N5 Production & Quality Control

Gateways to Engineering Studies - Chris Brink

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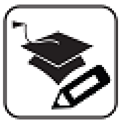
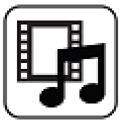
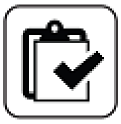
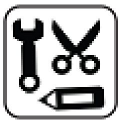
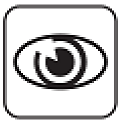
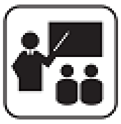
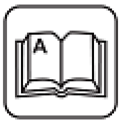
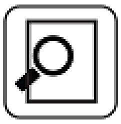
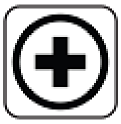
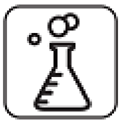
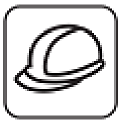
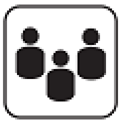
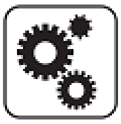
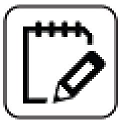
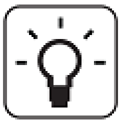
	Assessment / Activity		Multimedia
	Checklist		Practical
	Demonstration/ observation		Presentation/ Lecture
	Did you know?		Read
	Example		Safety
	Experiment		Site visit
	Group work/ discussions, role-play, etc.		Take note of
	In the workplace		Theoretical – questions, reports, case studies, etc.
	Keywords		Think about it

Module 1

Capacity control

Learning Outcomes

On the completion of this module the student must be able to:

- Describe the mechanics of capacity resource planning
- List the following techniques of capacity resource planning
  - finite capacity loading
  - infinite capacity loading
- Describe the techniques of capacity resource planning listed above
- Describe the advantages and disadvantages of finite and infinite capacity techniques
- Calculate capacity requirements given the following information
  - efficiency
  - machine utilisation
  - man hours
  - machine speed
- Define performance measurement in terms of capacity requirements planning
- Describe the following performance measurement criteria
  - productivity levels
  - actual input versus planned input
  - input and output variables
- Calculate productivity levels of all resources given the following information
  - planned man hours
  - planned machine hours
  - planned input/output raw material
  - actual man hours/machine hours
- Describe the application of each of the criteria of performance measurement listed above
- Describe the process of managing capacity requirements planning in terms of the following
  - set up time
  - overtime hours
  - bottle necks
  - alternate route
  - planned maintenance
- Describe the impact of quality considerations in terms of sub standard output and its effect on capacity requirements planning

- Describe with the aid of simple examples the following four types of capacity
  - staffing
  - equipment
  - tools
  - facility
- Describe how each of the four types of capacity listed affect capacity and the overall performance of a work centre and the related ripple implications
- Describe the following three types of capacity loading
  - scheduled receipts
  - planned orders
  - unplanned events
- Describe how each of the following inputs affect capacity planning
  - demand
  - routings
  - manufacturing times
  - work centres
- Describe four differences between the make to order method and make to stock method
- Describe each of the following characteristics associated with capacity requirements planning
  - units of measure
  - planning horizon
  - planning period
  - work centre definition
- Describe the difference between load and capacity
- Given the following information calculate demonstrated capacity
  - number of periods
  - output for each period
- Describe the following elements of lead time that influence the management of lead times
  - set up time
  - move time
  - queue time
  - run time
- Describe the following two methods of balancing capacity and load
  - capacity responses
  - load responses
- Describe the implications in respect of the following if the management of capacity planning is not carried out effectively
  - customer delivery promises
  - cost to work centres
  - backlog

1.1 Introduction

Of all the planning decisions in an organisation, the decision regarding a manufacturing location or service operation is probably made least often. It sometimes goes alongside the basic capacity decision about how much the organisation should produce or how many customers to serve over a period of years.

Location and capacity decisions are primarily made to enter new markets, or due to growth or rationalisation. These decisions have long-term implications because they usually cannot be changed easily or quickly.

1.2 Location management

The apparently simple question of where to locate quickly turns out to be far more complicated than where to get the cheapest rent per square metre.

Numerous trade-offs have to be made to find the optimal mix of location factors that work best for a particular organisation.

1.2.1 Location decision factors

Some approaches divide location decision issues into qualitative versus quantitative factors; others into demand-side versus supply-side factors.

Following Carroll and Dean, we will present the location management issues from the macro perspective, covering issues outside the site and/or plant, and then focus on the micro issues related to the site and/or plant directly, as illustrated in **Table 1.1**.

Macro issues	
Level	**Location issue**
Region	• Potential market share when competing against existing companies • Investment and operating cost of setting up and running the operation
Sub-region	• Transport costs of bringing materials in and shipping products out • National taxes, interest and exchange rates in the country/province • Raw materials' cost and availability in the country/province • Labour cost and availability in the country/province
Community	• Proximity to market/materials within the city/suburb • Costs of other inputs such as rentals, electricity, telecommunications • Availability of required skilled labour

	• Local taxes and municipal service costs • Availability of suitable sites • Local infrastructure such as roads and public transport • Community services such as schools, hospitals and the police
Micro issues	
Site/plant	• Connections to transport/communication networks • Suitability of site characteristics such as steepness and noise • Site and construction costs • Municipal services and property tax costs

Table 1.1

1.2.2 Contemporary location issues

Traditionally, location decisions were made primarily with the location, site facilities and local conditions in mind.

In recent times, several issues - such as globalisation, information and communication technology, regional trade pacts, and new approaches to production and service delivery - have changed the nature of location decisions.

1.2.2.1 Globalisation

Since organisations started transcending national and continental borders, the system of production and service delivery has changed fundamentally.

The idea that an entire product is manufactured under one roof no longer applies to many industries, such as vehicle manufacture, electronics and publishing.

Even airplanes like the Airbus have different parts manufactured in different European countries that are then assembled in France.

Think about it!
Today, many services are provided in one country and delivered in another.

For example, call centres in India and South Africa provide services to customers in Europe in industries such as insurance, financial services and travel.

1.2.2.2 Information and communication technology

Distributed production and service delivery has largely been made possible by increasingly sophisticated information and communication technology.

Initially, the Internet enabled improved communication, primarily through email. This made it possible for managers to exchange information quickly and cheaply wherever they were in the world.

Then organisations started linking their computer systems together so that management information, such as orders placed at a sales branch, could be automatically scheduled for production at a plant on another continent.

> **Did you know?**
> Today, the Internet has become a business tool in itself. More and more companies like Amazon, eBay and 24.com provide solely Internet-based services to a global market.

1.2.2.3 Regional trade pacts

The world has been divided into a number of regional trade zones, such as the North Atlantic Free Trade Zone, the European Union, and the Southern African Development Community.

Trade occurs more freely within these unions: for example, goods can be transported across borders without incurring customs charges. However, between these trade zones, a variety of barriers exists that limit global trade.

Sometimes these barriers are necessary to protect local industries: for example, where quotas exist for the importation of textile and clothing products in order to protect local jobs.

At other times, these trade barriers are controversial, such as when developed countries apply high quality standards.

The receiving countries argue that they are trying to protect their consumers, whereas the exporting countries contend that it is a means of keeping competitors out.

1.2.2.4 New approaches to production and logistics

The improvement of information flow between producers and retailers has led to a demand for producers to respond more rapidly to changes in demand.

The trend to 'Just-in-Time' production and increased automation of production equipment have made it possible for some assembly operations to respond rapidly to orders.

> **Did you know?**
> Some book publishers no longer keep books in stock and only print books once they have been ordered. This has created a need for courier and transport companies to significantly improve their delivery speed.

The advent of standard shipping containers made it possible to transfer goods quickly between ships, trucks, trains and airplanes. Many courier companies also provide overnight delivery by organising their transport logistics between transfer warehouses called hubs.

1.2.3 Methods for making location decisions

Although there are many more sophisticated methods for making a location decision, such as linear programming and regression analysis, we will only cover the factor-rating and centre-of-gravity methods.

1.2.3.1 Factor-rating method

The factor weighting method allows each factor under consideration to be rated independently for each potential site and for each factor to be weighted according to the relative importance of each factor.

You can use five simple steps to calculate overall scores using the factor-rating method:

Step 1: Identify the factors that will be considered
Make a list of factors that are most relevant to the decision where to locate.

Step 2: Allocate relative weightings to the factors
Decide how important each factor is in comparison to the other factors, and then allocate a percentage weighting which reflects the factor's importance. Make sure the weightings add up to 100%.

Step 3: Rate every site on each of the factors
Investigate the sites and allocate a rating out of 10 for each factor to indicate how suitable the site is on each factor.

Step 4: Calculate the score for the factors of all the sites
Multiply the ratings for each factor by the weighting for the factor to calculate the factor scores for each site.

Step 5: Calculate the overall score for each site
Add the factor scores for each site to get an overall site score.

Worked Example 1.1

When considering two possible locations, the following factor weightings and ratings for sites A and were used to compare the suitability of both locations.

Factor	Weighting	Site A	Site B
Close to customers	30%	7	5
Close to labour	20%	4	8
Location costs	25%	2	6
Regional incentives	15%	6	4
Traffic	10%	1	3

Table 1.2

Solution:
The scores for closeness to customers for site A and B are calculated as follows:
Site A: 30% x 7 = 2,1
Site B: 30% x 5 = 1,5

Next, the factor scores are added separately for each site.
So, the calculation for site A is: 2,1 + 0,8 + 0,5 + 0,9 + 0,1 = 4,4

The factor-rating calculation in **Table 1.3** shows that site B is preferable.

Factor	Importance weighting	Site A		Site B	
		Rating	Score	Rating	Score
Close to customers	30%	7	2,1	5	1,5
Close to labour	20%	4	0,8	8	1,6
Location costs	25%	2	0,5	6	1,5
Regional incentives	15%	6	0,9	4	0,6
Traffic	10%	1	0,1	3	0,3
Overall rating	**100%**		**4,4**		**5,5**

Table1.3

The advantage of factor-rating is that it's simple to use and enables a consistent method of comparison between sites.

However, the qualitative nature of assessing the importance of the weightings and estimating the ratings allows subjectivity to influence the outcome.

1.2.3.2 Centre-of-gravity method

The centre-of-gravity method is based on the premise that a warehouse located centrally to the shops that receive goods from it will minimise the overall costs of distribution.
This idea is illustrated in **Figure 1.1**.

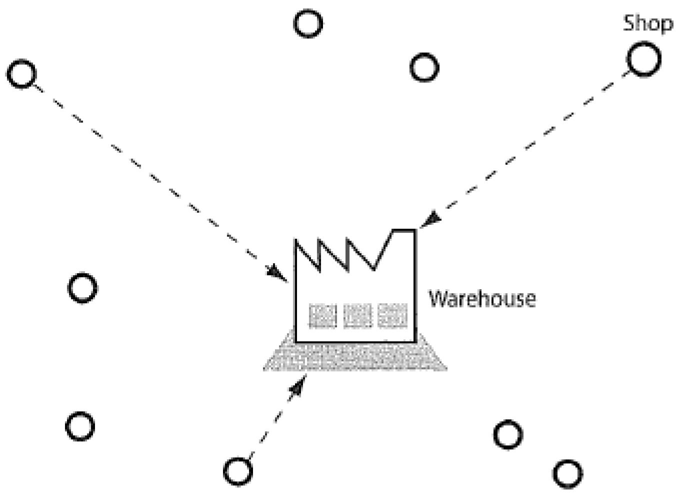


Figure 1.1

However, roads do not run in a straight line and different shops order different amounts of goods. So, you'd have to take both factors into account when making the comparison between two potential locations for the warehouse.

Use the steps below for the centre of gravity method.

Step 1: Collect the necessary information
You'll require two pieces of information for every delivery destination in order to make the centre of gravity calculation: first, the monthly number of units to be transported, and secondly the distance from the warehouse to the destination.

If this information is not readily available it must be collected or measured.

Step 2: Calculate the 'unit kilometres'
Multiply the units sold by each store per month with the distance from each warehouse to each store. Do this separately for every warehouse.

Step 3: Total the 'unit kilometres'
Add the 'unit kilometres' for all the stores for each warehouse to get a total 'unit kilometres' for each warehouse.

Worked Example 1.2

Table 1.4 shows the monthly units sold for three stores, and the distance from each store to two warehouses (A and B).

Store	Units sold pm	Distance	
		Warehouse A	Warehouse B
1	460	25 km	15 km
2	310	37 km	12 km
3	750	19 km	42 km

Table 1.4

The 'unit kilometres' for store 1 is:
Warehouse A: 460 units x 25km = 11 500
Warehouse B: 460 units x 15km = 6 900

The total 'unit kilometres' for warehouse A then adds up to:
11500 + 11470 + 14250 = 37220

Table 1.5 shows that warehouse A would have the lowest total transport cost.

Store	Units sold pm	Warehouse A		Warehouse B	
		Distance	Unit km	Distance	Unit km
1	460	25 km	11 500	15 km	6 900
2	310	37 km	11 470	12 km	3 720
3	750	19 km	14 250	42 km	31 500

Table 1.5

Note:

Remember, this way of calculating transport cost makes some simplifying assumptions - that the stores sell the same amount every month, that the trucks will be full on every trip, and that the transport cost per kilometre is the same over the different routes.

For instance, on some routes, the cost per kilometer may be increased due to heavy traffic, steep hills and tolls. You need to modify the calculation if these assumptions are not correct for a particular situation.

1.3 Capacity

In manufacturing operations, capacity to make products is created by investment in equipment, which, when operated by employees, manufactures products.

In service operations, employees play a more prominent role in creating capacity, as an employee usually serves each customer individually. However, it is unusual for no equipment to be involved in delivering services.

Even in innovative-type services, where service delivery depends mainly on people, consultants use projectors to do presentations, inventors use laboratory equipment to carry out experiments, and actors use props and lights to put on plays.

The way people in industry talk about capacity is sometimes confusing, because in operations management the term 'capacity' is used differently from how it is used elsewhere.

In operations, the word 'capacity' does not mean capacity in the same sense referred to by politicians, to indicate 'the ability to do". Neither does it refer to "volume" as in 'the capacity of the bucket is 20 litres. (See definition)

Definition:
Capacity is the rate of output that can be achieved from a process, measured in units of output per unit of time. The fact that capacity is defined as a rate means that any measure of capacity must contain two important elements: output and time.

Another issue surrounding the term capacity is that it's used at different levels of planning.

Sometimes we refer to the capacity of the whole operation; at other times, we are simply talking about the capacity of a department or even a single machine or person within the operation.

These different levels of usage are all consistent with the basic definition of capacity, although when we talk of capacity management, we are generally referring to the management of the overall capacity of the whole operation.

1.4 Capacity management issues

The issues surrounding capacity management are detailed in the next sections.

1.4.1 Long-term capacity management

Capacity management concerns the long-term management of the overall capacity of operations. The objective is to make enough production or service capacity available to satisfy total demand for products or services a few years into the future.

This usually involves making decisions about investing in new factories or service facilities. It can also involve decision-making over restructuring capacity by moving production or services to other locations, or the closing of entire production or service facilities.

Did you know?
Capacity decisions are fundamentally of a strategic nature, as an organisation's capacity (equipment) is probably the most critical determinant of the capability to create value for customers.

As with location issues, capacity decisions have long-term consequences because, once committed to, they are not quickly or easily changed.

1.4.2 Making capacity management decisions

There are two important considerations when making long-term capacity decisions.

First, what kind of capacity is required? And secondly, how much capacity is required.

1.4.2.1 What kind of capacity is required?

The kind of equipment used to make products or provide a service determines how an operation creates value. Let's take metalworking machinery as an example.

A basic milling machine would be cheap and flexible but requires setting up by a skilled artisan. This enables the operation to compete on customisation, but it would not be able to compete on high-volume, low-price products because skilled artisans are expensive to employ.

An automatically-loading milling machine would be more cost-effective for high-volume production, but such a machine would not be flexible.

Alternatively, a high-tech computer-controlled milling machine would be both flexible and able to produce high-quality complex shapes, albeit not cheaply.

Did you know?
The basic value drivers the organisation can compete on are often determined at the stage when the organisation decides what capacity to install.

Once you have installed expensive equipment that can produce high quality products, it is very difficult to become a low-cost producer because the loan interest payments will push up overheads.

1.4.2.2 How much capacity is required?

The total annual output of the operation is also an important capacity decision.

On the one hand, the annual demand for the product or service must be satisfied.

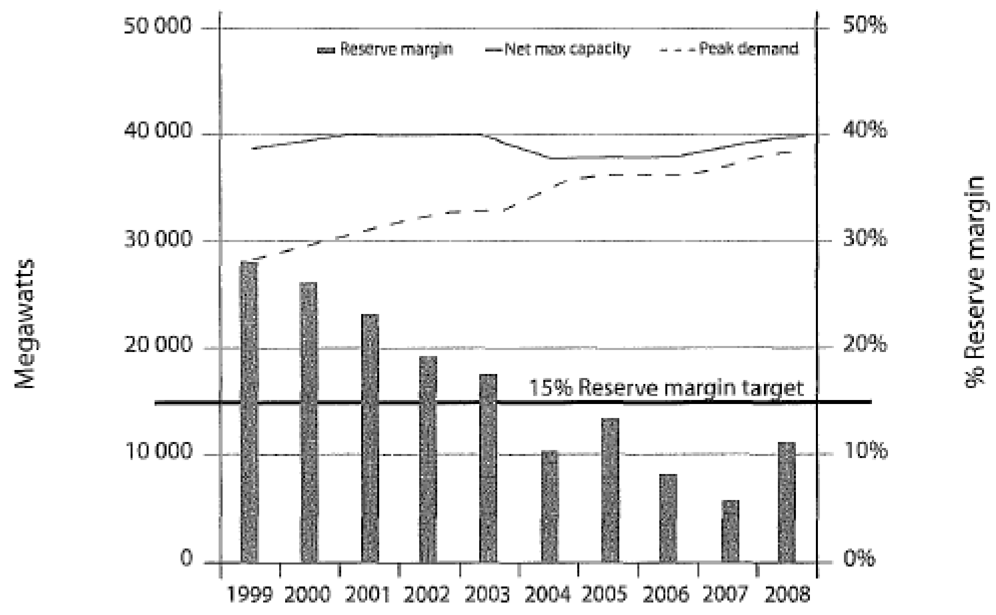
In other words, the operation must have the capacity to match the estimates of how much product or service can be sold.

On the other hand, the annual output of the operation is an important determinant of the financial viability of the operation. This is calculated by doing a break-even analysis.

Most manufacturing operations need to install only enough capacity to meet average demand because they can store finished products during periods of low demand in anticipation of high demand.

If it is not possible to make and store products or services in anticipation of demand, as in the fresh food industry, then the operation needs to have enough capacity to meet peak demand.

Case Study 1.1: The Eskom electricity generation capacity challenge



Eskom annual maximum capacity versus peak demand

Figure 1.2

Note 1: The reserve margin is not always equal to the difference between net maximum capacity and peak demand due to factors such as electricity imports and pumped storage regeneration schemes.

Note 2: Capacity is referred to as 'megawatts' in the shorthand way.

South Africa's best-known capacity problem is the load shedding that Eskom has been forced to do in recent years in order to protect the national electricity grid from collapsing.

The supply of electricity is an enormous challenge because it cannot be stored in large quantities, so national electricity suppliers like Eskom need to have enough power generation capacity at any one time to meet the highest possible demand for electricity.

The following extract from Eskom's Annual Report 2008 summarises the challenge:

"Between October 2007 and February 2008, emergency load shedding was implemented. In order to avoid a potential overall nationwide blackout, a national electricity emergency was. declared on 24January 2008.

The fundamental and underlying problem is that the power system has an inadequate reserve margin which is at an all-time low of around 8o/o. This does not compare well to our aspiration of 15%.

Since 1994, the demand for electricity has grown by about 50% on the back of robust economic growth. This welcomed growth has all but exhausted Eskom's surplus electricity generation capacity.

We were only given the go-ahead to start building new plant in October 2004. Taking into account the long lead times to build new stations, there was not sufficient time to build new power stations to ensure adequate generation capacity in the short-term.

Eskom is embarking on a very large infrastructure expansion programme, which has a board approved budget of R343 billion up to 2013 and is expected to grow to more than a trillion rand by 2026. Ultimately, Eskom will double its capacity to about 80 000MW by 2026.

Eskom has established a recovery task team around the supply and demand side of the business. In response to a call for a sustained 10% reduction in demand, key industrial customers are already voluntarily providing 1 200MW in load reduction.

Unfortunately, only limited reductions were forthcoming from other customers by the end of March 2008. Should these initiatives not result in the [required] energy savings, there is an increased risk of load shedding from 2010 until the supply side options are available:'

1.4.3 Capacity expansion

Long-term capacity expansion decisions are difficult because most of the time it is not possible to expand (or contract) long-term capacity in small increments.

Think about it!
It doesn't really work well to build half a production line or a quarter of a football field.

So capacity expansion needs to be made in 'chunks', while demand is likely to increase more smoothly over time. Therefore, decisions must be made regarding to what extent capacity should lead demand versus lagging demand, as shown in **Figure 1.3a** and **Figure 1.3b**.

