimed at flexible adaptation to fluctuations in demand quantity and variety in the market.
- “Flexible” means with short production lead time.
- This lead time is involved in several operations.

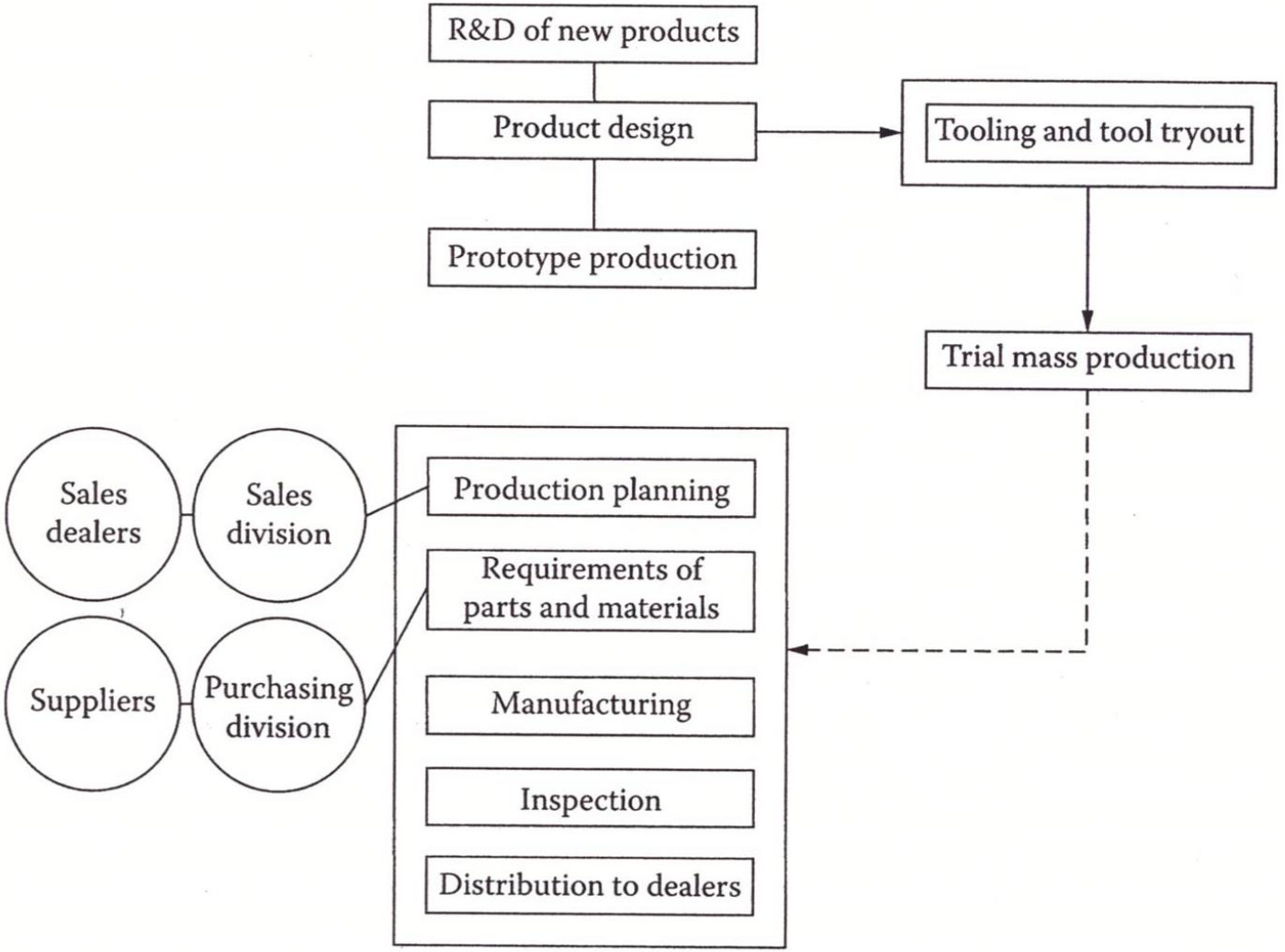


FIGURE 7.10
System of operations surrounding production.