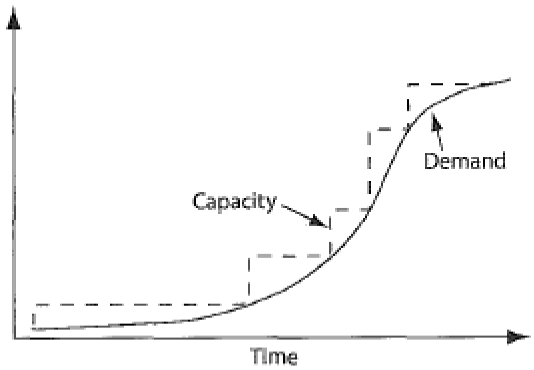


Figure 1.3a Capacity leading demand

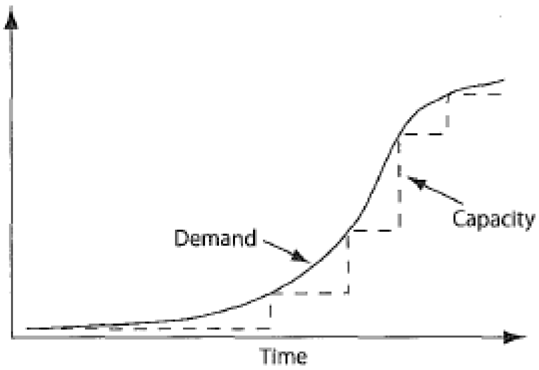


Figure 1.3b Capacity lagging demand

In reality, capacity expansion rarely happens as pure leading or lagging approaches.

Mixed approaches are more common, where initially there is more capacity than required until demand exceeds capacity and for some time there may be a shortage of capacity until new capacity becomes available.

Over and under-capacity may also influence demand, with demand increasing above the long-term trend during times of over-capacity, and shrinking below the long-term trend due to shortage in times of under-capacity.

The end result is more likely to resemble **Figure 1.4**.

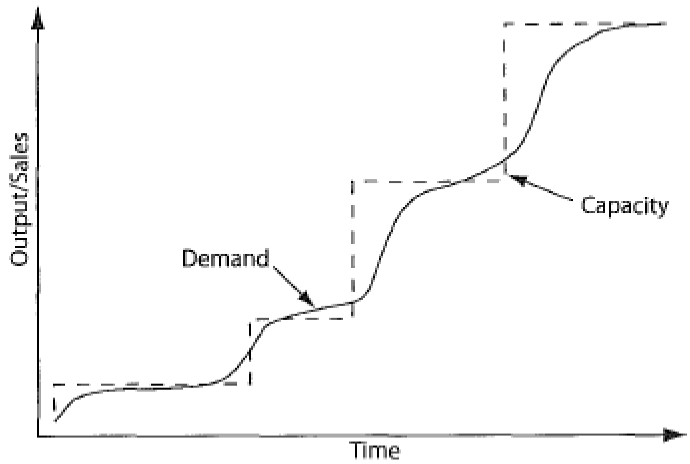


Figure 1.4 A mixed-capacity expansion approach

The advantage of the over-capacity approach is that sudden increases in demand can be accommodated relatively easily because the equipment is already in place.

However, while standing idle, the excess capacity will cause high overhead costs. Conversely, an under-capacity approach may lose sales but avoids high overheads.

1.5 Bottlenecks

The resource (equipment or people) that determines the slowest rate of output in a process is the bottleneck. It determines the capacity of the entire process.

This may be difficult to understand because we tend to think that fast and slow machines work independently of one another.

However, if a part has to go through all the steps in a production process, then no matter how fast other machines are working before or after the slowest workstation in a process, the slowest activity will determine the rate of output of the whole process.

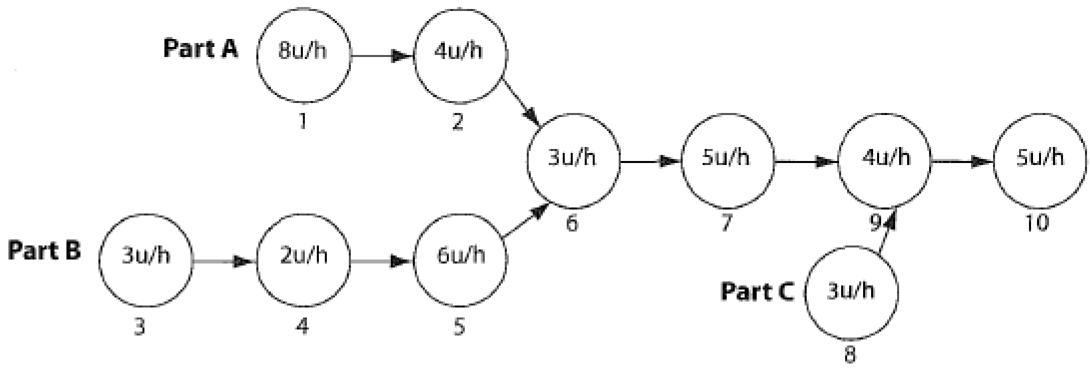


Figure 1.5 Bottleneck in a simple process

In Figure 1.5, activity 4 is the slowest activity as it works at 2 units per hour. Even though workstation 3 can make 3 units per hour, the extra unit per hour will pile up in front of workstation 4 because it cannot process the work faster. And even though workstation 5 can make 6 units per hour, it is limited to processing the 2 per hour coming from workstation 4.

Note:

Putting two machines processing at 2 units per hour in at workstation 4 will not increase the capacity of the whole process to 4 units per hour because work stations 3, 6 and 8 can only process 3 units per hour. So any activity can become the bottleneck in a process.

In fact, in job shops the bottleneck sometimes moves around, as different jobs require different amounts of processing time at different workstations.

Sometimes the bottleneck is hidden when demand is lower than capacity. Then it may look as if the process can cope with everything that needs to be done, but if the demand increases beyond the capacity of the bottleneck, it becomes a problem.

Did you know?

The bottleneck is often found at the most expensive piece of equipment in a process because the capital for another piece of equipment is not available, even though it might be needed.

So it's important to manage the bottleneck carefully to avoid any loss of production there, as it also causes lower productivity in every other part of the operation.

In some operations, workers do extra shifts only in the bottleneck area to keep the whole operation busy during normal working hours.

1.6 Measuring capacity

It is necessary to measure capacity in order to establish how well we are using the assets that create capacity, and to identify what actions can improve the performance of the operation.

Capacity is the rate of output that can be achieved from a process, measured in units of output per unit of time.

The fact that capacity is defined as a rate means that any measure of capacity must contain two important elements: output and time.

Some examples of capacity measures:

- cars produced per shift
- students graduated per year
- kilobytes downloaded per second
- passengers transported per week
- megawatts generated per hour

Think about it!

Unfortunately, in practice, operations managers sometimes use a shorthand way to refer to plant capacity and use only the annual output to refer to the size of a plant.

For example:
"Toyota Motor Kyushu completed its second factory in September of 2005, lifting production capacity to 430 000 vehicles:'3 Note that in these cases the time period is almost always implied to be over a year, even though it is not actually stated.

By measuring capacity in three different ways, we are able to ascertain different kinds of information about the performance of the operation. This information helps us to know what to do as managers of the process.

The three types of capacity measures are:
- design capacity
- effective capacity
- actual capacity

1.6.1 Design capacity

Design capacity is the rated output the equipment was designed to produce when running under normal conditions without stoppages.

Definition: Design capacity
Can be defined as the maximum designed capacity of a plant, process or machine.

While the equipment was probably tested to run at its design capacity, for practical purposes, design capacity is a hypothetical figure because in the real world we rarely operate 24 hours per day for 7 days a week, year after year.

For the purposes of managing capacity, it provides a benchmark against which we can assess how well we are utilising the assets.

1.6.2 Effective capacity

Effective capacity is the planned capacity of an operation, process or machine.

It takes into account that we plan not to operate for reasons such as:

- there is too little demand or raw material supply to run 24/7
- the plant works only one or two shifts
- lunch breaks, teatime, etc
- planned maintenance, annual shutdowns, etc
- staff training, union meetings, etc
- machine stoppages for set-ups and changeovers from one product to another
- regulations (working hours, safety, noise) that prevent working all the time

Definition: Effective capacity
This is what a factory manager expects to achieve in a normal day's work. It is almost always less than design capacity.

1.6.3 Actual capacity

Definition: Actual capacity
The output actually achieved over a period of time.

Actual capacity is affected by numerous, mostly unplanned, losses in the production or service process, such as:

- machine breakdowns, start-up losses, slow running speed, power failures, etc
- bad work organisation, poor employee skills, etc
- absenteeism, go-slows, strikes, etc
- raw material, labour and other shortages
- poor productivity
- rework due to poor raw material or process quality, customer returns, etc

Whereas the other two types of capacity measures can be calculated, actual capacity can only be measured as events unfold in the real world. Actual capacity is usually less than effective capacity.

1.7 Calculating capacity

When calculating capacity, you need to use a measure with the appropriate units of production/service and an appropriate unit of time.

Think about it!
It is not very helpful to measure tons of coal shipped per year when you are a hardware store that sells only a few bags of coal a week. It is often practical to use more than one measure of capacity to keep an eye on different aspects of a process.

For instance, a retailer may want to measure sales per square metre per week, and sales per employee per week. In production operations, the bottleneck is likely to be the most convenient and the most important - point in the process to measure capacity.

1.8 Design capacity

To calculate design capacity, you use the rated output, based on the maximum output the process or equipment was designed to deliver. The period of operation is assumed to be 24/7; therefore, you do the calculation as if you were working all day and night, even though it does not happen in reality.

Worked Example 1.3

If an industrial oven were designed to bake 50 loaves of bread per hour, what would the design capacity be?

Solution:
50 loaves per hour x 24 hours = 1 200 loaves per day, or
50 loaves per hour x 24 hours x 7 days = 8 400 loaves per week, or
50 loaves per hour x 24 hours x 7 days x 52 weeks = 436 800 loaves per year.

Worked Example 1.4

If a cashier takes, on average, 4 minutes to check out a customer, what would the design capacity be?

Solution:
60 minutes per hour + 4 minutes per checkout = 15 checkouts per hour
15 per hour x 24 hours = 360 checkouts per day, or
15 per hour x 24 hours x 7 days = 2 520 checkouts per week, or
15 per hour x 24 hours x 365 days per year = 131 400 checkouts per year.

Note:

There can be slight differences in the time period over which capacity is calculated, which will affect the answer.

For practical purposes, most people accept that there are 52 weeks in a year, but 52 weeks x 7 days = 364 days and there are actually 365 days in a year.

For simplicity's sake, we sometimes use 12 months x 30 days per year or 7 days x 4 weeks per month. In practice, use the time period that is most convenient for the circumstances that you are working in.

When you do calculations, remember to read the questions carefully because they will specify what period to use.

1.9 Effective capacity

To calculate effective capacity, you take into account the planned time of operation.

Worked Example 1.5

If the bakery works 2 shifts of 8 hours per day for 6 days per week (assume there are 4 weeks per month), then what would the effective capacity of the oven be?

Solution:
50 loaves per hour x 16 hours x 6 days = 4 800 loaves per week, or
50 loaves per hour x 16 hours x 6 days x 4 weeks = 19 200 loaves per month.

Worked Example 1.6

If the cashier works 8 hours per day, minus ½ hour lunch on the basket-only checkout lane, where the average checkout time is 3 minutes, for 5 days per week then effective capacity would be as follows:

Solution:

- First calculate the number of checkouts per hour ...
  60 minutes - 3 minutes per checkout = 20 checkouts per hour
- Then calculate the working hours per day ...
  8 hours - ½ hour = 7 ½ hours per day
- Then you can calculate the effective capacity ...
  20 checkouts x 7 ½ hours = 150 checkouts per day, or
  20 checkouts x 7 ½ hours x 5 days = 750 checkouts per week, or
  20 checkouts x 7 ½ hours x 5 days x 52 weeks = 39 000 checkouts per year

1.10 Actual capacity

As mentioned, actual capacity can only be measured as it occurs. To find the actual capacity of the oven or the cashier, you need to count and record the number of loaves actually baked or the number of checkouts actually done over the time period chosen to do the capacity measurement.

Think about it!

If you are assessing the actual capacity in an operation where these figures are not being recorded, you need to go and count the output of the operation yourself.

You might be able to record the figures for a couple of hours and then extrapolate these figures for longer periods, provided that the hours during which you did the measurements are representative of the other working hours of the operation.

For example, it's no good simply measuring the number of checkouts at a supermarket in the morning if afternoon sales are lower and then rise again during late afternoon when people do their grocery shopping after work.

1.11 Assessing the capacity gaps

Having calculated the different capacities, you are now in a position to use them to assess the capacity gaps between the types of capacity.

There are two types:

- Utilisation
- Efficiency

1.11.1 Utilisation

Utilisation is calculated as a ratio or percentage by using the following formula:

$$\frac{Actual\ capacity}{Design\ capacity} = Utilisation$$

If the actual output per day achieved for the oven was 700 loaves and the cashier did 105 checkouts per day, then their respective utilisations were:

$\frac{700}{1\ 200}$ = 0,583 or 58,3% for the oven
$\frac{105}{360}$ = 0,292 or 29,2% for the cashier

Utilisation provides us with an assessment of how well resources that have been invested in are being utilised. In our example, an investment has been made to buy an oven and a cash register.

Whenever that equipment is not being used, potential revenue is being lost. But repayments on the loan to buy the equipment still have to be repaid, whether the equipment is being used or not.

1.11.2 Efficiency

Efficiency is calculated as a ratio or percentage by using the following formula:

$$\frac{Actual\ capacity}{Effective\ capacity} = Efficiency$$

With the same actual capacities as above, their respective efficiencies were:

$\frac{700}{800}$ = 0,875 or 87,5% for the oven
$\frac{105}{150}$ = 0,7 or 70% for the cashier

Efficiency provides us with an assessment of the operation's productivity. This is a reflection of how well the process is being managed during the time it is in operation.

It is primarily the responsibility of the operations manager, as all the losses that cause poor production or service output are mostly under the control of management.

1.11.3 Interpreting utilisation and efficiency figures

Utilisation can vary widely, depending on the operating hours that are feasible.

Continuous process-type operations tend to have relatively high utilisation because of the need to make the plant pay for the large capital investment it usually requires.

> **Think about it!**
> Service operations often have very low utilisation, sometimes as low as 10%, because the equipment has been installed in anticipation of peak demand.

Think of the tills in a supermarket. Not even half of them are used most weekdays, but on Saturday morning every till has a cashier because that's when the majority of customers prefer to do their grocery shopping.

Well-run manufacturing operations can run at an efficiency of about 80%, but efficiencies as low as 50% are not uncommon. Clearly, if that is the case, there's significant room for improvement.

In addition, service operations often have relatively low equipment efficiencies, although if the scheduling of employees' working hours is matched well with demand for their services, the efficiency of service agents in operations like call centres and restaurants can be quite high.

1.12 Break-even analysis

Determining how much output is required to make a profit involves calculating the break-even point, where the value of the volume of output equals the fixed and variable costs of the operation.

Note:
Value of the volume of output is the value of the quantity of products produced or services delivered to break even.

So if 1 000 units is the break-even volume and they can be sold for R5 each, then the fixed cost and the variable cost of 1 000 units must add up to exactly R5 000.

Fixed cost refers to the expenses incurred in having the facilities to manufacture products or provide services, before anything has been produced.

These are primarily overhead costs such as rental, telephone, interest on loans, maintenance, transport, and other costs that do not result in a product being made despite money being spent on the facilities to make the products or services.

Note:
Variable costs are directly linked to each unit produced and therefore increase with each additional product manufactured or service delivered.

They usually include primarily raw materials, consumables, packaging and direct labour expenses.

The simplest form of break-even analysis requires three bits of information:

- the income per unit of sales
- the cost per unit of production
- the fixed cost per period

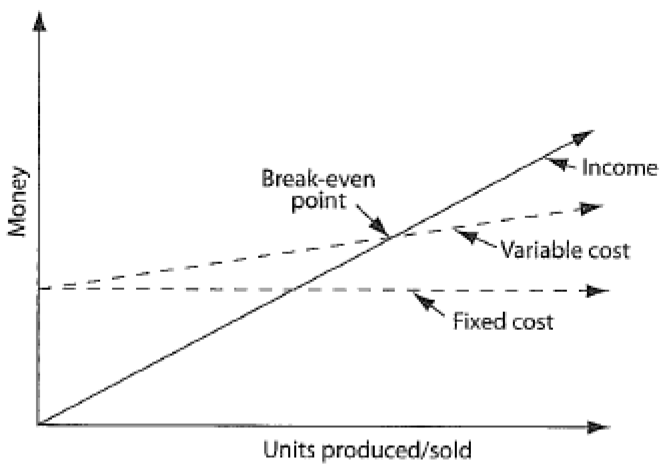


Figure 1.6

As shown in **Figure 1.6**, income increases from zero for every unit produced and sold. However, the fixed cost sets a higher minimum level of expenses before a single unit is produced.

Note:
Variable costs increase at the cost per unit from that point for every unit produced and sold. Break-even occurs where the total cost (fixed and variable) crosses the income line.

At the point where income and total costs intersect, they would be equal to one another. You can determine the production output at the break-even point by setting the formulas for income and total cost equal to one another.

The two formulas are:

$$\begin{aligned} Income &= Output \times Price\ per\ unit \\ &= O \times P \\ \text{Total cost} &= Fixed\ cost\ per\ year + (Output \times Variable\ cost\ per\ unit) \\ &= FC + (O \times VC) \end{aligned}$$

If $O \times P = FC + (O \times VC)$

Then $(O \times P) - (O \times VC) = FC$

And $O \times (P - VC) = FC$

And $O = \frac{FC}{P-VC}$ which is the formula for break-even volume

To calculate the operating profit or loss, use the following formula:

$$Operating\ profit = Actual\ output - (Break - even\ vol) \times (Price - Variable\ cost)$$

Remember, you can do break-even analysis over different periods- monthly or weekly, for example. Then all figures used need to be calculated to the same period.
So, for a break-even volume over a month, overhead costs for a month have to be used.

Worked Example 1.7

Given the following values:
Income per unit of sales R12
Cost per unit of production R8
Fixed cost per year R10 000

How many units have to be produced and sold to break even?

Solution:

$$\begin{aligned} O &= \frac{FC}{P-VC} \\ \therefore\ O &= \frac{10\ 000}{12-8} \\ &= 2\ 500 \text{ units} \end{aligned}$$

If 3 000 units were produced per year what would the operating profit be?

= $(3\,000 - 2\,500) \times (12 - 8)$

= 500×4

= $R2\,000$ operating profit per year

In this simple worked example, the assumption has been made that the prices and costs will remain constant for the period over which the calculation has been made.

Of course, this may not hold in reality, in which case the calculation has to be reworked.

Think about it!
Having worked out what the operation's capacity must be to become financially viable, it remains to be seen whether there is enough demand to sustain the required sales.

It's often the case that smaller operations are viable at low levels of demand/output because their fixed costs are relatively low.

However, these operations often have relatively high unit costs, making them expensive at higher levels of demand/output.

Operations with a higher fixed cost but low variable costs are usually not viable at low levels of output, because of the high interest payment of larger upfront capital investment that has to be repaid.

However, once demand/output exceeds the break-even volume, operations with this kind of cost structure make more profit per additional unit produced due to the larger margin between the selling price and the variable cost per unit.

1.13 How this operational capability influences operations strategy

Deciding on overall capacity involves making an important trade-off between two operational capabilities that work in inverse ways to underpin two key value drivers.

Closely matching capacity with demand keeps the investment required to create the capacity as low as possible, which in turn will keep overheads down due to relatively low interest payments.

If the operation is also run efficiently it should be possible to manufacture cost effectively, which would support the value driver of low price.

The trade-off would be with volume flexibility, because if an operation is producing close to capacity it won't be possible to respond quickly to additional demand.

Think about it!
If the operation is serving a market that is prepared to pay a premium for quick delivery for unexpected orders, then it makes more sense to use a capacity leading demand approach to capacity expansion.

The kind of capacity installed is also an operations strategy choice. In an operation that requires high process quality it would be necessary to install sophisticated equipment capable of working to the close tolerances required.

For example, in a factory where jet engine parts are machined to tolerances of one-hundredth of a millimetre, special air conditioning equipment has to be installed because variation in the temperature can make the metal parts shrink or expand beyond what the specifications allow.

Making spare parts for lawnmower engines does not require anywhere near such high process quality and therefore much cheaper 'off-the-shelf' equipment can be bought to create that kind of capacity.

Case Study 1.2: Rapid Sport: Location and capacity management

Facts and figures in the case have been simplified to make the case easier to understand. They are not a true reflection of the actual situation at Rapid Sport.

Philip started his business in his lounge at home. When the lounge simply wasn't big enough anymore, he moved the cutting tables and sewing machines into a small 80 m² factory in Wynberg and ended up employing about four people working on eight machines during high season.

However, his suppliers were reluctant to deliver to Wynberg and so in the early 1990s Philip moved to Salt River, where he also found it was easier for customers to come to the factory.

In those days he sold from a sample rack, making up the products as the orders came in, and the business occupied about 200m². The operation grew to a core group of six machinists who were permanent employees, plus another three casual workers during the high season.

In 2000 Philip decided to move into the centre of Cape Town to be more accessible to his customers. He rented larger premises of 700m² so that, in addition to the manufacturing side of the business, he could open up the factory shop with a display area.

However, rental costs were high and in 2005 he decided that it made more sense to buy a building where they also had space to store fabrics. This enabled him to buy from suppliers in the Far East, because he could buy better quality fabrics at lower prices than those of local suppliers if he bought the fabric in bulk.

The number of people employed remained more or less the same, but over time he bought more machines when he could afford it. Eventually, he owned about 60 machines to do all the specialised stitching, over-locking, closing and other functions required by the technical fabrics.

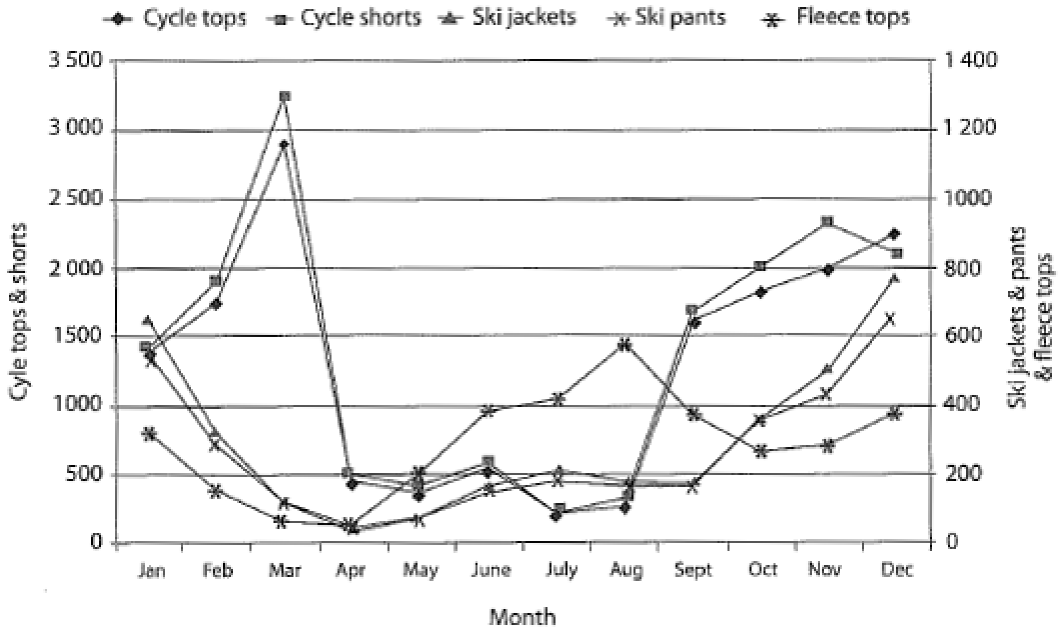
Last year, Philip kept accurate figures on his main product lines and was able to put together the monthly sales figures for each type of garment, as shown in **Table 1.6**.

He also calculated the number of labour minutes required, according to the time it took to manufacture one of each type of garment. That enabled him to work out how many labour minutes he needed every month to produce the required number and mix of garments.

Product	Cycle tops	Cycling shorts	Ski jacket	Ski pants	Fleece tops	Total garments per month	Labour minutes required per month
Minutes	12	6	36	24	16		
Jan	1 350	1 410	640	530	320	4 250	65 540
Feb	1 750	1 880	330	280	150	4 390	53 280
Mar	2 900	3 230	120	100	60	6 410	61 860
Apr	450	490	40	30	50	1 060	11 300
May	360	400	70	60	200	1 090	13 880
Jun	540	580	160	140	380	1 800	25 160
Jul	220	200	210	170	410	1 210	22 040
Aug	250	320	180	150	570	1 470	24 120
Sep	1 600	1 710	170	150	370	4 000	45 100
Oct	1 820	1 980	360	340	260	4 760	59 000
Nov	1 980	2 310	500	420	280	5 490	70 180
Dec	2 230	2 090	770	640	370	6 100	88 300
Total per annum	15 450	16 600	3 550	3 010	3 420	42 030	539 760

Table 1.6 Last year's sales figures by product for Rapid Sport

It was also interesting to see how the demand pattern for the different products changed, as shown in the graph in **Figure 1.7**.



Demand patterns of main product lines at Rapid Sport (Note different scales)

Figure 1.7

Cycling gear sold well during summer, but also had a pronounced sales peak in March at the time of the Argus cycling race in Cape Town. Snow skiing gear sold mostly during the Northern hemisphere skiing season when it is summer in South Africa, but there were also some sales during the local winter season.

Fleece tops sold together with ski tops and were also in demand during the local winter. That helped to offset the low sales during the local winter season, but overall sales at Rapid Sports were still much higher at year-end than during the local winter.

To get some idea of the efficiency and utilisation of the manufacturing operation at Rapid Sport, Philip had to find a way to standardise the Standard Minute Value (SMV) across the different garments that they produced.

To do this he calculated the weighted average SMV for the garments they produced by taking into account the quantity of each type of garment they produced last year. Then he calculated the weighted average SMV across the garments in their product line.

It worked out to approximately 13 minutes per garment. This enabled him to work out the design and effective capacity of the operation in numbers of garments by multiplying the number of minutes available to work every day with the number of working days per year and the number of permanent employees, and dividing that by the weighted average SMV.

(For the sake of simplicity he assumed that the whole eight hour working day was used only for production and that there were four weeks in every month, with five working days each.)

Philip also worked out the weighted average cost of materials (R100,06), labour cost (R6,42) and wholesale price (R227,79) per garment, and compiled the following monthly figures on the overhead expenses in his business:

Bond payment	30 000	Telephone	6 000
Marketing	42 000	Maintenance	5 000
Bookkeeping	3 000	Insurance	4 000
Managers	30 000	Transport	15 000
Security	2 000	Interest on loans	32 000
Bank fees	1 000	Electricity	7 000

Case questions:
Where the case study does not provide specific information, you can make realistic assumptions to answer the questions.

1. What were the four most important location factors that influenced Philip's decision on where to move?
2. Name a globalisation issue that affected Rapid Sport?
3. Which of the capacity expansion approaches was used at Rapid Sport?
4. Name the most appropriate overall capacity measure for Rapid Sport.
5. What is the design, effective and actual capacity of Rapid Sport? (For the sake of convenience, assume a month has four weeks and a week has five working days.) At what utilisation and efficiency are they working?
6. How many garments did they have to produce and sell to break-even at Rapid Sport?

Activity 1.1

1. What factors should be taken into consideration when deciding on a location?
2. What are the basic methods to compare the suitability of different locations, and how should they be used?
3. What are the key capacity management issues?
4. What are the basic capacity expansion approaches?
5. What are the three basic types of capacity measures, and how should they be used?
6. How can you make efficiency and utilisation calculations?
7. How can you do break-even analysis?
8. When deciding on the suitability of two locations for a warehouse to distribute books to schools, the Department of Education considered four factors with ratings for each site as indicated and weighted according to

importance. Decide which site to choose using the factor rating method. Hint: You will need to make your calculations to the second decimal point.

Factor	Weighting (%)	Site A	Site B
Close to schools	35%	5	7
Close to major access roads	25%	3	8
Warehouse rental	25%	4	2
Condition of warehouse	15%	6	4

Table 1.7

9. The Department of Education decided to use the centre-of-gravity method to check their earlier decision. They used the number of students as an indicator of how many books would need to be transported, and measured the distance to each school from the location sites under consideration. With the information provided, show the calculations using the centre-of-gravity method.

School	Students	Distance	
		Site A	Site B
1	650	76 km	124 km
2	1 200	26 km	54 km
3	900	144 km	95 km
4	2 500	58 km	78 km

Table 1.8

10. You are the owner of an events management company that specialises in organising outdoor events. Most of your business consists of organising weddings, anniversaries, and company events for about 100 people at a time.
    Occasionally, your company is contracted to organise large events attended by up to 500 people. Your company has been growing steadily and, as the cost of renting equipment is high, you are considering taking a loan to invest in tables, table linen, cutlery and crockery. You are also considering buying a marquee, which will be a large capital investment but will give you a competitive edge for securing more of the large outdoor event business.
    Give reasons for your answers to the following questions:
    a) With respect to the kind of capacity required, would you buy high quality silver cutlery and bone china crockery or more durable stainless steel cutlery and chip-resistant crockery?
    b) What capacity expansion approach would you use for the tables, table linen, cutlery and crockery?
    c) What capacity expansion approach would you use for the marquee?
11. You are the production manager of a specialist chocolate manufacturing business. Every year, about a month before Easter, you set up a short production line to make chocolate Easter bunnies. The available

equipment consists of two mixing and heating bowls, one moulding machine, which can work with one mould that holds 10 bunnies at a time. There are 5 extra moulds for cooling.

12. The steps in the process are as follows:
    - Prepare and mix ingredients for a batch of 100 bunnies (30 minutes).
    - Heat up one batch of chocolate slowly to avoid burning the chocolate until it is at the right temperature to pour (1 hour).
    - Pour chocolate into moulds, insert moulds into rotating setting machine and rotate until chocolate is spread evenly inside mould and chocolate has set so that mould can be taken out of machine (10 moulds at a time which takes 15 minutes).
    - Allow chocolate in moulds to cool off until hard enough to take out of mould (50 moulds, which take 2 hours each to cool).
    - Take bunnies out of mould (1 minute per bunny).
    - Wrap bunny in cellophane, tie up with a ribbon and put label on (3 minutes per bunny).

    a) Assuming there are just enough employees so that all the tasks can be done as quickly as possible, calculate the hourly rate of production for each step in the process. Now determine where the bottleneck is in the process.
    b) If you allocated two people to work at the bottleneck what would the rate of production be at the bottleneck, and to where would the bottleneck shift?
    c) With two employees working at the final step in the process, what equipment would you spend money on to further increase production?
13. The production line in question 12 can produce 40 bunnies per hour, but actually produces 277 bunnies in an 8-hour working day. Of these, on average, 6.5% have to be re-melted because they come out of the mould broken.
    a) What is the daily design capacity of the operation?
    b) What is the daily effective capacity of the operation?
    c) What is the daily actual capacity of the operation?
    d) What is the utilisation of the operation?
    e) What is the efficiency of the operation?
14. The monthly expenses for the chocolate Easter bunny operation are as follows:

Interest on loan to buy equipment	R2 000
Rent of premises	R4 000
Telephone, electricity, transport	R3 000
Manager's salary	R10 000

    The ingredients cost R10 per bunny and the labour cost is R5 per bunny. Each bunny sells for R20.
    a) How many bunnies do they have to produce to break-even?
    b) Assuming a month has 20 working days and they were still producing at the original rate of 20 bunnies per hour in an 8-hour working day, with a 6,5% defect rate, would the business be profitable?

c) How much operating profit or loss would the business be making at the actual rate of production of 277 bunnies per day, with a defect rate of 6.5%?

Self-Check

I am able to:	**Yes**	**No**
• Describe the mechanics of capacity resource planning		
• List the following techniques of capacity resource planning		
o finite capacity loading		
o infinite capacity loading		
• Describe the techniques of capacity resource planning listed above		
• Describe the advantages and disadvantages of finite and infinite capacity techniques		
• Calculate capacity requirements given the following information		
o efficiency		
o machine utilisation		
o man hours		
o machine speed		
• Define performance measurement in terms of capacity requirements planning		
• Describe the following performance measurement criteria		
o productivity levels		
o actual input versus planned input		
o input and output variables		
• Calculate productivity levels of all resources given the following information		
o planned man hours		
o planned machine hours		
o planned input/output raw material		
o actual man hours/machine hours		
• Describe the application of each of the criteria of performance measurement listed above		
• Describe the process of managing capacity requirements planning in terms of the following		
o set up time		
o overtime hours		
o bottle necks		
o alternate route		
o planned maintenance		
• Describe the impact of quality considerations in terms of sub standard output and its effect on capacity requirements planning		

• Describe with the aid of simple examples the following four types of capacity		
o staffing		
o equipment		
o tools		
o facility		
• Describe how each of the four types of capacity listed affect capacity and the overall performance of a work centre and the related ripple implications		
• Describe the following three types of capacity loading		
o scheduled receipts		
o planned orders		
o unplanned events		
• Describe how each of the following inputs affect capacity planning		
o demand		
o routings		
o manufacturing times		
o work centres		
• Describe four differences between the make to order method and make to stock method		
• Describe each of the following characteristics associated with capacity requirements planning		
o units of measure		
o planning horizon		
o planning period		
o work centre definition		
• Describe the difference between load and capacity		
• Given the following information calculate demonstrated capacity		
o number of periods		
o output for each period		
• Describe the following elements of lead time that influence the management of lead times		
o set up time		
o move time		
o queue time		
o run time		
• Describe the following two methods of balancing capacity and load		
o capacity responses		
o load responses		
• Describe the implications in respect of the following if the management of capacity planning is not carried out effectively		
o customer delivery promises		

o cost to work centres		
o backlog		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 2

Shop floor management

Learning Outcomes

On the completion of this module the student must be able to:

- Describe how shop floor control interfaces with material requirements planning and capacity requirements planning
- Describe each of the following techniques of the shop floor scheduling process
  - operation scheduling
  - floor control scheduling
  - kanban
  - bottle neck management
  - mixed model production
- Define what is performance measurement in terms of shop floor control
- Describe the following performance measurement criteria related to shop floor control
  - lead times
  - work in progress
  - reprocess
  - scrap
  - shrinkage
- Describe how each of the criteria listed impacts on overall performance and the implications to the areas
- Describe how each of the following competitive elements influences shop floor control
  - batch sizes
  - lead times
  - set up time
  - queue time
- Calculate shop floor control schedule given the following information
  - labour utilisation
  - work in progress
  - number of shifts
  - machine efficiency
- Describe the following functions of the shop floor control system
  - scheduling of work
  - loading of work
  - operation dates
  - monitors work in progress

  - detailing of records
  - dispatch system
  - customer service
  - status and production reporting
- Describe how training influences the effectiveness of shop floor control system
- Describe the following compensation methods associated with shop floor control systems
  - flat rate plus overtime
  - industrial piece work
  - team piece work
  - production bonus
- Describe the management of material handling in respect of the following elements
  - material input
  - material in process
  - finished product
- Describe the relationship between shop floor control and the following departments in an organisatlon
  - customer service
  - engineering
  - supplier scheduling
  - inventory management
  - quality control
  - accounting
- Describe the factors influencing the effectiveness of scheduling techniques
- Describe the benefits of project scheduling in terms of the following:
  - clear planning
  - scheduling
  - resource allocation
  - control
  - communication
- Explain what is meant by expediting and de-expediting
- Explain what is meant by least total cost
- Given the following details, calculate least total cost
  - ordinary cost
  - holding cost
  - item cost
- Given the following details calculate the productivity of a work centre
  - actual hours worked
  - standard time allowed
  - machine hours available
- Describe the four rules governing the management of queue time
- Describe the documentation process involved in setting up the shop floor control system

2.1 Introduction

During the early 1990s, the Toyota Production System (TPS) became widely accepted across the industrialized world. Companies from different industries gained in experience by applying lean principles as well as by developing and refining customized approaches to optimize products and processes.

From a practical standpoint, the implementation of TPS-elements such as one-piece-flow, visual standards or U-shaped layouts, can easily be identified on the shop floor.

Meanwhile, most of the underlying management processes and structures remain hidden to the outside observer. Closing this major gap is the objective of shop floor management.

Note:
Shop floor management provides and formalizes an integrated framework of processes with defined roles, responsibilities and competencies to sustain and improve efficiency.

Its fundamental principles include a focus on:

- Prevention
- frequent high decision making
- empowered teams, consisting of:
  - experts
  - managers
  - operators

Scientific research has focused mostly on lean principles, behavior and rules rather than on describing management processes in more detail. Due to the abstract nature of these rules, their interpretation and implementation still represents a major challenge for practitioners.

Jeffrey Liker notes in his 4P Lean Enterprise Model that most companies are on the "process" layer, ie they focus their effort on reducing the seven types of waste while not substantially addressing their philosophy, people and external partners. (see **Figure 2.1**)

The concept of shop floor management emerged from recognizing the need for efficient, on-site problem solving and therefore contributes to the highest layer in the 4P-model.

Figure 2.1 4P model

In practice, problem solving or performance tracking have not been necessarily set up as supporting processes to address the real needs of the production floor but rather for satisfying external requirements such as management reporting.

> **Note:**
> While it is essential for managers to be present on the shop floor, there is often a lack of structures and standards to efficiently improve decision making aligned with operational implementation.

Therefore, the objective of SFM described here is to close, as much as possible, the gap between individual behavior and organizational guiding principles and their application in a systematic, process-oriented industrial approach.

To do so, the it is necessary to take into account existing definitions for shop floor management supporting a pragmatic and process-oriented implementation.

Suzaki defines shop floor management as practicing the three reals:

- genba (real place)
- genbutsu (real thing)
- genjitsu (real fact)

First, *genba* refers to the location where the value is created which can be either the factory floor or a business process in case the final product is a specific service or information.

The second focus, *genbutsu*, requires all associates to understand the nature of problems rather than relying on documented information.

Finally, *genjitsu* implies that the connections between the current problems and their final root causes have been mapped based on valid and consistent data.

Definition: Shop floor management
Suzaki defines shop floor management as a closed loop process to observe the problems on site as well as to understand and eliminate their underlying root causes.

Slightly different but with a broader scope, Spear identified four main TPS rules to design, operate and improve process efficiency in 33 Toyota plants through embedded research.

While not specifically limited to shop floor management, these rules imply that any improvement has to be performed using a systematic methodology, supported by a qualified coach and executed at the lowest possible level in the organization.

Note:
A cross-functional rule requires the equipment and process design to meet first time right quality.

As a consequence, the organization is able to address continuous, systematic, highly frequent deviations from standards indicating potential risks or current problems.

Following Peters definition, SFM consists of recognizing visual deviations from standards and initiating effective countermeasures.

In addition to that, he differentiates three maturity levels.

- The focus on the lowest level is to react quickly to process failures, ie the problems have already occurred. A typical example might be the breakdown of a single machine or a section of the production line.
- The second level emphasizes preventative problem avoidance, ie potential sources of risks are systematically monitored and actions are put in place as necessary.
- On the highest level, deviations from standards have to be closely monitored to prevent the occurrence of problems, implying that root cause and effect is well understood.

Note:
More advanced levels can only be achieved through a better understanding of system behavior and standardization of prevention rules and the corresponding action plans.

Finally, managing closed loop control systems to reduce variation in production processes constitutes the concept of daily management.

In addition to sustaining standards, daily management also focuses on improvement in current conditions as well as managing change points.

Because deviations from standards refer to the process output, change point management is instead used to control input parameters when reaching critical thresholds. It thus anticipates severe impacts on product quality.

> **Note:**
> A strong focus on systematic change point management (CPM) contributes to plan and executes preventative counter measures in a scheduled way with positive impact on process variation and overall efficiency.

The brief discussion of the various approaches will be concluded with the formal definition. In general, shop floor management is a precondition for the implementation of lean systems.

It defines an organizational framework with standardized processes and activities taking place on the shop floor.

Empowered, multi-skilled teams with a profound understanding of system behavior decide and facilitate the sustainable implementation of effective and efficient counter measures.

Abnormality control, attainment of change points, deviations from standards, current problems and the continual efficiency improvement along the value stream are the major drivers for activities and counter measures.

2.2 Shop Floor Management Process Model

Figure 2.2 shows the extended SFM process model based on the previous definition.

The display of the hexagon has been chosen to express that the elements complement and interface with each other while the six step process illustrates the rigid, cycle-by-cycle structure leading to its implementation.

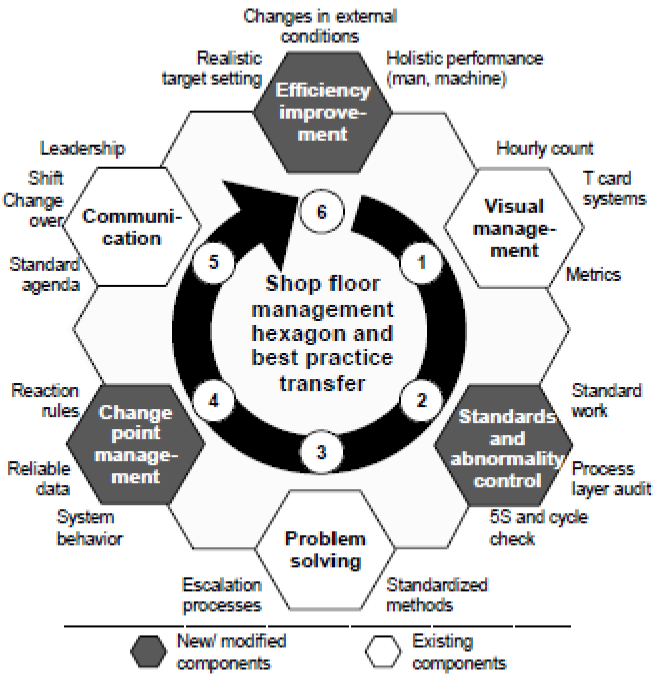


Figure 2.2 Hexagon of shop floor management

The tools next to the elements have to be interpreted as enablers of the process.

Changing the perspective from a tool-oriented implementation view, eg the introduction of standard work combination sheets or 5S standards, to the process perspective helps team and management to understand their "real" contribution to efficiency improvement.