7.5 A BROAD APPROACH TO REDUCING PRODUCTION LEAD TIME

- From the JIT point of view, the following five principles are required.

- Install multiple compact facilities to enable small lot size production.

- Develop a technology for shortening chemical reaction time.

7.5 A BROAD APPROACH TO REDUCING PRODUCTION LEAD TIME

- From the JIT point of view, the following five principles are required (continued).
  - Eliminate excessively speedy facilities.
  - Connect machines so products can flow rapidly.
  - Plan flexible manufacturing systems (FMS) for the future.

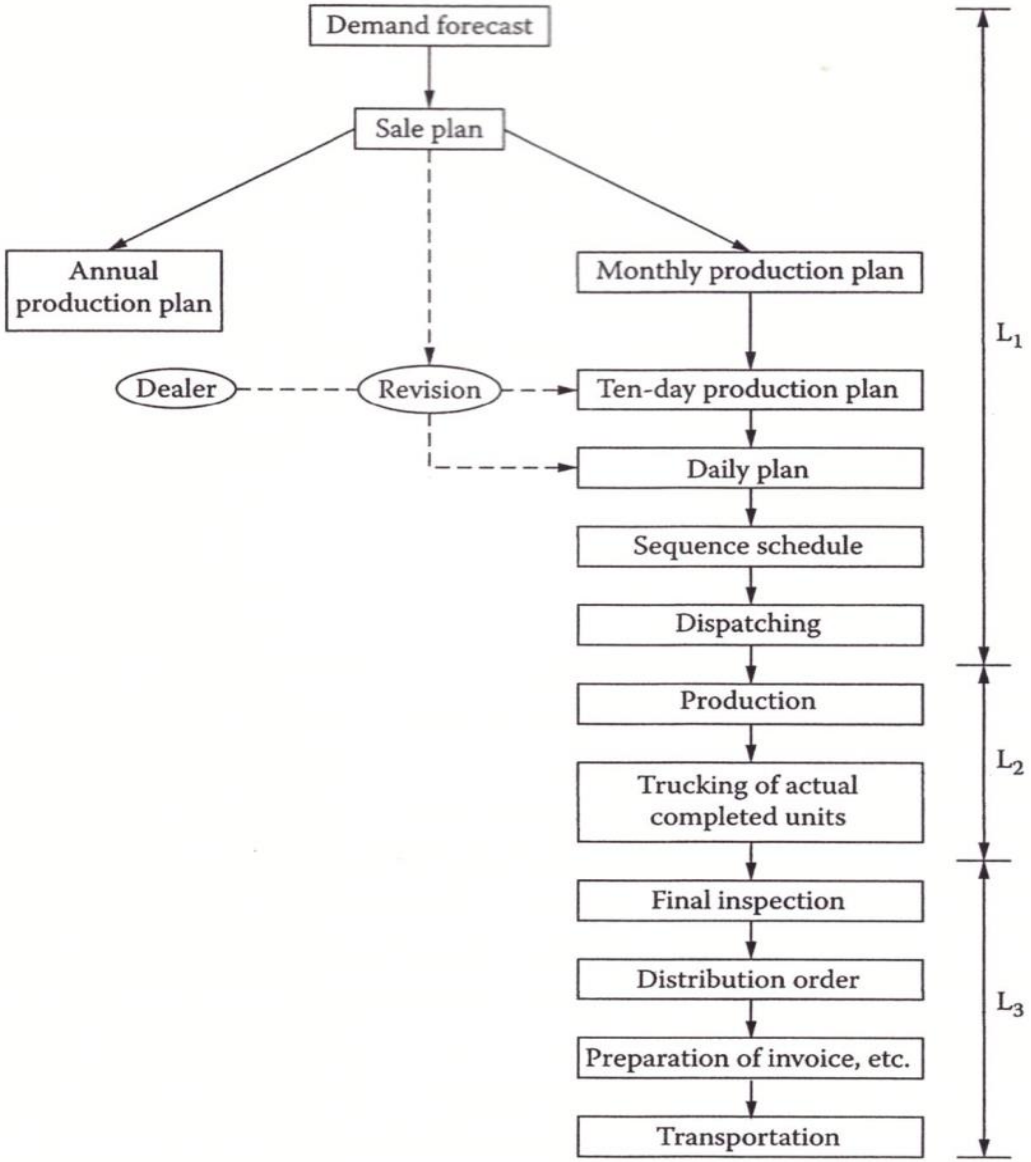
7.5 A BROAD APPROACH TO REDUCING PRODUCTION LEAD TIME