Think about it!
The benefit of SFM relies not on the presence of tools but rather on their consistent, process-driven application.

Although there is no contradiction between this model and Peters' concept, three major differences must be acknowledged.

- First, the elements change point management and efficiency improvement have been added. Managing change points systematically emphasizes prevention and thus reduces effort required for reactive problem solving.

  The objective of efficiency improvement is to break down changed external or internal conditions in a standardized way into realistic targets on the operational level by looking holistically at performance (man, machine, organization).

- The second difference is the change in mind from an element or even tool implementation perspective to a process orientation as stated above.

- Finally, systematic, best-practice transfer is an integral part of SFM. It ensures knowledge exchange across teams, increases efficiency in problem solving and leads to a focus on prevention rather than on reacting to problems in the long term.

Visualization enables organizations to:
- effectively communicate
- focus teams on common goals
- facilitate decision making on the shop floor

Did you know?
For implementation purposes, shop floor displays and t-card systems are simple but effective tools.

This concept does not specify methods for problem solving. Nevertheless as a general condition, a systematic approach based on reliable standards, for example, 8D, Kepner-Tregoe, Six Sigma, is mandatory to avoid trial-and-error problem solving and leads to significant better results.

Depending on the market environment and product specifications, industry guidelines have to be adopted.

In addition to the problem solving approach itself, a suitable escalation process has to be defined and aligned with the management levels of the organization.

Finally communication refers to standardized and scheduled exchange of information within the team.

2.2.1 Abnormality Control

The objective of this sub process is to enhance the ability to see and correct abnormalities in the short-term that can contribute to poor quality and customer complaints.

Based on project experience and scientific research, the importance of abnormality control is often understated.

The perception of many western managers is that 5S simply describe basic housekeeping elements rather than a means for managing continuous improvement.

Definition: S5
sort, set in order, shine, standardize and sustain.

Thus implementing stable 5S initially relies upon a strong belief in its importance since the relationship between poor 5S status and its impact on key performance metrics is not directly transparent.

This approach thus requires establishment of abnormality control as a consistent process within the shop floor management concept.

Finally the process scope should not only encompass 5S, but also incorporate safety related and equipment abnormalities. Some practitioners call this combination of 5S levels and safety the 6S concept.

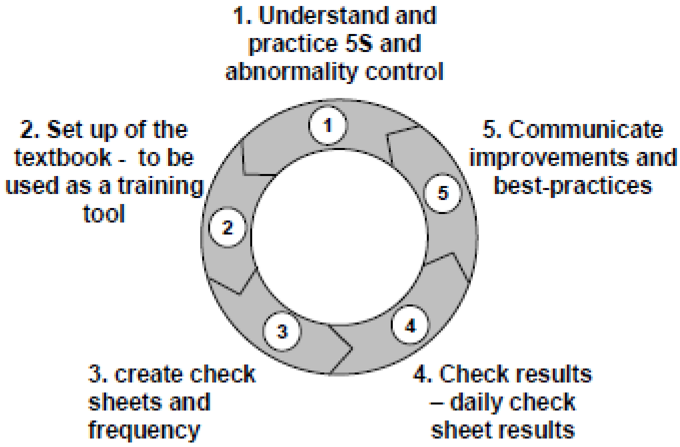


Figure 2.3 Abnormality control cycle

Figure 2.3 displays the continuous process to start and stabilize abnormality control.

In the first step, a common understanding of each of the 5S levels has to be developed within the shop floor management team.

In addition to that, abnormalities have to be analyzed in a holistic way rather than scattered around the production cell.

In addition to observations on the shop floor, external data in terms of process parameters should be taken into account for example, applied pressure or temperatures of a molding press.

Note:
Sources for this kind of data could be shop floor data based on manufacturing execution (MES) systems.

In the second step, these findings are consolidated and their target situation is described (see **Figure 2.4**.)

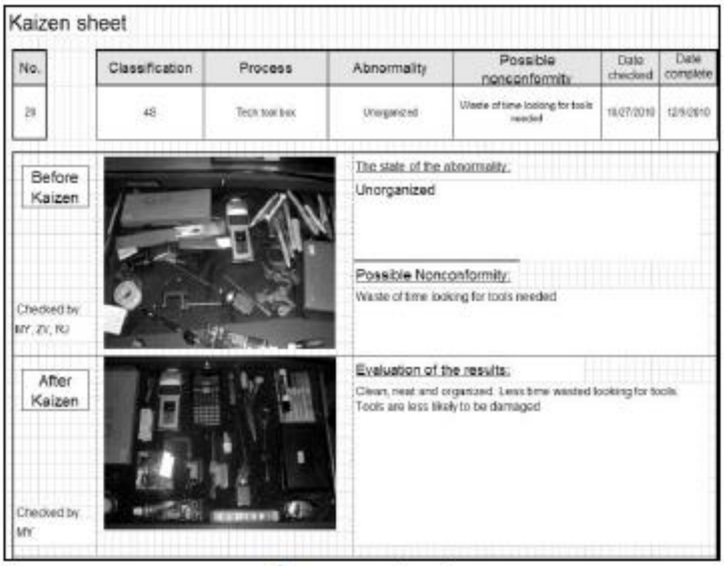


Figure 2.4

Each abnormality found is classified (5S, safety, equipment), assessed regarding its possible nonconformity and assigned to a shop floor team member to be solved.

Once completed, the problem-solving steps and responsible team member must be tracked in the third step.

As abnormality control is considered a continuous process, existing check sheets are updated incorporating new or modified standards and their check frequencies.

Step four encompasses the regular monitoring and documentation of the implementation status with visual tracking sheets in the production area.

The abnormality control process cycle is concluded with presentation of findings and best-practice solutions to other shop floor management teams before restarting the same activity in a different cell.

Note:
The conduction of these events is based on a continuous schedule.

2.2.2 Change Point Management

In general, issues regarding product quality are the result of a change. In its introduction, the Toyota handbook for CPM links quality problems with the corresponding nature of a change.

According to that, about half of all issues stem from so called programmed changes such as new part numbers, product models or new production process introductions.

Considering that these processes are managed by other major business units prior to start of production and thus not primarily owned by the shop floor – for example the product development process - other quality issues that erupt can be considered systemic.

Their main drivers are setup and changeover processes, operator changes and abnormal conditions in terms of machine or tool malfunction.

Therefore, CPM always starts with a holistic analysis of potential change points (see **Figure 2.5**.)

Change points in each of the four categories have to be discussed regarding root causes impacted by man, machine, material and methods using Ishikawa diagrams.

Note:
Past experiences, current problems and future potential risks have to be taken into account in this brainstorming stage.

While the challenge for planned changes is to minimize disruption of current production, the focus of the second and third category is to define suitable reaction rules for personnel facing clearly described abnormal situations.

Finally, visualization is the key to manage gradual changes. Upper and lower control limits combined with real-time process data, for example, sharpness of tools, indicate whether change points have been approached or already reached.

Six Sigma tools can be used to model the system behavior in case process data cannot be directly measured.

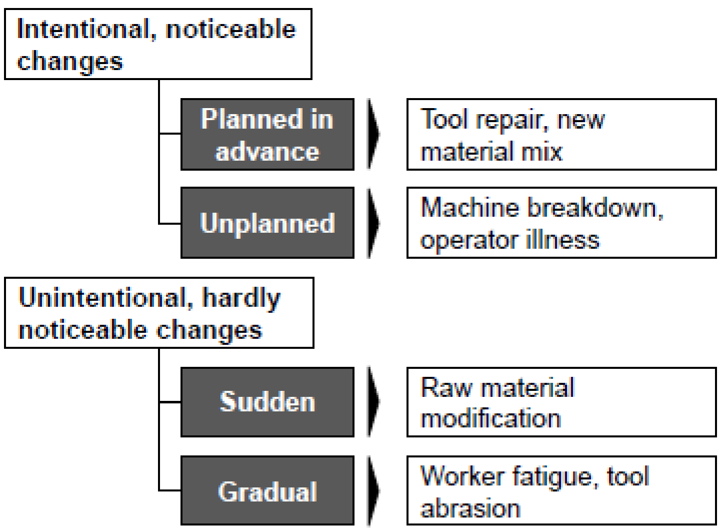


Figure 2.5 Change point analysis

Definition: Six Sigma
Set of techniques and tools for process improvement.

Once the analysis is complete, standard reaction rules have to be agreed upon and described in abnormality reaction rule displays, (see **Figure 2.6**).

They connect the change points on the left with the corresponding escalation levels to the right, commencing with the operator at the machine and moving up the chain to the operations manager.

They describe specific actions to be taken according to the competencies of each role. The levels have to be aligned to other escalation processes such as layered process audits.

The standard agenda on each level starts off with an evaluation and assist phase to agree on the same problem and root cause understanding, followed by recording and reporting the change point event.

The record history facilitates internal or external tracking specifications and also helps to understand in detail the impact of the change point to the process output.

Note:
If the directly initiated counter measure has been effective, regular operations will be resumed and an escalation to the subsequent level is not required.

To ensure a quick response and information tracking, standard lead times can be defined for each level after automatically being forwarded to the next layer.

Nevertheless this automated flow must not be designed too aggressively, ending up potentially with either with too much detail on higher escalation levels or overloading the process.

Even with a highly skilled and trained workforce, these displays serve as a guideline and check list of necessary actions.

They are not a substitute for more detailed process descriptions such as quality control plans.

Finally, they illustrate standard reaction rules to outside observers and thus explicitly describe the dynamic behavior of the production system.

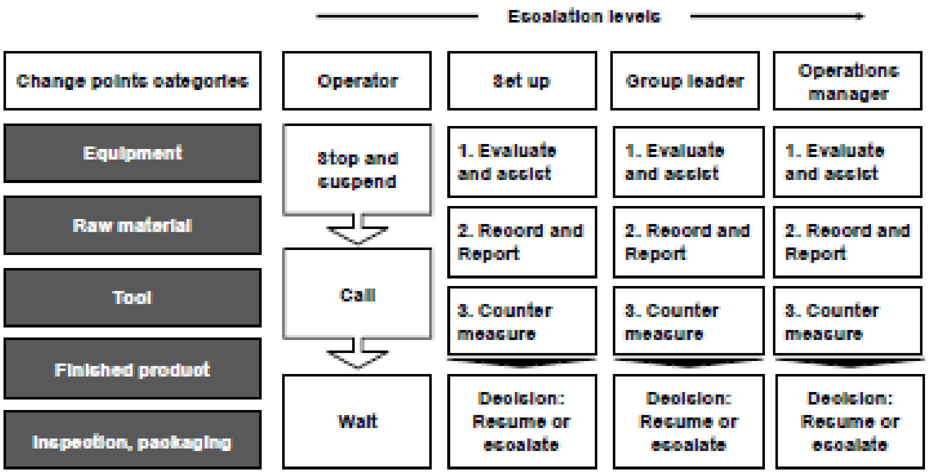


Fig. 6. Reaction rules

2.2.3 Efficiency Improvement

In addition to maintaining existing standards, SFM has to provide a consistent approach and methodology to facilitate sustainable efficiency improvement.

External conditions and performance targets are may continuously change and the TPS also specifies ongoing waste reduction. The following standardized five step process satisfies these exogenous and endogenous specifications.

The first step consists of defining the current needs and focus of the improvement. It can be either induced by modified external conditions, for example, production volume increases requested by the customer, or strategic decisions such as internal product transfers.

> **Note:**
> Key performance indicators that will be impacted have to be selected and top down targets formulated.

Following the guidelines of the TPS, the balance between the following has to be ensured.

- Quality
- Lead time
- Productivity
- Safety related targets

Additionally general conditions in terms of constraints must be defined.

The second step incorporates an in-depth analysis of the current performance of the production cell or line.

To do so, the limits of the production area have to be grasped using schematic layouts of equipment. Before starting detailed time studies, standard operator movements have to be observed and mapped.

The quantity of current production (articles and volume) and resources in terms of operator staffing (shifts or allocated hours) in a representative time period have to be analyzed.

Supporting resources such as set up associates have also to be taken into account and if needed, allocated using suitable key factors to the respective production area.

This phase is followed by detailed time studies on the shop floor focusing on standard work as well as non-standard activities (changeover, machine breakdowns etc).

> **Note:**
> For both types of analyses, the accuracy of time measurement units depends on the observer's choice and the current degree of standardization.

For standard work analysis purposes, **Figure 2.7** outlines a potential guideline to derive the right detail for the measurement units.

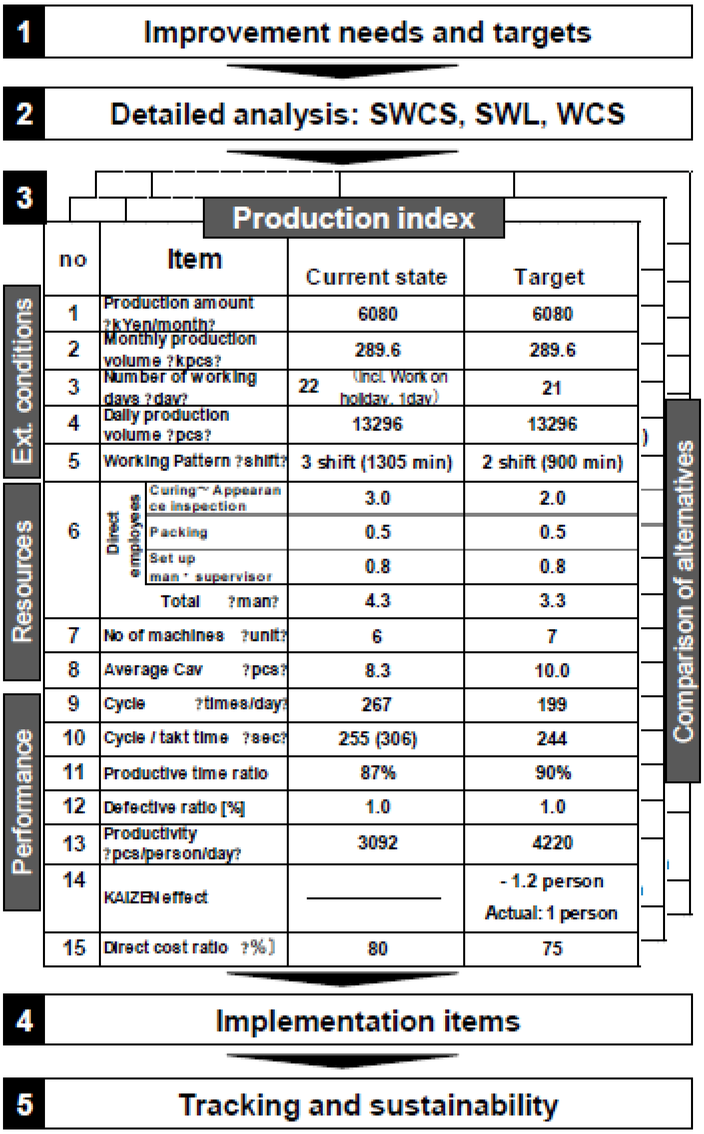
In general, their choice should be based upon the ability to distinguish between activities that add value and those that result in waste.

The same concept can be applied to benchmark similar machines against each other on a process step level.

Precise time durations to open or close a press, vertical or horizontal movements or the pressure build up phase can be compared among similar types of equipment and the root causes for deviations can be identified.

As a final step, a virtual good-practice machine cycle based on the lowest time for each process step should be determined.

The final results of the standard work analysis are documented using standard work combination sheets (SWCS) as well as standard work layouts (SWL).



no	Item		Current state	Target
1	Production amount ?kYen/month?		6080	6080
2	Monthly production volume ?kpcs?		289.6	289.6
3	Number of working days ?day?		22 (incl. Work on holiday, 1day)	21
4	Daily production volume ?pcs?		13296	13296
5	Working Pattern ?shift?		3 shift (1305 min)	2 shift (900 min)
6	Direct employees	Curing~ Appearance inspection	3.0	2.0
		Packing	0.5	0.5
		Set up man · supervisor	0.8	0.8
	Total ?man?		4.3	3.3
7	No of machines ?unit?		6	7
8	Average Cav ?pcs?		8.3	10.0
9	Cycle ?times/day?		267	199
10	Cycle / takt time ?sec?		255 (306)	244
11	Productive time ratio		87%	90%
12	Defective ratio [%]		1.0	1.0
13	Productivity ?pcs/person/day?		3092	4220
14	KAIZEN effect		————	- 1.2 person Actual: 1 person
15	Direct cost ratio ?%)		80	75

Figure 2.7 Production index

In addition to that, the intention of work content studies (WCS) is to get a deeper performance understanding over a longer period of time, typically on a 24-hour basis in a three shift operation.

During this period, each associate in the area under consideration is observed separately without interruption.

The WCS also encompasses non-standard work such as shift change activities, changeover processes or response to machine failures.

The production index has three main tasks in the third process step:

- First, it consolidates the current performance data and therefore determines the baseline for efficiency improvement.
- Second, it serves as a model to break down overall efficiency targets to specific performance parameters of the production cell as shown in **Figure**

2.8. For example, reduction in cycle time, increase in overall equipment efficiency or scrap reduction positively contribute to a top-down productivity target of +20 percent.
- Third, it is able to quickly compare different scenarios with each other before final targets are set.

Line items 1 through 5 usually incorporate external conditions such as the shift pattern and production volumes.

Items 6 through 8 represent current resource consumption (personnel, machines and tools), while line items 9 and 10 reflect the major results of the previous time studies.

The productive time ratio (11) expresses the percentage of time being spent with production of parts and constitutes the first major performance parameter.

This ratio also tracks the current efficiency level of the cell by measuring associate productivity in terms of pieces.

After defining the baseline, the production index is applied to derive sub targets. To do so, external conditions which are not subject to change such as production volume and scrap rate are kept stable.

Here, a challenging top down target of more than 25% operator efficiency improvement has been given upfront.

The production index is now the vehicle to indicate the right levers and derive the corresponding sub targets: integration of an additional machine in the operator cycle (item 7), more efficient use of tool cavities (line 8) and an increase of +3%of the productive time ratio (item 11).

Note:
If achieved, these levers increase efficiency by 36 percent (item 13).

The fourth step defines implementation items to satisfy the above mentioned sub targets and benefits from the detailed time studies and data analysis in earlier steps.

For instance, the SWCS represents the simplest simulation tool to check the plausibility of integrating the additional machine in the standard work.

It also quantifies how much process steps have to be optimized through waste reduction.

If possible, each improvement has to be time studied separately on the shop floor and its impact has to be verified ceteris paribus.

Note:
This best-practice approach ensures an easy transfer of optimization ideas to equipment with slight modifications outside the respective area.

Non-standard work activities usually cause disruption of regular operation, thus their main levers for optimization are to perform these tasks in a scheduled and standardized way.

Similarly, tool efficiency benefits from preventative maintenance activities that are provided by dedicated expert support teams with fast and reliable response times.

Once all improvement items are chosen and their time-related impact verified, the fifth step encompasses their sustainable implementation.

Technical changes of equipment, training of employees and updating of standards is being conducted step-by-step.

Until the targeted efficiency has been achieved and stabilized, the production index is being tracked on a shift-by-shift basis.

The implementation is managed by the dedicated shop floor management resources.

Until now, there has been limited research regarding SFM approaches and the explicit formulation of its processes. Information presented in this article will help close this gap.

Further reading material:

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By discussing related scientific research, the formal definition for SFM has been expanded to represent the foundation for the developed model.

The process model is designed to prevent abnormalities, to ensure highly reactive decision making and to facilitate continuous efficiency improvement.

Due to their novelty, abnormality control, change point management and efficiency improvement have been described more in detail.

It is important to understand this approach as a consistent guideline rather than a catalogue of tools to be implemented. Involved associates will not only experience a steep learning curve but also a higher motivation as a team.

Following this approach, organizations will benefit from more stable processes and aligned decision making rather than reactive problem solving.

2.3 Deployment of lean thinking

Cloth is woven by stretching many threads of yarn vertically on a loom and then passing a shuttle between the vertical yarns to insert threads that run horizontally in the cloth.

Did you know?

In the early 1900s, weaving machines were still controlled manually.

An operator had to be ready to stop the loom in order to prevent defective cloth being made if one of the threads broke under the tension of being stretched. If the loom wasn't stopped, a line appeared in the cloth where the vertical thread was missing.

Sakichi Toyoda figured out an ingenuous way to prevent this problem by passing each vertical thread through the eye of a needle, which would drop as soon as a thread broke and stop the machine automatically.

This was a major innovation at the time, not only because it improved the quality of the cloth but also because it allowed one operator to look after several machines.

Toyoda sold the patent for his mechanism to an English loom manufacturer for what was then a small fortune, and he invested the money in developing the first Japanese car during the 1930s.

And so the Toyota Motor Company started, as well as the beginnings of an approach to managing operations known today as 'lean thinking'.

Maintaining acceptable quality against a specified standard does not necessarily improve the performance of the operation.

Towards the end of the 1900s Japanese industry, followed by industries worldwide, became much more competitive because they developed the operational capability to continuously improve how their processes worked and consequently their operational performance.

It is important to understand the principles behind lean thinking in operations management, and how to deploy it.

2.4 Principles, programmes, systems and techniques

Many books and articles have been written about the various approaches to the new way of managing operations.

Some of these approaches are:

- Lean Thinking (LT)
- Total Quality Management (TQM)
- Just-in-Time (JIT)
- Total Productive Maintenance (TPM))
- World Class Manufacturing (WCM)

Did you know?
Sometimes, texts on lean thinking are confusing because the management issues and practices are written about in an unstructured way. So it's useful to distinguish between different levels of understanding about a lean thinking approach to management.

- *Principles*: The fundamental guidelines that are based on the thinking or philosophy behind a management approach such as lean management. These principles are abstract and generalised, and therefore need to be translated into real-world systems and practices when the management approach is applied to a specific operation.
- *Programmes*: Organisation-wide initiatives to deploy a management approach such as LT. Programmes usually have at least the following two dimensions:
  - *Strategy*: The policies (eg, the decision to improve the skills of employees) and management practices (eg, the actual training of employees) that are deployed in the organisation.
  - *Deployment*: The roll-out of a programme according to the deployment plan, which includes specified time periods for executing the activities in the plan and completion deadlines.
- *Systems*: The S2 level systems that give effect to S1 level strategic decisions. The new management approaches sometimes require traditional systems (eg, MRP) to be replaced with new operational systems (eg, Kanban) because they are based on different principles and therefore work differently.
- *Techniques*: The methods or procedures used to collect and analyse operational information, or to execute tasks. Decision-making techniques to improve production and service processes are an integral part of lean management that were not used in traditional approaches.

Definitions:

Terminology used by authors and practitioners of lean approaches can be confusing. You may find it useful to distinguish clearly between the following terms.

You often hear about *best* practice, as in 'the *best* practice in this industry is ... This way of talking usually fails to distinguish between *management practices* as opposed to *work practices*.

Management practices are best thought of as what are referred to as S2 level systems. For instance, teamwork is a common management practice nowadays, but from an operational point of view it is really just an S2 level system to achieve S1 level objectives by organising employees to work in a particular way.

Conversely, *work practices* are how people on the shop floor or shop front do value-adding work.

In other words, the *S3* level work that directly creates products or delivers services.

While most people use the word '***implementation***' to refer to both *management* and *work practice* execution, the Japanese distinguish between ***programme deployment*** (***hoshin kanri***) and *work practice* implementation.

Deployment puts in place new management practices, but does not yet directly impact on value-adding activities.

For instance, training people in teamwork may be a necessary part of programme deployment, but it does not mean that people will work as a team according to the way they were trained.

Implementation refers to changing work practices, or production or service delivery systems that directly alter the way in which value is created or delivered.

An example of implementation is when a team tries to work differently, according to new work practices they have decided to adopt to improve their performance.

2.4.1 Principles of lean thinking

After a substantial research project to understand why Japanese car manufacturers were so successful, Womack and Jones summarised the lessons they learnt as five principles of lean thinking.

- ***Define value from the perspective of the end customer***: This fundamental principle directs management's attention to the product and service characteristics that are of actual value to customers. A clear understanding of exactly what creates value for customers is necessary in order to focus all the efforts and resources of an organisation on creating value.
- ***Identify the value stream for each product/service and eliminate waste***: Understanding each step in the process of how a product or service is produced or provided is necessary to determine which steps create value and which do not. Those that do not create value are regarded as waste and should be eliminated.
- ***Make the remaining value-creating steps flow***: Obstacles to the flow of WIP, people or information through the production/service process need to be eliminated or reduced.
- ***Provide only what the customers want and only when they want it***: Traditional manufacturing attempts to balance demand with capacity by holding inventory. The new approach is to develop the capability to respond quickly to customers' needs so that it's only necessary to make what they want when they want it. This approach consumes the least resources and therefore costs less.
- ***Pursue perfection***: This principle is aimed at continuously improving the production/service process to deliver better operational performance. Perfectly satisfying customers whenever they require it may not be possible, but trying to achieve 'perfection' sustains efforts to improve the operation.

An important part of understanding lean thinking lies in the fundamental distinction between value and waste.

Once people learn to see waste as more than just the off-cuts, rejects or delays in a production or service process, and see it rather as anything that does not create value for the customer, they can start eliminating the time, effort and resources wasted on those activities.

Case example 2.1 will help you to understand how the principles of lean thinking can be applied in a service environment.

Case Example 2.1: Value versus waste

Students who need to make copies in the library for study purposes don't need faxing or scanning facilities. Installing photocopiers with these functions would be a waste as it does not add value for those customers.

However, the complete process of accessing study material involves locating the book on the shelves, making copies and paying for them.

Therefore, positioning self-service copiers close to the library shelves and linking the copiers to a pre-paid card payment system eliminates unnecessary movement between the book shelves, the photocopiers and the cashiers.

This, in turn, speeds up service and enables late-night students to make copies whenever they need to, which does create value for them.

Taiichi Ohno of Toyota first identified seven of the most common wastes in manufacturing, as listed below.

- ***Over-production***: Making products that are not actually required at the time of production due to poor forecasting, planning or inappropriate incentive systems. For example, uncertainty over how many photocopies are required for a class often leads to making a few extra, 'just in case'.
- ***Inventory***: In addition to the usual costs associated with inventory, it also hides problems (like defects) under piles of stock and leads to a mindset conducive to over-production.
- ***Processing***: Unnecessary work during the production process. For example, first stacking parts onto a workbench before starting work instead of taking the parts directly from the delivery crate.
- ***Defects***: An obvious source of waste, because fixing a defect requires time and effort that could have been spent on making new products.
- ***Waiting***: Workers or machines standing idle while waiting for raw materials, instructions or repairs are an obvious waste.
- ***Transportation***: Long distances between work stations and unnecessary double handling of materials and WIP can be very wasteful.
- ***Motion***: Human or machine movement that does not add value. For example, re-arranging papers without purpose, using unnecessary hand movements during a task, or a computer-controlled drilling machine not taking the shortest route between holes.

The following forms of waste in service operations have been adapted from those identified by John Maleyeff.

- ***Delay***: Time before service can begin, such as people in a queue, documents in an In-box or a call that has been logged at a helpline.
- ***Mistakes***: Errors and omissions that cause rework or customer complaints.
- Inspection: Checking of work for errors and omissions, such as review of documents by supervisors, language editing or service evaluation by customer service assessors.
- ***Duplication***: Repeating work, such as making written notes before typing minutes, filing a hard copy of electronic information or double capturing data to ensure accuracy.
- ***Movement***: Transport of information, people or equipment, such as walking between offices to deliver files, travelling to meetings instead of videoconferencing.
- ***Processing Waste***: Doing tasks inefficiently, such as working in a disorganised way, discussing irrelevant issues during a consultation, not using templates to generate reports repeatedly.

- ***Resource Waste***: Waste of staff, equipment, materials, or capital, such as keeping staff waiting or using skilled employees for basic tasks.

2.4.2 Lean programmes

Many of the programmes based on the principles of LT have similar elements and have become well known in their own right.

As their names suggest, TQM focuses on quality, JIT on materials handling and the supply chain, and TPM on equipment utilisation - but they all share a common foundation of creating value for customers, eliminating waste, and increasing flow.

These programmes have been characterised in many different ways by various authors, however, only the key elements of the programmes will be covered.

2.4.2.1 Total quality management

Total quality management programmes are often used in batch and assembly operations, where process quality has a big effect on performance. The programmes usually include four elements.

These four elements are:

- ***Customer orientation***: This entails exposing the whole operation to market requirements, not only by developing the operational capabilities that will most directly deliver value to their customers, but also by activities such as customer visits by shop floor employees.
- ***Continuous process improvement***: As well as doing everyday direct production work or service delivery, TQM programmes include investigation of operational information to make regular and ongoing improvements to the production or service processes.
- ***Employee participation***: Team-based work organisation is used and employees are involved in decisions on how to make process improvements. The contributions of shop floor employees are recognised, appropriately rewarded and developed by training.
- ***Leadership***: The huge organisational change when TQM is adopted requires strong leadership. Once it becomes a way of life in an organisation, leaders are expected to make visible efforts to show their support, communicate effectively, resolve disputes, and allocate the necessary resources to sustain the programme.

2.4.2.2 Just-in-Time

Just-in-Time programmes are most appropriate for operations that manufacture products with many parts, and long supply chains in which materials handling and logistics play a large role.

JIT is regarded by some commentators as the original formulation of the new approach to manufacturing, and so their view of JIT includes some of the fundamental principles of LT.

Given our view of JIT, as focused on reducing waste from the supply chain and internal production process, the deployment of a JIT programme would include at least five elements.

- ***Production at the rate of customer demand***: The closest practical approximation of the principle of making only what customers require and only when they require it is to directly link goods scheduled for production to the rate of demand. This is achieved by levelling the production schedule and making use of pull production control.
- ***Process-based shop floor layout***: Traditional factories are laid out by departments in which similar activities are performed together (eg, separate cutting, sewing and packing departments). JIT operations group activities necessary for products with similar production requirements together in a process-based layout, where teams work in manufacturing cells using equipment dedicated to the production of those products only.
- ***Reduction of WIP***: To facilitate fast, even flow of WIP through the production process, smaller batches of WIP are used. This necessitates more changeovers between batches, so particular emphasis is placed on the reduction of set-up and changeover times.
- ***Quality at source***: Having less WIP in the process reduces the buffer stock available in the event of production disruptions. Therefore, JIT production cannot afford for defects to be passed on down the line, and doing work 'right first time' becomes essential at each workstation. In-line quality checks and process improvement by shop floor employees - as well as giving them authority to stop the production line when a problem cannot be fixed quickly - are used to maintain high process capability.

Note:
Supplier development and collaboration: Suppliers are expected to deliver parts with few or no defects just in time to be used, and sometimes several times a day.

In order to achieve reliable supply, some manufacturers help their suppliers to improve their quality management systems and work with them on component designs that are easier to produce and assemble.

2.4.2.3 Total productive maintenance

In capital-intensive industries, where equipment downtime is very costly, the principles of LT have been incorporated into TPM programmes that are particularly suited to eliminating waste of downtime and increasing yield.

Elements commonly found in TPM programmes are preventative maintenance, autonomous maintenance, and equipment upgrading.

- ***Preventative maintenance***: Rather than 'run to breakdown', TPM programmes pay special attention to preventative maintenance plans

and/or equipment condition monitoring to identify potential machine failure and carry out pre-emptive maintenance.
- ***Autonomous maintenance***: Equipment operators often know their machines so well that they can hear noises or feel vibrations that indicate a potential breakdown. So, operators are trained to identify potential breakdowns and to carry out minor maintenance on equipment.
- ***Equipment upgrading***: Teams of engineers and shop floor employees work together to make equipment more reliable and easier to maintain than when it was originally installed.

Seeichi Nakajima identified six losses associated with equipment, all of which contribute to the waste of Overall Equipment Effectiveness (OEE):
- Downtime from set-up and adjustment of equipment
- Downtime from occasional or repeated equipment breakdowns
- Minor stoppages, such as when equipment is idling, input materials are not available or output cannot go to the next machine because it is not working
- Reduced operating speed due to adjustments being made, or a machine not working correctly, or other parts of the process running slowly
- Defects and rejects caused by worn-out or faulty equipment
- Reduced yield due to not operating at the correct temperature, pressure, worn-out blades, etc; or due to start-up losses when equipment is not yet
- running correctly

2.4.2.4 Other programmes to improve performance
This section covers several other programmes consistent with LT principles that deserve mention:
- Toyota production system
- world class manufacturing
- six sigma
- theory of constraints

Toyota production system
To this day, the Toyota Production System (TPS) is the model of LT that many other companies aspire to. According to Toyota,5 the roots of TPS are JIT and Jidoka.

Following a visit to the American Ford factory in 1935, Eiji Toyoda developed TPS - although Taiichi Ohno is credited with being the most important contributor.

Ohno's determination to improve continually was legendary. Apparently, he once told engineers, who reported that they halved the time it took to set up large car body-part presses, to halve it again.

Spear and Bowen identified the unique characteristic of the TPS to outperform almost every other car manufacturer over a long period of time as the systematic improvements to Toyota's production process, carried out according to scientific principles.

Definition: scientific principles
Used in this context it means using facts to generate improvement suggestions, which would then be tested before implementation.

Then, everyone works strictly according to the improved work practices, because doing the same task differently introduces waste of one kind or another.

So the flexibility to change constantly for the better is complemented by the discipline of using the single best way of creating value during normal production.

World class manufacturing
Richard Schönberger was one of the first authors to spread the word about Japanese manufacturing techniques. His 16 WCM points provide a good overview of what a lean programme should include:
- Team up with customers and organise production by customer/product family.
- Capture and use customer, competitive and best-practice information.
- Make continual, rapid improvement in what customers want.
- Involve shop floor/frontline employees in change and strategic planning.
- Use only the best components and suppliers.
- Cut flow time and distance of WIP, and set-up and changeover times.
- Operate close to the customers' rate of demand.
- Continually train everybody for their new roles.
- Expand variety of rewards, recognition and pay.
- Continually reduce process variation and quality failures.
- Shop floor/frontline employees record their own performance data.
- Eliminate the root causes of problems, thereby reducing the need for checking.
- Align performance measures with value drivers based on customer requirements.
- Improve current capacity before installing new equipment or automation.
- Use simple, flexible, low-cost equipment rather than big, expensive machines.
- Promote and market every improvement.

Six sigma
Six sigma programmes derive their name from the goal of achieving high enough process capability so that the operation's process variability is low enough for three standard deviations on either side of the target average to fall within the tolerances set for the product quality specification, and less than 3,4 parts per million are defective.

Improvement project facilitators, called 'black belts', use statistical techniques to monitor performance plus a five-step process improvement method known as DMAIC.

Definition: DMAIC
It stands for define, measure, analyse, improve, and control.

Six sigma projects aim to improve quality as well as financial and other business goals.

Theory of constraints
Although purists may not consider it to be lean thinking, the Theory of Constraints (TOC) developed by Eliyahu Goldratt attempts to minimise waste at the bottleneck activity.

According to Goldratt, the bottleneck activity determines the capacity of the entire operation. TOC works on what is called the 'drum-buffer-rope' system.

- The drum is the output rate of the bottleneck activity, which sets the pace of production for the whole operation.
- The buffer is a small amount of WIP just before the bottleneck to ensure that it is never starved of work.
- The rope is the production schedule for other parts of the process, which is based on the capacity of the bottleneck activity to balance the entire process.

TOC also regards process improvement as important, but focuses improvement on the bottleneck. Of course, if the output rate of the bottleneck activity is enhanced, it is possible that another activity may become the bottleneck.

2.4.3 Lean systems
This section covers some of the systems used by lean operations. The systems are not all used by every lean operation, but 5S and visual management are regarded as a foundation for any lean operation.

2.4.3.1 5S workplace organisation
5S represents five Japanese words that describe the steps in a process to organise the workplace for effective work.

- *Seiri* (sort out): Identify the necessary tools and get rid of the unnecessary.
- *Seiton* (organise): Keep the necessary tools and equipment tidy and available.
- *Seise* (maintain): Regularly inspect and clean your workplace.
- *Sheiketsu* (best practice): Improve and make the practice a way of life.
- *Shitsuke* (good habits): Develop the discipline to stick to SS.

Did you know?

In Western industry, SS has become known as a housekeeping system, but the Japanese believe that it isn't merely a way of keeping the workplace tidy.

They regard SS as an application of the LT principles in that tools and equipment not required to do the work that creates value for customers actually get in the way, and represent a form of waste.

Keeping required tools and equipment tidy and in place means less time is wasted searching for missing tools.

2.4.3.2 Visual management

Visual management refers to making the information required to do tasks properly easily available to shop floor employees.

This could include:

- Displaying the correct work procedures
- Providing daily production schedules to the shop floor
- Keeping records of quality and other performance data on process charts.
- Displaying information about employees' responsibilities
- Using simple pictorial posters to convey safety and other messages
- Using colour-coded crates (eg, red for defects)

The application of visual management differs in every lean operation, but the basic objective remains the same: to enable employees (and even strangers) to understand quickly and easily what is the right way of doing the job and where to find or put things.

2.4.3.3 Levelled production schedule

While JIT production has the advantage of eliminating the waste of overproduction, it does not work well in circumstances where the production schedule changes frequently.

Apart from uncertainty about whether supplies and resources are available if the production schedules change frequently, it is difficult to communicate the changes down the supply chain.

Therefore, JIT producers use levelled production schedules, where the fluctuations in demand have been levelled according to the average short- and medium-term demand patterns.

Note:
Levelled production is facilitated by standardising product lines and using modular parts.

For example, car manufacturers produce different model vehicles on the same production line by using the same chassis, suspension, engine and gearboxes, yet fitting different bodies and interior fittings.

So a car, pick-up truck or panel van may come off the same 'production platform'.

This system requires a way of accommodating the different rates of demand for the different models of the products.

Mixed model production - or Heijunka as it is known in Japanese - spreads the different rates of demand across the sequence of production rather than producing batches of each model.

If the demand for vehicles in a month is 600 cars (C), 400 pick-up trucks (T) and 200 panel vans (V), rather than produce batches of these quantities, the mixed-model production sequence would be: C, T, C, T, C, V.

In this way, the required mix of product would be made all the time. Levelled production scheduling requires not only the capability to switch seamlessly between the assembly of different models, but also that the whole supply chain is organised to deliver the correct parts for the sequence of models produced.

2.4.3.4 Pull production control

In traditional manufacturing, production is 'pushed' by a production schedule originating from the MRP system that tells everyone what to produce and when.

The problem with these types of production scheduling systems is that when an unforeseen stoppage or other problem occurs it is difficult to rapidly update the schedule.

Situations result where one department of the factory produces goods that cannot be processed by the next department, which then end up in unnecessary WIP.

Lean production scheduling often uses a 'pull' system, whereby the signal for commencing production of a particular part is given by the 1'equi1'ements of the next workstation that needs the part.

This means that there is no overall production schedule; each workstation simply produces what its internal customer workstations require, and does not produce when there is no actual demand for a part or product.

Did you know?

The term 'pull' production sometimes causes confusion in that it's also possible to produce according to the requirements of the next workstation with a 'push' system.

The real issue is not whether the system literally pulls or pushes production, but whether there is WIP or queue limitation. This is an automatic mechanism which limits production at a workstation on the basis of real-time requirements.

So if, for whatever reason, the WIP or queue in front of the next workstation reaches a predetermined quantity, production must stop.

The system for communicating production requirements between workstations is also known in the West by its Japanese name Kanban.

Definition: Kanban
Meaning 'signal'. A Japanese manufacturing system in which the supply of components is regulated through the use of an instruction card sent along the production line.

Many different versions of Kanban systems exist, but the key characteristic is that the system uses simple, practical and easy-to-see ways of controlling production rather than production schedules based on sophisticated planning.

Probably the simplest Kanban system is to have a marked space for a small amount of WIP between workstations and where more goods are only produced once the WIP is used - then the empty space acts as a signal that more must be produced.

A two-bin Kanban system works on the principle that when the parts in one crate are used up, then the empty crate becomes the signal for the previous workstation to refill it while the parts in the other crate are used.

Kanban cards are often used to control the amount of WIP when there are many bins in a Kanban system, and also when the goods need to be transported between parts of a factory, or even between different factories.

Figure 2.8 demonstrates, in six steps, how the system works.

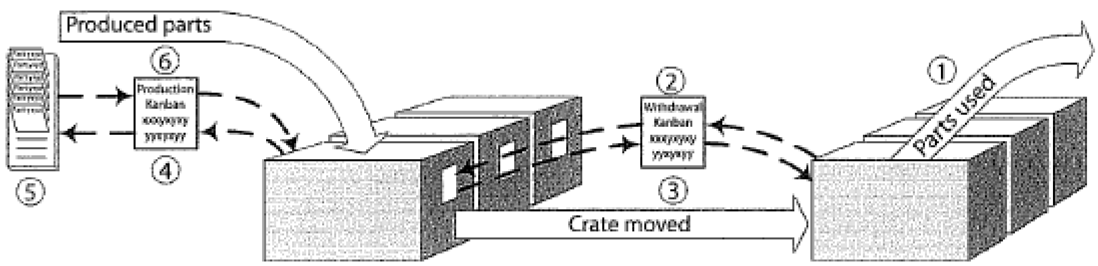


Figure 2.8 A multi-bin, two-stage Kanban system in operation

- When a crate at the assembly work station is emptied of parts, it is removed and ...
- ... the withdrawal Kanban is taken to the store of incoming parts and inserted into the pocket on the crate, which allows ...
- ... the crate to be moved to assembly together with the withdrawal Kanban.
- When a crate is moved from the store, the production Kanban that was on the crate is sent to the part production workstation where ...
- … it is placed on a production scheduling rack in the order of arrival which determines the production sequence and ...
- ... new parts are produced and put into a crate together with the production Kanban.

2.4.3.5 Cellular manufacturing

In lean production, long-line layouts are often broken up into smaller work cells known as cellular manufacturing.

Cells are formed by grouping products with similar production requirements together into product families that are produced by cells, with machines and employees dedicated to manufacturing those products.

Cells are often laid out in a U-shape, which allows operators to move around between the machines and look after more than one machine, as illustrated in **Figure 2.10**.