- Concerning the manufacturing system, lead times can be broken down in the following three categories.

- L_1 = lead time of data processing
  (from demand forecasting to production dispatching).

- L_2 = lead time of the manufacturing activity itself

- L_3 = lead time of delivering completed products to customers



TPS works on shortening L_2

FIGURE 7.11
Three types of lead time in a manufacturing system.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

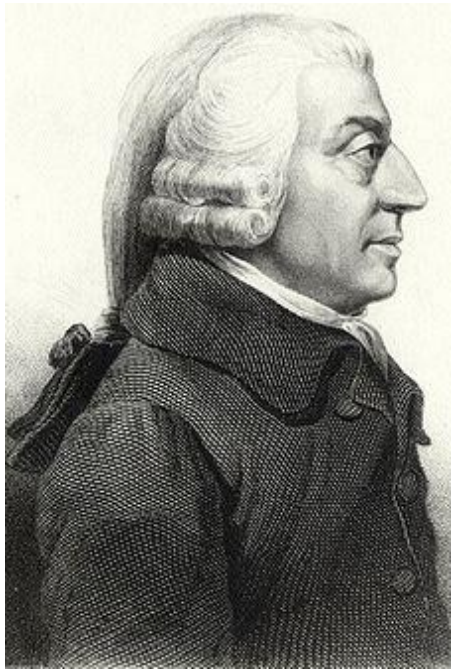
- The division of labor is the specialization of cooperating individuals who perform specific tasks and roles.

- In *The Wealth of Nations* (1776), *Adam Smith* foresaw the essence of industrialism by determining that division of labor represents a qualitative increase in productivity.

- His example was the making of pins.

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- Adam Smith (1723 – 1790) was a Scottish moral philosopher and a pioneer of political economy.

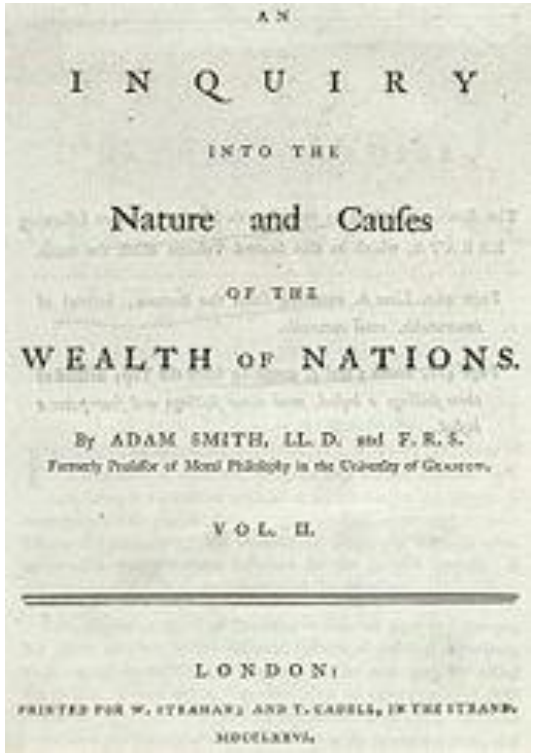


- He is best known for two classic works: *The Theory of Moral Sentiments* (1759), and *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776).

7.3 SHORTENING PROCESSING TIME THROUGH SINGLE-UNIT PRODUCTION AND CONVEYANCE

- *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776), usually abbreviated as *The Wealth of Nations* (國富論), is considered his magnum opus and the first modern work of economics.

- Smith is cited as the "father of modern economics".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