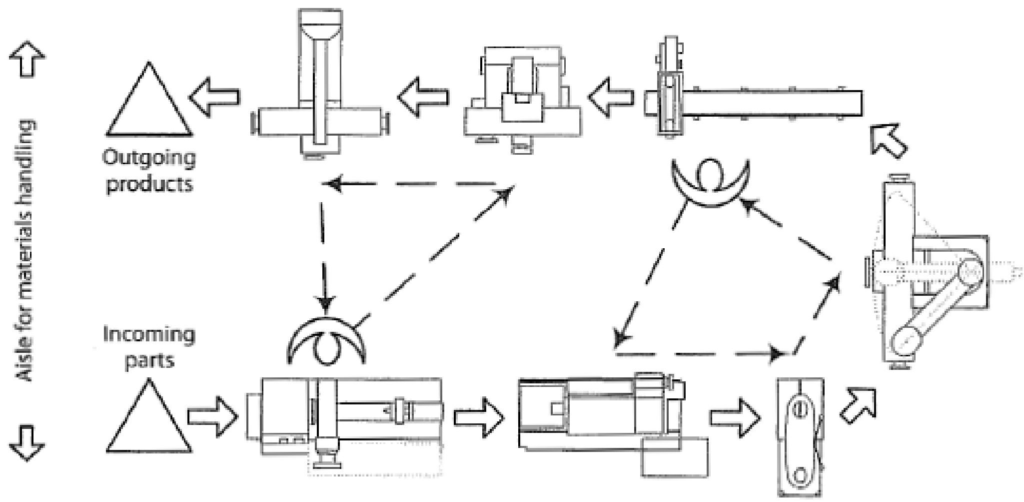


Figure 2.10 A U-shaped manufacturing cell

The handling of materials to and from the cell is improved because incoming parts and materials and outgoing finished goods can go to the same side to be moved in or away from a central aisle.

WIP is minimised because when one machine is finished working on a part, it can be moved directly to the next machine by the operator or with a sliding chute.

Other characteristics of cellular manufacturing include:

- Changeover and set-up times can be reduced because when machines are dedicated to doing one task they do not need to be adjusted as much, if at all.
- Some cells have movable machines that can be reconfigured depending on the production requirements, thereby facilitating production flexibility.
- Workers can communicate and help one another more easily, provided they are multi-skilled, because they are in closer proximity to one another.
- Quality and other problems can be fixed quickly because the problem can be referred directly to the person/machine that is causing the defects.
- Teams can measure, monitor and improve operational performance themselves.
- Being able to take charge of a process to make a product or deliver a service from beginning to end helps teams develop a sense of identity and responsibility.

Volume flexibility is easier with cellular production. The output rate of a traditional production line is often difficult to change because of the need to balance the line on the basis of cycle time (determined by the task with the longest cycle time).

However, the output rate of cells can be changed because the capacity of a cell can be altered by varying the number of people working in the cell without affecting their productivity.

Cells are run on takt time which is determined by the rate of demand for products rather than the rate at which they can be produced.

The formula for takt time is:

$$Takt\ time = \frac{Time\ available}{Required\ production}$$

Worked Example 2.1

If the demand for a certain type of shoe is 80 per day and the cell works one shift of 8 hours, then the takt time is:

$$\frac{8\ hours \times 60\ minutes}{80\ shoes} = \frac{480\ minutes}{80\ shoes} = 6\ minutes\ per\ shoe$$

If the cell has 4 people working in it, their productivity will be:

$$\frac{80\ shoes\ per\ shift}{4\ employees} = 20\ shoes\ per\ employee\ per\ shift$$

If demand drops to 60 shoes per day, the takt time will be:

$$\frac{8\ hours \times 60\ minutes}{60\ shoes} = \frac{480\ minutes}{60\ shoes} = 8\ minutes\ per\ shoe$$

By reducing the number of workers in the cell to 3 and rearranging their tasks, their productivity will remain the same:

$$\frac{60\ shoes\ per\ shift}{3\ employees} = 20\ shoes\ per\ employee\ per\ shift$$

In this way, overproduction can be avoided during a drop in demand. An increase in demand can also be accommodated, without putting too much pressure on the workers, by increasing the number of people in the cell up to the point where equipment capacity constraints may become the bottleneck.

2.4.3.6 Quality at source

While lean production can be highly efficient, it cannot cope well with too many disruptions and failures because there is little buffer inventory in the process.

For this reason, defect rates need to be driven down to the absolute minimum as they can be a major source of disruption.

Rather than do quality inspections at the end of the line, long after the defect has been created - and fixing it in a 'cripple bay', as is done in vehicle assembly factories - lean operations try to have 'quality-at-source' by empowering shop floor and shop front employees to do quality assurance at their workstations during the production/service process.

Think about it!
Training and making it possible for direct production workers to inspect their own work before passing it on enables them not only to fix defects immediately, but also to figure out ways of improving the way they work in order to prevent potential defects.

Once again, the Japanese have developed fail-safing into a fine art, and they use three different systems (often simultaneously) to achieve it.

- *Poka-yoke*: Systems or mechanisms to prevent defects, such as pegs on parts that fit into jigs to ensure the parts are positioned correctly before drilling holes.

- *Jidoka*: Automated error detection and control, as in the loom described in the introduction to this chapter. In the TPS jidoka is described as 'automation with a human touch' because it makes work easier for people.
- *Andon*: Lights or other signals that workers can use to indicate that a problem has occurred during production and that the line may have to be stopped.

2.4.4 Process improvement

Another cornerstone of LT is process improvement (PI), also known as continuous improvement (CI)- or, to give it its Japanese name, Kaizen.

Did you know?
Process improvement is the systematic identification and elimination of waste in processes. It is so fundamental to LT that some people see PI as a programme in its own right.

However, process improvement is probably best viewed as a system for improving production/service processes just like the many other systems required to turn LT principles into reality.

There is one difference though: whereas most other operational systems are reactive in that they are geared to coping with customer requirements or maintaining normal operation, PI is proactive (when it is done properly) in that it aims to make a well-performing process work even better.

Lean programmes such as TQM, JIT and TPM all include worker involvement in PI, in addition to direct production or service delivery.

Participation in PI is where worker involvement is at its most effective because PI relies on the intimate knowledge that the workforce has of their work situation to make process improvements.

2.4.4.1 How to do process improvement

The PDCA cycle, originally proposed by Walter Shewhart and developed by Edward Deming is the model on which many of the process improvement methods used today are based.

Deming is revered in Japan for teaching how to do PI as part of the Marshal plan to reconstruct Japanese industry after the Second World War.

The plan consisted of four steps:

- *Plan*: Collecting information and analysing it to make a plan for improving the
- process.
- *Do*: Implementing the plan and monitoring it to see whether it works.
- *Check*: Checking whether the results of the implementation meet the improvement objectives.

- *Act*: If the plan has worked, make it the standard practice throughout the process. If it did not work as expected, repeat the PDCA cycle.

As mentioned previously, there are many different PI methods. The following nine steps summarise the steps most commonly found in PI methods:

- Identify the problem, improvement objective or part of the process for the project
- Get to understand the process in that area by drawing a process flow diagram
- Clarify what activities in the process create value for the customer
- Identify appropriate measures of value and waste, and collect the data
- Analyse data to identify wastes where most improvement is possible
- Identify possible countermeasures and decide which to implement
- Plan and implement the countermeasures
- Evaluate the results against improvement objectives and repeat if necessary
- Update process documentation with improved work practices

Note:
Whatever PI method you choose, you must use the method systematically step by step. People who are inexperienced in doing PI often become frustrated, try to rush ahead and do not collect adequate operational data on the problem they are investigating, only to find that they end up fixing the wrong problem.

Process improvement is usually done by two types of teams:

- natural work groups
- cross-functional teams

Natural work groups consist of people who normally work together, quite often in the same department or cell. Their improvement projects frequently arise from problems identified as the result of their ongoing performance monitoring.

These projects are typically known as Kaizen projects that mostly make small incremental changes to work practices at S3 level.

Cross-functional teams are people from different departments who are put in a team to tackle a Kaikaku project that usually involves changing S2 level systems or work practices affecting processes that run across departmental boundaries.

One technique for planning, implementing and reporting on PI projects that has become increasingly popular is A3 reports. This type of report derives its name from the fact that all the essential information about the project is recorded on one AJ size page, in the format illustrated in **Figure 2.11**.

This format makes the report easier to distribute and display, and people are more likely to read it because it is concise and to the point.

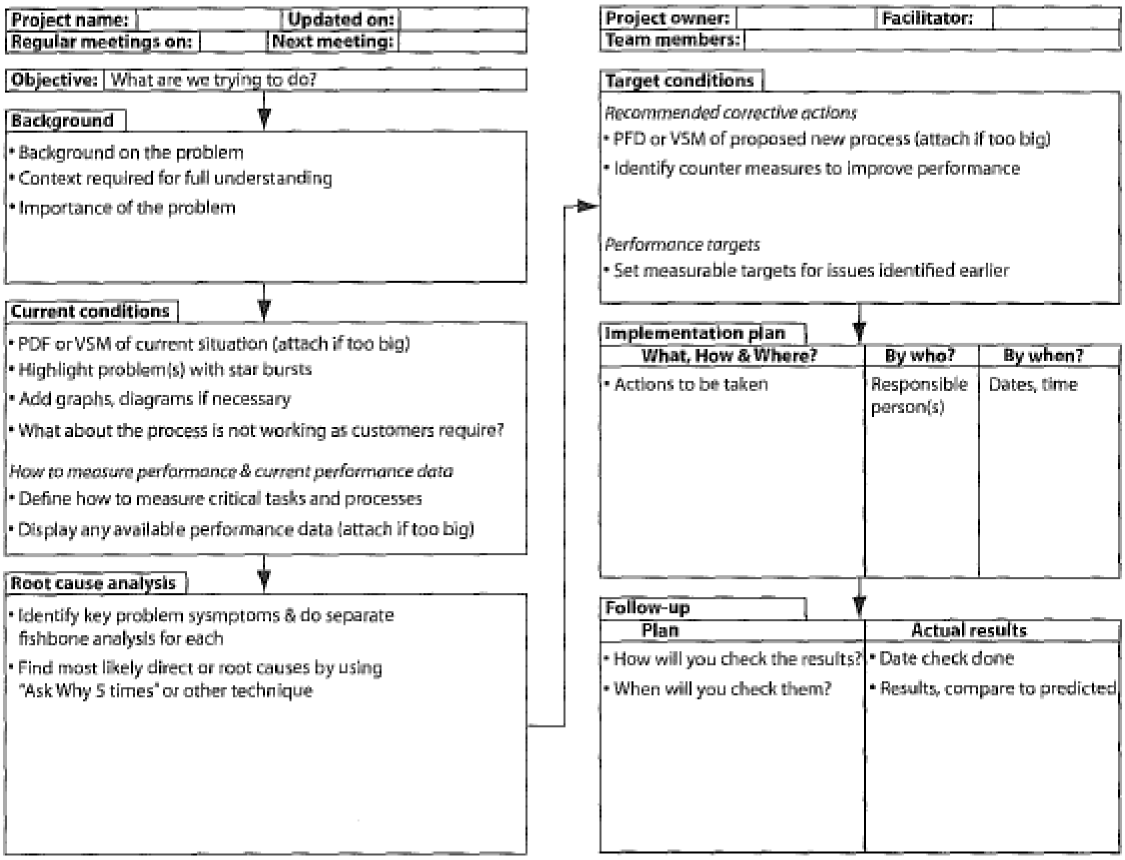


Figure 2.11 A3 report with guidelines

2.4.4.2 The management of process improvement

The biggest obstacle to process improvement is that workers need time off from direct production/service duties to focus on their improvement projects.

As this results in an immediate loss of output, many managers who are responsible for achieving daily targets are reluctant to release workers for improvement projects.

To counteract this reluctance, it is important for managers to understand that process improvement is an investment in improved future performance that will pay back the loss of current production if it is done properly.

The next management challenge is for process improvement teams to spend their time doing the project effectively because it is easy to lose focus and waste time.

⚠	**Note:** Following the process improvement steps systematically helps to avoid this pitfall. This not only guides the team as they go through the decision-making process, but also assists over-eager participants to do the process correctly.

Some teams do not appreciate the importance of collecting accurate information about the current process and jump to the wrong conclusions on the basis of incorrect perceptions.

It is important that adequate resources for implementing the team's recommendations are made available by management.

Teams are usually enthusiastic about their improvement suggestions, but there is nothing as demotivating as having to wait weeks for management approval or the resources to implement the suggestions.

Finally, it is critical to sustain PI. One improvement project will make very little difference to the overall process performance of an operation.

It is only when the improvements from many projects start working together that a synergy develops, which starts to show in the operation's overall performance measures.

This is because the investment in PI works like compound interest. With a financial investment you eventually get interest on interest; with PI the payback comes from increased time and effort savings, which can then be ploughed back into more PI.

In most cases, this will take anything from 3 to 5 years. Top management have to be committed to seeing the programme through the early years, or else the effort put into the initiative will be wasted.

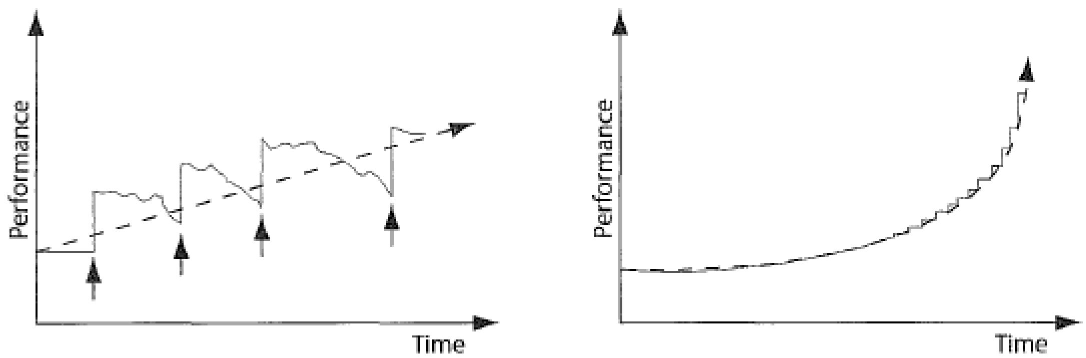


Figure 2.12 Step-change (left) versus incremental PI (right)

As **Figure 2.12** shows, even though the performance improvement from incremental process improvement takes longer to accelerate, it ultimately catches up and overtakes performance improvement from big step-change projects that deteriorate between initiatives, provided the small improvement projects are sustained over time.

2.5 Process improvement techniques

It is helpful to think of PI as a decision-making process which, broadly speaking, goes through the following three stages:

- Collect information about what is actually happening in the project area
- Analyse the information to understand the mot causes of the wastes
- Make recommendations and try them out to see whether they work

The PI techniques are conceptual tools that are useful at different stages of the decision making process. The PI techniques each have a different purpose and are therefore useful at different stages of PI.

Note:
It is important to use the techniques in the correct order during an improvement project in order to avoid poor decision-making.

There are too many process improvement techniques to cover all of them, so only the most commonly used techniques will be described.

2.5.1 Process flow diagram

It is almost always necessary to do a process flow diagram at the outset of a PI project (see PI step 2), even if those doing the project are familiar with the process in that area.

Quite often, activities that have become routine, but that are actually wasteful, come to light when the flow of materials, people or information is documented accurately.

Another kind of process map, known as Value Steam Mapping (VSM), is often used in PI projects.

VSM does not detail all the activities in an operation, but rather provides a one AJ page summary of the most important processes, material and information flows in an operation.

VSM usually starts with the PI team walking-the-*gemba* through the actual process of production or service delivery, from the output end upstream to the input end, and making notes on key performance measures and information such as:

- takt time
- demand patterns
- value-adding time
- WIP and other inventory
- throughput and lead times
- defect rates
- cycles and set-up times
- the number of employees in each section

Definition: *gemba*
Japanese for 'the real world'

This information is used to draw a 'current state' VSM, which shows the operation as it is. VSM uses a particular set of symbols to highlight the most significant information about the operation, but illustrating how to draw a VSM is not covered here.

Most importantly, the process of doing VSM shows graphically where the biggest wastes and main obstacles to flow exist in the operation. Frequently, the ratio of value-adding-time to lead time is found to be less than 5%.

Sometimes, it's the first time that senior managers get the chance to see what really goes on in the process.

Based on this experience, a 'future state' VSM that incorporates improvement recommendations is drawn up and the recommendations implemented.

2.5.2 Run chart

Run charts show the trend of pe1jormance data overtime. They are basically the same as control charts (explained in Chapter 10), but without control limits.

They can be used in PI step 1 to identify poor performance - which has to be addressed by an improvement project - or in PI step 5 to identify a possible source of waste.

Once a problematic pattern has been identified on the run chart, the cause of that pattern must be identified - either through investigating the sequence of events that took place in the process leading up to the pattern, or by making use of other techniques such as Pareto analysis or fishbones.

2.5.3 Check sheets

Check sheets are used in PI step 4 and 5 for collecting attribute data, such as how often certain types of defects occur. The different defect categories have to be identified first to make up the check sheet.

It is sometimes helpful to include an 'Other' category for unanticipated defects to be recorded. In the example in **Figure 2.13**, it is clear that the biggest loss was caused by dirty garments.

Garment defects	in Cell 3						
Fabric faults	✓	✓	✓				
Button off	✓	✓					
Seam loose	✓	✓	✓	✓			
Sewing wrong	✓	✓	✓				
Garment dirty	✓	✓	✓	✓	✓	✓	
Other	✓	✓					

Figure 2.13 Example of a check sheet

2.5.4 Pareto analysis

Pareto analysis is also known as the 80/20 principle, which suggests that most of the losses associated with a process can be traced back to a few causes.

Therefore, the technique can be used in PI step 5 to identify which losses to prioritise for further investigation, as it is rarely possible to work on eliminating all sources of waste at the same time.

In the **Figure 2.13** example, it is easy to see where the biggest loss occurred.

⚠	**Note:** Ehen there are many categories, it is helpful to draw a histogram in which the categories are sorted in order of biggest to smallest number of occurrences.

In the example in **Figure 2.14**, defects A and B should be investigated further.

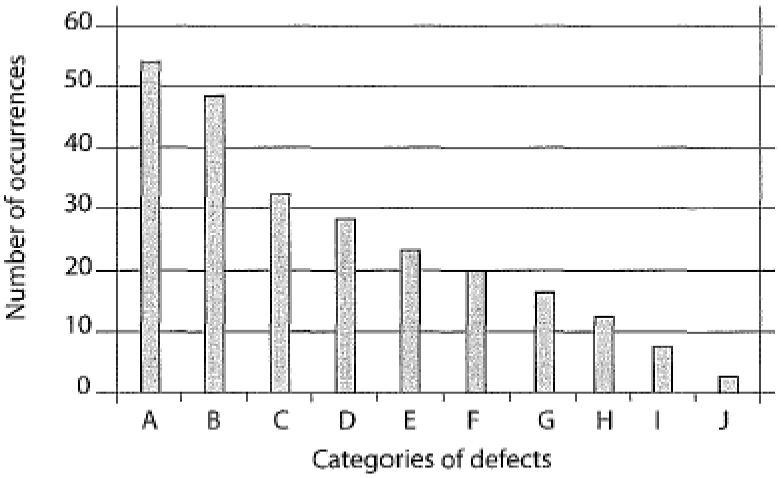


Figure 2.14 A Pareto chart

2.5.5 Time bar

The time bar is used mostly in step 5 and is useful to identify waste of time, such as in set-up time reduction projects. The activity times on the bar must be to scale in order to show the value-adding versus wasted time accurately.

The example in **Figure 2.15** is coded so that it is easy to see which of the activities are value-adding (blank), which are non-value-adding but necessary (dotted), and which are waste (black).

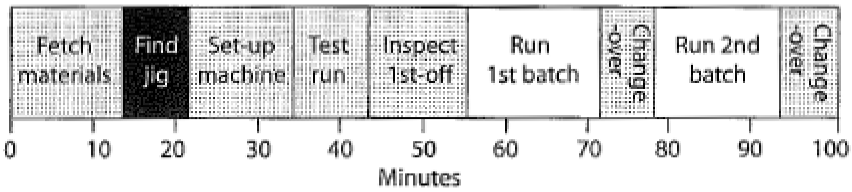


Figure 2.15 Time bar of the set-up of a process

In this example, only 32% of the recorded time is actually used to create value for the customer. The time spent on finding the jig is pure waste and should be eliminated entirely from future set-ups.

Activities such as fetching materials, setting up the machine, doing a test run, inspection and changeovers do not create value, but cannot be eliminated either. Such activities should be minimised.

2.5.6 Fishbones

Fishbones are also known as cause-and-effect diagrams because they are used to record as many as possible potential causes of a problem before deciding which causes to focus on for the purpose of developing counter-measures.

Fishbones are used mostly during PI steps 5 and 6.

It is important to do separate fishbones for each problem and to be clear about the difference between causes and effects. The problem is a consequence (or symptom) of underlying causes; therefore, it must go on the head of the fish bone.

The possible causes go onto the bones, under the appropriate headings. It is not necessary to use exactly the same headings, or to list causes under each heading if there aren't any. **Figure 2.16** shows an example of a fish bone for the problem of dirty garments.

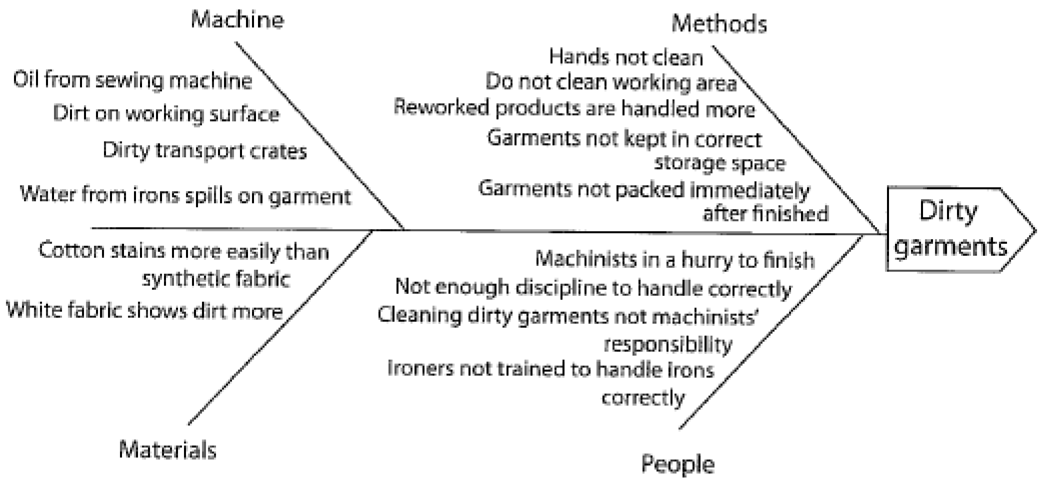


Figure 2.16 Example of a fish bone for the dirty garment problem

2.5.7 Ask-Why-5-Times

In contrast to the fish bone, which is used to gather all possible causes of a problem, Ask-Why-5-Times is a technique for delving deeper into the causal chain.

The technique is used to explore important causes to find out what their possible causes are.

For example, you could do the following to find the root cause of not packing garments immediately after they are produced:

Why were the garments not packed immediately after they were finished?
Because the plastic bags and labels were not available.

- → Why were the plastic bags and labels not available?
  Because the plastic bags and labels were out of stock.
  - → Why were the plastic bags and labels out of stock?
    Because they were not ordered in time.
    - → Why were they not ordered in time?
      Because no one knew they were required.
      - → Why did no one know they were required?
        Because they were not on the bill of materials.

So, one of the recommendations to reduce or eliminate the defect of dirty garments may be to update the bill of materials for the garment so that it includes not only the fabric, thread, and trims such as buttons, but also the plastic bags and labels for packaging.

It turned out that one of the contributing causes to this problem was far removed from where the problem was being experienced. Using the Ask-Why-5-Times technique helped to identify the root cause of the defect.

Think about it!

It is extremely important to identify and eliminate the root cause of problems, waste and poor flow.

There's a simple way of knowing whether the root cause has been eliminated: if a problem keeps recurring after something has been done to try and fix it, the root cause has not been eliminated.

The Ask-Why-5-Times technique can sometimes lead to very general root causes outside the control of the PI team. For instance, 'poor skills' are a problem everywhere, but 'improving the education system' is not a practical recommendation.

So it's better to use the Ask-Why-5-Times technique to identify the proximate root causes.

These are root causes that are operationally related to the problem, and which the PI team can often do something about, such as writing clear instructions with pictures to help unskilled or illiterate people use the correct work practices.

2.6 Programme deployment

A critical issue concerning these new management approaches has emerged in recent years.

While the principles and practices of the new approaches often make sense to the people who make the strategic decision to adopt lean thinking, there have been numerous failures when organisations try to deploy programmes based on these principles.

Think about it!
Even if the principles of lean thinking are sound, and the type of lean programme is suitable for the operational and organisational environment, it needs to be deployed properly in order to succeed.

Having outlined some of the salient features of LT and the programmes, systems and techniques associated with it, the next section provides a brief overview of the important issue of programme deployment and the obstacles that may be encountered.

2.6.1 Steps of programme deployment

Seeing one PI project through to implementation of recommendations is hard enough. Deploying an organisation-wide programme to make the principles of LT and lean practices a way of life in the operation can be a huge challenge.

The following steps summarise the actions that may have to be taken to fully deploy such a programme.

The steps need to be applied judiciously, and the specific actions and sequence of deployment must be adapted as necessary, so that both are appropriate to the organisation's operations and circumstances.

- Establish vision: Create a compelling unifying vision for the deployment
- Get informed: Acquire knowledge of LT and its deployment
- Design plan: Develop a deployment plan for the organisation
- Set goals: Prioritise initiatives, and set goals
- Remove obstacles: Anticipate possible resistance and resource requirements
- Communicate: Inform people throughout the organisation
- Get buy-in: Ensure a critical mass of stakeholders buy in to the process
- Change agent: Designate a champion to facilitate the change process
- Support staff: Ensure that support staff with appropriate skills are available
- Change attitudes: Provide orientation and manage the organisational change
- Do training: Provide training in new skills, roles and thinking required
- Pilot project: Decide whether to pilot or do full-scale deployment
- Restructure organisation: Make the necessary organisational and layout changes
- Process improvement: Start PI projects early and involve everyone in them
- Measurement: Establish measurement standards and procedures
- Monitor progress: Evaluate progress against internal and external benchmarks
- Provide incentives: Provide appropriate incentive and recognition systems
- Adapt plan: Adapt the deployment plan where necessary
- Sustain initiative: Maintain initiative over the long-term until institutionalised

2.6.2 Success factors

Much has been written about why lean programmes fail. Equally, the success factors are well documented.

The following factors are themes that are repeatedly cited:

- Commitment: Starting with top management, commitment to the success of the programme is mentioned most often. The reasons for the programme and its deployment process needs to be communicated to all stakeholders.
- Programme design: A thorough programme plan that is aligned with the operations strategy, including adequate resources and driven by a task force of people from within the organisation.
- Pre-conditions: Job security should not be threatened by the programme and there needs to be adequate organisational and financial stability to see it through the turbulence of organisational change.

- Participation: Employee involvement through teams with appropriate levels of autonomy and incentives to act consistently with new organisational roles.
- Training: Sufficient and timeous training in the new skills required for all in the firm by competent training facilitators.
- Process focus: A structured and sustained approach to process improvement and resources to rapidly implement PI recommendations.
- Monitoring: Visual performance measurement at the lowest levels, with rapid feedback to the source of poor performance and regular assessment against strategic objectives.

2.6.3 Lean programme deployment maturity

Daniel Jones is one of the authors of the book that brought lean thinking to the West.

He identified the following three levels that indicate how well lean thinking has been institutionalised in an organisation:

1. Whether there is real evidence that lean thinking has taken root at the Gemba.
2. Whether the organisation works across departmental boundaries to see and redesign their core processes end-to-end and to align all their support processes with them.
3. Whether top management sets strategic goals for action across the organisation by
   a) Turning strategic goals into clear performance gaps that need to be closed.
   b) Understanding that these goals will only be met by using lean methods to redesign the core value-creating and support processes from end-to-end.
   c) Value stream managers making a business case for the resources needed to accomplish this as a basis for organisational budgetting.

2.7 How this operational capability influences operations strategy

Lean thinking defines anything that does not create value for the customer as waste and has developed systems and techniques to eliminate, or at least minimise, waste of all kinds.

Therefore, if an organisation has truly developed the operational capability to have lean processes and people who are lean thinkers, it should be able to improve its performance on all the value drivers.

Depending on what has been identified as the value driver(s) where its operational capability is lacking, systematic PI should enable the organisation to get closer to its customers' requirements.

However, lean processes can be vulnerable to supply shocks. With little inventory in the supply chain, JIT operations may not be able to maintain delivery reliability in the event of disruption in the supply chain.

Also remember that lean thinking is not self-perpetuating. It needs to be sustained, or else waste will filter into the operation again. Further, if the organisation has become complacent it may go unnoticed that it's no longer providing full value to customers.

Case Study 1.3: Rapid Sport: Deployment of lean thinking

Facts and figures have been simplified to make the case easier to understand. They are not a true reflection of the actual situation at Rapid Sport.

The consultant advising on quality issues at Rapid Sport told Philip and Ursula about another clothing factory where he had previously helped to deploy a lean approach to managing production.

In that case, one of the first actions was to convert the traditional straight production line into cells. This enabled machinists to move around more easily and help out at other machines that were running behind.

Other initiatives included training the machinists in teamwork, monitoring their own work performance, shop floor quality management, and other practices associated with a lean operation.

The major customer at the other factory was a big retail chain that demanded exceptional quality.

For this reason, they had a quality assurance department where quality control officers checked a sample of the garments produced by each cell and then reported back to the cell team members if they found unacceptable levels of defects.

Philip thought that switching to teams working in a cellular layout sounded like a good idea, so he discussed the new way of working with Ursula. She wasn't convinced, but was willing to try it out.

They met with the consultant and decided that the production operation at Rapid Sport was small enough not to need a pilot project. Besides, it worked at the other factory so why wouldn't it work here?

After studying the available space, they decided to break the existing line up into two cells: one for cycling gear; the other for skiing gear.

One Sunday, when the changes would not disrupt work, they did all the basic layout changes. The machines used for sewing the cycling gear were moved to the cycle gear cell, and the machines for the skiing gear were put in the other cell.

There was still quite a lot of sorting out to do - for instance, the racks with the cycling and skiing trims still needed to be separated into two racks that were closer to each of the new cells - but they left that for Ursula to do later.

When the employees returned to work on Monday they were surprised to see the changes, but soon settled into their new work positions. Ursula was still busy sorting things out, and so they carried on working as they used to.

Each machinist worked until the bundle on her table grew big enough to be passed on to the next person.

After a fortnight, the consultant came back and explained about keeping visual performance measures like an hourly target board, and recording the number of defects that had to be fixed so that trends could be tracked.

The workforce listened quietly to his ideas and had no questions when asked whether there was anything that required more detailed explanation.

Together with Ursula, the consultant identified the key performance measures that needed to be tracked, and he had new performance boards installed.

When the consultant returned a few days later, he found that almost no performance information had been recorded. Ursula told him that while he was away the machinists had expressed dissatisfaction with the new seating layout.

They were used to their old seating arrangement, and weren't keen on the idea of getting up and moving to another machine when their work was done.

If there was anything that needed to be fixed they simply passed it back to whoever needed to fix it, and they didn't see the need for the extra work involved in recording the hourly production and defect rates.

The consultant realised it was necessary to help the workforce adjust to the new work practices. They needed to develop the discipline to record their own performance data and maintain work practices that led to good quality.

As Ursula was unfamiliar with lean systems and techniques, the consultant arranged a training session where he explained the importance of process improvement to the workforce and how to use techniques such as Pareto analysis and fishbones.

However, there wasn't much more that he could do because, being a fairly small company, Rapid Sport could only afford to pay for a limited amount of his time.

Case questions

Where the case study does not provide specific information, you can make realistic assumptions to answer the questions.

1. Which type of lean programme would be most appropriate at Rapid Sport? Give two reasons for your answer.
2. Compare what was done at Rapid Sport to deploy the new work arrangements with the steps for programme deployment. Give your assessment as to how successfully it was done.
3. What was the level of programme deployment maturity of the initiative at Rapid Sport?

Activity 2.1

1. How does shop floor control interface with materials requirements planning and capacity requirements planning?
2. What are the techniques used for the shop floor scheduling process?
3. What are the differences between the principles, programmes, systems, techniques and work practices of lean thinking?
4. What are the principles of lean thinking?
5. What are some of the programmes that are consistent with lean thinking?
6. What are some of the most important systems associated with lean thinking?
7. What is process improvement and how is it done?
8. What techniques are used to do process improvement?
9. How should lean programmes be deployed?
10. What are the success factors for the deployment of lean programmes?

Activity 2.2

The purchasing department in a large government organisation is responsible for handling all tenders for products and services supplied to the organisation.

The tender process starts with a memorandum being drawn up by the requesting manager to motivate for the procurement of the product or service.

The memorandum includes a description of the product or service required and an estimated budget. If the annual cost of the product or service is estimated to be more than R50 000 per year, then at least three suppliers must be asked to submit tenders; if not, the manager can request an order number directly.

After the organisation's Chief Executive Officer (CEO) has approved the memorandum, the financial director has to approve the budget. Then the procurement manager can finalise the tender specifications, advertise a request for tenders, and convene a tender committee.

The tender committee members have to be approved by the procurement director to ensure that they are not an interested party.

The suppliers must submit their tender documents to the procurement department by the due date.

These documents must include descriptions and prices of the products or services to be supplied, payment terms and conditions, proof of the supplier's legal registration and a tax clearance certificate, the supplier's Black Economic Empowerment scorecard, CVs of the supplier's principal members, and any other documents required by the tender.

Once the tenders are in, and have been checked for all the relevant documentation, the tender committee evaluates them. The committee's evaluation is carried out according to a weighted scoring system.

The score for each tender is included in the committee's recommendation on which supplier should be awarded the tender. The final tender documents go back to the CEO and finance department for final approval and issue of an order number.

The whole tender process can be divided into seven stages:

No.	Stage	Start to end of stage
1	Drafting	Manager drafts memo - Memo submitted to CEO
2	Approval	Submit memo - Memo approved by Finance
3	Finalisation	Memo to procurement - Tender specifications finalised
4*	Advertise	Advertise tender - Tenders submitted
5	Convene comm.	Convene committee - Committee approved
6	Evaluation	Tender submissions received - Evaluation scores completed
7	Issue order No.	Recommendations to CEO - Order number issued

*In stage 4 the tender regulations require a minimum of 15 working days from advertisement to tender submission to allow time for suppliers to tender.

Figure 2.17

Complaints were made by the requesting managers about how long it took for the tenders to be awarded. This led to an investigation into four tenders for office furniture, security services, a building contract and courier services.

Information on the four tenders was compiled, as follows:

Stg	Office furniture			Security services			Building contract			Courier services		
No.	TPT	VAT	Rtns	TPT	VAT	Rtns	TPT	VAT	Rtns	TPT	VAT	Rtns
1	4	1		17	2		26	4		3	1	
2	5	1	0	14	1	2	15	1	3	9	1	1
3	12	3	1	10	3	0	11	4	1	4	2	0
4	15	15	0	20	20	0	20	20	0	15	15	0
5	6	1	1	22	1	3	16	1	3	5	1	0
6	7	1	0	11	1	1	19	2	2	5	1	1
7	7	2	0	9	2	0	11	2	1	7	2	0

TPT: Throughput time in working days for the stage of the tendering process. (How long the stage took to complete for the tender.)
VAT: Value-adding time in working days. (The time it took to do the actual work.)
Rtns: The number of times in each stage that the tender documents were returned to a previous stage for correction.

Figure 2.18

The people involved in the tender process were interviewed as part of the investigation. Their complaints were recorded:

- *Managers*: "We draft the memos and then they sit on someone's desk for ever waiting to be signed. Procurement is always asking us to sit on the tender evaluation committees, but we've got our own work to do."
- *CEO*: "I receive many tender memos that I have to return because basic documentation is not attached, or the memo is incorrectly drafted. Sometimes I wonder whether my managers know how to use the spell checker when they draft memos. And then, when tender recommendations are made, I wonder whether the correct issues were considered in making the recommendation."
- *Finance*: "We have to check all the budget calculations because some of the calculations are wrong, or they exceed the budget. Occasionally, documents to support the estimates are also missing. Every now and again we have to send the tender recommendations back because the evaluation scores are not included or are wrongly calculated."
- *Procurement Manager*: "I have great difficulty convening the tender committees because people don't want to sit on them. When we do get people to sit on the committee our director often disqualifies some of the members because he thinks that they are interested parties when they clearly are not. Sometimes, suppliers submit their tenders without the required documents and so we have to disqualify them, but then we don't have enough tenders."

1. Draw a process flow diagram of the tendering process. Indicate on the diagram where each stage of the process begin and ends. Take care to show the approvals as decision diamonds where documentation that is not approved has to be returned to a previous stage for correction.
2.

   a) Calculate the total value-adding time required to do the work at all the stages for each tender.
   b) Calculate the total throughput time from start to finish of each tender. Take into consideration that the stages of advertising and convening a committee can take place at the same time.
   c) Based on your calculations, comment on whether the complaints were justified.
3. Calculate the average throughput time for each stage. Draw a time bar of this information, and comment on your findings.
4. Calculate the average throughput ratio (VAT - TPT) for each stage. Identify on which stage(s) you would focus your improvement efforts.
5. Calculate how many returns took place at each stage of these tenders, and comment on how this relates to the throughput ratios of the stages.
6. Draw a fish bone diagram to record explanations given by the interviewees for the causes of returned documentation for correction. Comment on what can be done to improve the process.

Self-Check

I am able to:	**Yes**	**No**
• Describe how shop floor control interfaces with material requirements planning and capacity requirements planning		
• Describe each of the following techniques of the shop floor scheduling process		
o operation scheduling		
o floor control scheduling		
o kanban		
o bottle neck management		
o mixed model production		
• Define what is performance measurement in terms of shop floor control		
• Describe the following performance measurement criteria related to shop floor control		
o lead times		
o work in progress		
o reprocess		
o scrap		
o shrinkage		
• Describe how each of the criteria listed impacts on overall performance and the implications to the areas		
• Describe how each of the following competitive elements influences shop floor control		
o batch sizes		
o lead times		
o set up time		

o queue time		
• Calculate shop floor control schedule given the following information		
o labour utilisation		
o work in progress		
o number of shifts		
o machine efficiency		
• Describe the following functions of the shop floor control system		
o scheduling of work		
o loading of work		
o operation dates		
o monitors work in progress		
o detailing of records		
o dispatch system		
o customer service		
o status and production reporting		
• Describe how training influences the effectiveness of shop floor control system		
• Describe the following compensation methods associated with shop floor control systems		
o flat rate plus overtime		
o industrial piece work		
o team piece work		
o production bonus		
• Describe the management of material handling in respect of the following elements		
o material input		
o material in process		
o finished product		
• Describe the relationship between shop floor control and the following departments in an organisatlon		
o customer service		
o engineering		
o supplier scheduling		
o inventory management		
o quality control		
o accounting		
• Describe the factors influencing the effectiveness of scheduling techniques		
• Describe the benefits of project scheduling in terms of the following:		
o clear planning		
o scheduling		
o resource allocation		
o control		

o communication		
• Explain what is meant by expediting and de-expediting		
• Explain what is meant by least total cost		
• Given the following details, calculate least total cost		
o ordinary cost		
o holding cost		
o item cost		
• Given the following details calculate the productivity of a work centre		
o actual hours worked		
o standard time allowed		
o machine hours available		
• Describe the four rules governing the management of queue time		
• Describe the documentation process involved in setting up the shop floor control system		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 3

Inventory management

Learning Outcomes

On the completion of this module the student must be able to:

- Describe the following inventory policies
  - order backlog
  - operating efficiency
  - customer service
- Describe the following cost evaluation methods of inventory control
  - FIFO (First in first out)
  - LIFO (Last in first out)
  - weighted moving average
  - standard costing
- Calculate weighted moving average given the following information
  - unit costs
  - total received
  - total issued
- Compare the advantages and disadvantages of FIFO and LIFO systems
- Describe the nature of the following types of stock items
  - raw material
  - finished goods
  - work in progress
- Describe how each of the stock items listed has an impact on inventory level and its impact on other areas
- Describe the process of managing inventory in terms of the following
  - lot sizes
  - lead times
  - batch sizes
  - shrinkage
- Describe the inventory systems in terms of the following
  - re-order point
  - replenishment
- Describe the process of distribution requirements planning in terms of the following
  - distribution network
  - forecasting
  - transportation
- Calculate inventory levels given the following information:

  - scrap performance
  - lead times
  - stock levels
- Describe each of the following inventory storage methods
  - dedicated storage
  - random storage
  - zone storage
- Describe the advantages and disadvantages of each of the methods listed above
- Describe four consequences of inaccurate record keeping of inventory
- Describe the following pre-requisites necessary for inventory accuracy and the effect on inventory management
  - space
  - tools
  - training
  - incentive
  - accountability
  - creation of sub-stores
  - job description
- Describe the following inventory calculation methods
  - annual inventory
  - cycle counting
- Describe the advantages and disadvantages of each calculation method listed above.
- Describe how an effective inventory management system achieves the following
  - optimal customer service
  - optimal inventory investment
  - optimal operational efficiency
  - optimal return on investment
- Calculate annual carrying cost given the following
  - interest rate
  - unit costs
  - lot size
- Calculate annual ordering cost, given the following information
  - cost per order placed
  - demand rate
  - lot size

3.1 Introduction

Materials management is one of the main activities of the production department. Taken overall, materials management is concerned with the flow of materials from the initiation of the raw material order until the completed product is in the shipping department or stored in the finished goods store.

Most manufacturing establishments purchase raw materials, transport them to the manufacturing point (or have them transported), and process them into goods which are then sold and delivered to customers or vice versa (delivered to other points for subsequent sale).

Think about it!
Efficient materials management coordinates the inflow of material with the production demand.

The aim of materials management is consequently to provide the correct material at the correct work point at the right time, in the right form and at the lowest cost.

The following kinds of material/inventory are usually found in a manufacturing firm, namely raw materials, components or parts, semi-finished products, finished products, and consumables or indirect materials.

- *Raw materials*: Raw material stocks include all items that have to be processed further before becoming an identifiable part of the finished article. It is obvious that the finished product of one manufacturing establishment, for example sheet metal, can be the raw material input of another plant.
- *Components*: This category of material relates to inventory items which require no further processing before being incorporated in the final product. Thus tyres and batteries will be the final product of one manufacturing enterprise, but will be classified as components in a motor-vehicle manufacturing firm.
- *Semi-finished products*: All materials that leave the raw material store or the component store are classified as semi-finished goods or semi-finished stock until the final product is completed and placed in the finished goods store. The flow of these materials is controlled by the production planning and control department.
- *Finished goods*: This category of inventory relates to the completed articles in a factory which are awaiting shipment or are stored in warehouses, or to finished goods stocked by dealers on behalf of the manufacturer.
- *Consumables/indirect materials*: Consumables or indirect materials are those stocks which are required for operating purposes, but which are not incorporated in the final product. Lubricating oils, cleaning materials, bulbs and many other items fall into this category.

3.2 Materials management functions

The most important functions of materials management are illustrated in **Figure 3 .1**.

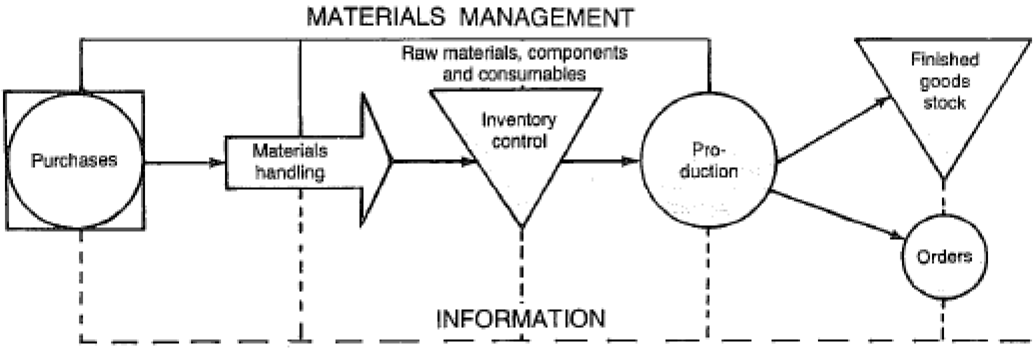


Figure 3.1 Material flow and the functions of materials management

The various materials management functions are:

- purchases
- materials handling
- stock keeping and control
- production planning and control

They can be performed by one department in a firm, whereas in other establishments separate departments may deal with each of these functions.

An umbrella materials policy is, however, necessary owing to the fact that the different departments may come into conflict as each strives to optimise its own results.

Figure 3.2 illustrates the conflicting objectives with regard to materials management.

Effective materials management is intimately associated with each of the respective departments which all have to work together in order to achieve the objectives of maximising customer satisfaction, minimising investment in inventory and producing at the lowest possible cost.

Think about it!
Materials management must therefore never be seen in isolation, but always in relation to the total business system. Thus materials management is linked to demand forecasting, since it is only when materials management is efficient, that sales can proceed smoothly.

Materials management is also very closely linked to production there can be no continuity and cost saving in production if materials management is not efficient. This implies that the total cost concept must be applied to material inputs in order to optimise conflicting operating objectives.

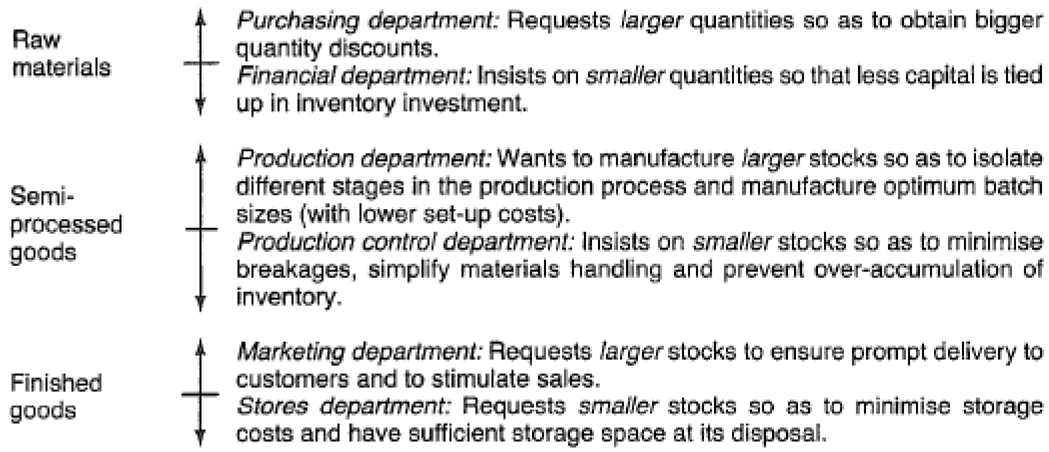


Figure 3.2

3.2.1 Purchasing

The purchasing function is the link between a firm and its suppliers. From the viewpoint of the suppliers the firm is seen as a client; the firm is served by the sales representatives of the suppliers, and it is affected by the marketing strategy of its suppliers.

To the firm, on the other hand, the purchasing function is the point of supply providing the requirements for production, and it serves as a clearing house, monitoring the smooth flow of production.

⚠	**Note:** The purchasing function is very closely linked to the other business departments.

Figure 3.3 illustrates some of the important points of contact.

- *The marketing department* provides information on the expected output. Reliable demand forecasting is essential, since considerable time can be taken in preparing orders, selecting suppliers, issuing buying orders and receiving goods.

?	**Did you know?** By closely studying price trends, a sufficient inventory can be accumulated in respect of goods for which price increases are expected.

- *The production department* usually initiates purchases and withdraws stocks as required.

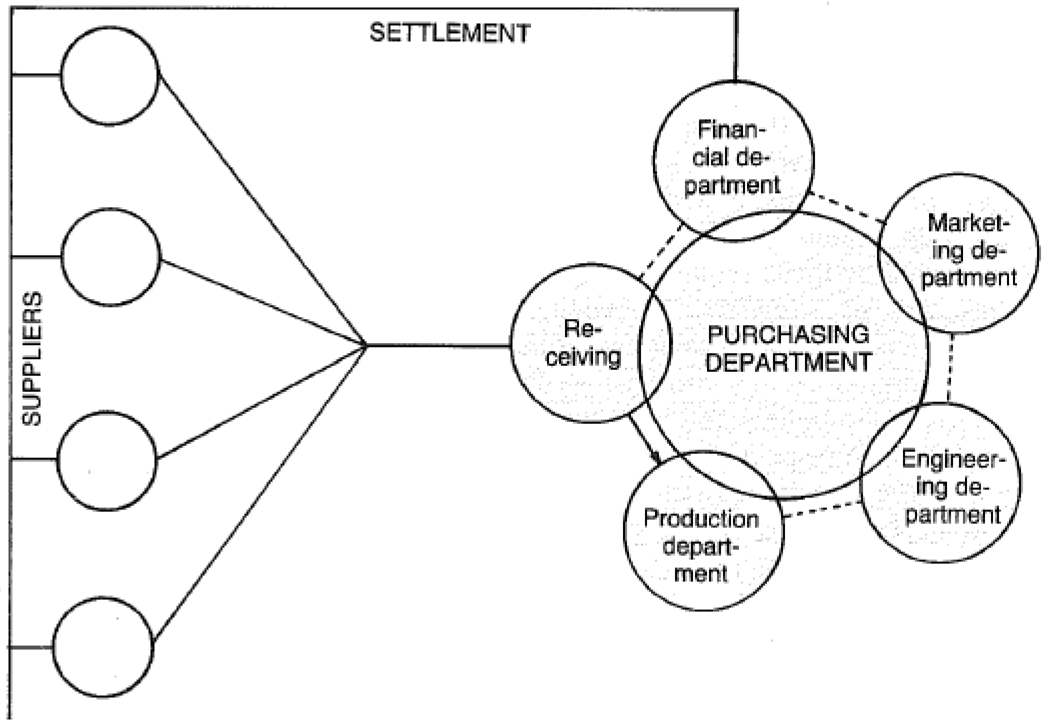


Figure 3.3 Interaction of the purchasing department with other business departments

- *The engineering department* issues specifications in respect of the types of stock and the quality standards expected.
- *The receiving department* reports on the quantities and quality of stocks received. After receipt stocks are sent to the production department or stores.
- *The financial department* settles accounts after being informed of the quantities and quality of the stocks received.

The purchasing cycle normally starts when the decision is made to purchase stock and ends when the relevant department receives the material.

Did you know?
Purchasing responsibilities extend from the first to the last points, and include various intermediate responsibilities.

The most important responsibilities of the purchasing department may be summarised as follows:

- ***Receipt of purchasing requisitions or orders***. Purchasing requisitions are received from the various departments. The requisition forms usually provide for information on what is required, the quantity required, when the items must be available, and who the requisitioner is. The time that elapses between planning the official company order and receiving the stock, is referred to as the lead time. This lead time plays an important role in purchasing and inventory control. For this reason, most purchasing departments normally insist that purchasing requisitions are initiated timeously.

- ***Revision of purchasing requisitions***. The purchasing department is usually not empowered to prescribe substitute material. This department does, however, have the responsibility of questioning orders and suggesting alternative materials at lower prices. When purchasing requisition forms have to be completed and a system is followed which enables the purchasing department to evaluate requisitions carefully, greater care will be displayed by those requisitioning material.
- ***Selection of suppliers***. Knowledge of suppliers is normally acquired through contacts with sales representatives, advertisements in trade magazines, catalogues and correspondence with suppliers. From these sources a register of suppliers can be compiled in which the different suppliers are evaluated in respect of quality, price, service and reliable delivery.
- ***Compiling a price register***. A comprehensive price register of the various products must be compiled so as to keep the purchasing department abreast of current prices and the discounts applying to different order sizes.
- ***Placing of orders***. After a close study of the purchasing market has been made and a decision taken as to the most opportune time to buy, negotiations are entered into with suppliers and the order is placed. The following points must be established clearly: the price, quantity and quality and the delivery date.
- ***Monitoring of orders***. The purchasing department serves as the link between the suppliers and the production department, and any deviations by the suppliers with regard to delivery times or change in production demand, must continuously be assessed and remedied.
- ***Receiving of goods***. After receipt of the goods, they must be inspected as regards quantity and quality, after which a goods received voucher is prepared and sent to the purchasing department. The goods received voucher is compared with the invoice as well as with the original order. If the purchasing department is satisfied after comparing these documents, approval is given to the financial department for the settlement of the account. The final price is usually subject to trade, quantity and cash discounts.

3.2.2 Materials handling

Materials handling is seen as a necessary evil in the production process, because this activity contributes nothing to the value of the final product, but can constitute a large cost component.

Did you know?
Material handling costs can, in many firms, represent more than 2% of the average inventory value.

The total production system is, however, dependent on materials handling, as it provides the link between the different stages in the production process -from raw material to final product.

This relationship is illustrated in **Figure 3.4**.

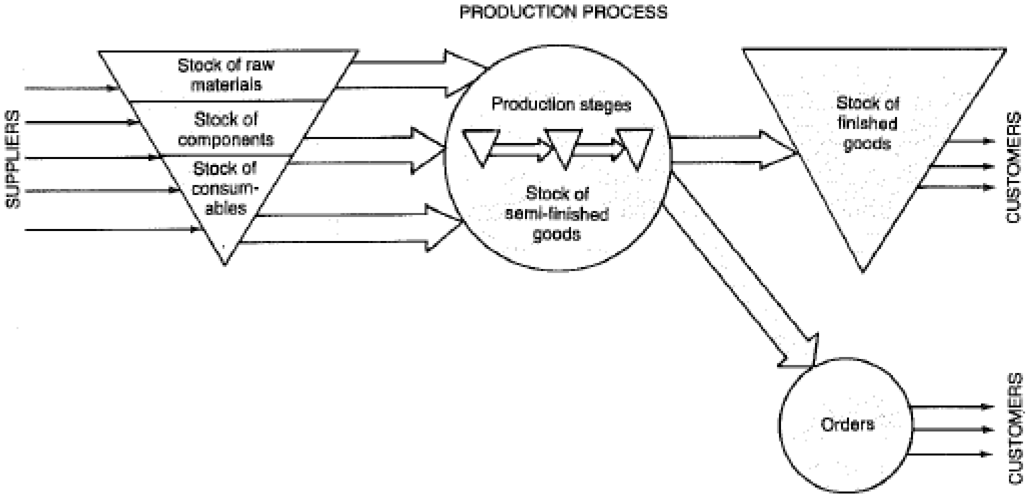


Figure 3.4 The relationship between materials flow and stock keeping

The flow of materials in a firm may be compared to the flow of water in a stream. A delay or bottleneck in the material flow is similar to an obstruction in the stream.

When a number of storage dams are deliberately introduced at different stages, the flow of water becomes more controllable because the water supplies in each dam can be fed into the system in the desired quantity and at the desired time.

Some important materials handling principles:

- Eliminate transport, or reduce transport distances.
- Keep material moving, or shorten the loading time at different points.
- Plan easy routes and prevent the backtracking of material.
- Transport payloads in both directions, or reduce the movement of empty containers.
- Transport economic quantities, or reduce size of containers.
- Make use of gravitational force, or employ an alternative cheap and reliable source of energy.

3.2.3 Stock keeping and inventory control

The main purpose of all production activities is to realise the maximum profit in the long term. Efficient stock keeping and inventory control are of the utmost importance in achieving this objective.

3.3 Stock keeping

Ideally, stock should be used or sold as soon as possible after being received; in other words, no stocks should be kept on hand.

In practice this is simply not possible as adequate stocks have to be available for various reasons:

- The fundamental reason why inventory should be carried, is that it is physically impossible and economically impractical to purchase each and every stock item as and when it is required. In addition, stocks on hand also serve as a buffer against uncertainties.
- The consumer usually insists that his needs be met immediately and that a reasonable variety be offered. If delivery does not occur promptly or delivery promises are not kept, this may lead to customer dissatisfaction, reduced orders and lower sales. Stock keeping consequently assists in matching demand and supply.
- In the manufacturing industry inventory promotes the smooth flow of production by eliminating production delays which might result from the non-availability of raw materials, components, tools and consumables. A shortage of a single part can bring a manufacturing process to a complete halt. Adequate stocks must therefore be available to facilitate production planning and control, and to eliminate overtime and rush orders as far as possible.
- At each stage of the production and distribution process, inventory serves a decoupling function with regard to successive operations, starting with raw material purchases, then the various manufacturing activities, and eventually the shipping and marketing activities. Buffer stocks between the various stages assist in balancing the production line and ensure that the various activities are carried out independently and efficiently. In this way economic quantities will be ordered, optimum batch sizes will be manufactured and economic payloads will be transported. All these advantages, however, could be forfeited in cases where manufacturing takes place against individual orders.

3.4 Inventory control

Inventory control must occur for various reasons, and it is often necessary to compromise when objectives clash.

The most important aims of inventory control are the following:

- To keep capital investment in stock at a m1mmum. The investment in inventory represents a substantial amount in many businesses. It is not uncommon that 25% of the total capital employed in manufacturing industries is invested in inventory. The absence of a scientific inventory control system may lead to excessive capital being tied up in stock, which could result in a serious shortage of floating capital. Management practices leading to a small saving in terms of total inventory, may result in substantial savings in terms of money. It must not be deduced from this, however, that all capital invested in stock is unproductive.
- To effect savings in storage costs.
- To prevent damage, theft, obsolescence and the spoilage of stock.
- To eliminate, where possible, unnecessary varieties, and to promote the standardisation of raw materials, parts and equipment.

- To prevent inventory losses resulting from poor inspection on receipt.
- To ensure the availability of sufficient stocks of raw materials, parts and indirect materials, so that the production department will not experience any shortage of stock.
- To ensure the efficient transportation of stocks- including transport to the plant, handling during manufacture and transport to the client.
- To undertake demand forecasting, in order to determine inventory requirements.
- To liaise with the purchasing department so that economic purchasing can take place.
- To design an efficient inventory information system which may, in turn, serve as a basis for efficient production planning, efficient purchasing, hedging against price fluctuations, correct cost-accounting and precision in the compilation of financial statements.

Note:
The overriding aim of stock keeping and inventory control is to maintain optimum stock levels and ensure maximum stock turnover so that the business unit may maintain maximum productivity in the long term.

For these requirements to be met, the right material in the right quantity and the right quality must be available at the right time and place. The responsibility for designing an efficient inventory control system rests with production management.

The most important focal points in any inventory control system may be reduced to two problem areas, namely:
(i) How much must be ordered. In solving this problem a balance must be sought between inventory carrying costs, on the one hand, and the cost advantages attached to large orders, on the other hand - particularly as a result of quantity discounts and hedging against inflation.
(ii) When orders must be placed. Solutions to this problem must be sought because insufficient stocks can lead to production stoppages, lost orders and client dissatisfaction.

In order to solve the above problems, it will first be necessary to consider the various types of inventory costs and the behaviour of the different categories of such costs.

3.5 Inventory costs

Inventory costs1 cannot be determined with absolute accuracy; yet the amount tied up in the different inventory cost categories must be known in order that analytical techniques may be applied as accurately as possible in the calculation of optimum stocks.

It is therefore the task of management to evaluate the influence of the different inventory cost categories on total inventory costs, in order to reconcile the contrasting influences optimally. Inventory costs may be divided into two main categories, namely inventory carrying costs and ordering costs.

3.5.1 Inventory carrying costs

Inventory carrying costs relate to all costs attached to the carrying of stocks over a period, for example capital costs, storage costs, handling costs, obsolescence costs, depreciation, spoilage, theft and insurance costs.

3.5.1.1 Cost of capital (interest costs)

When a firm borrows money to finance inventory, it is relatively easy to determine the capital cost, because the rate of interest is stipulated when the transaction is entered into. When inventory is financed out of own funds, however, it is difficult to estimate the cost of the capital involved.

> **Note:**
> In practice, estimates vary from business to business, from the bank rates quoted for safe investments, to the rates that could be earned through alternative investment possibilities.

The marginal efficiency of capital with regard to alternative inventory investments is illustrated with the aid of **Figure 3.5**.

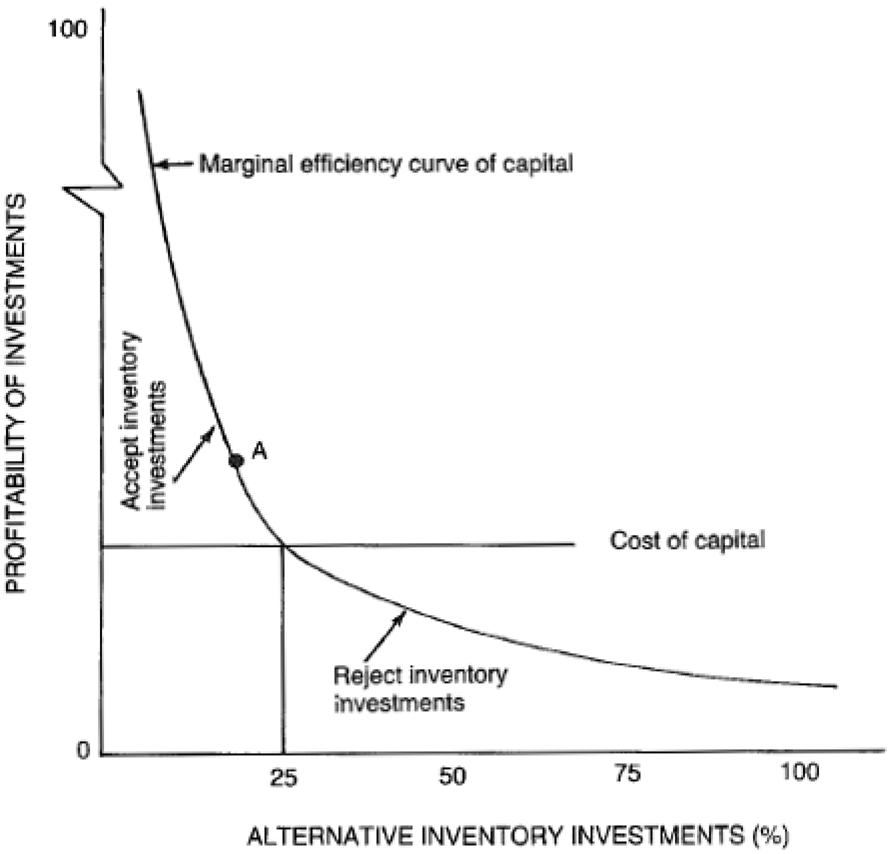


Figure 3.5

The marginal efficiency curve of capital shows that only 25% of the alternative inventory investments will earn a profit above the cost of capital.

These 25% investment alternatives (including A in the example) should be accepted, while the 75% investment alternatives which will yield less than the cost of capital, should be rejected taking into account the costs attached to possible stock shortages and other hidden costs.

If the marginal efficiency curve of capital for all investment alternatives is evaluated, it will be clear that capital investment in inventory competes with many other investment alternatives - whether with investments in new machines, equipment, buildings and training, or even with investment outside the business.

Did you know?
It is sometimes reasoned that the costs of inventory investment is determined by the opportunity cost in respect of alternative investment possibilities.

3.5.1.2 Storage and handling costs (space costs)
A considerable proportion of the inventory costs is made up of storage costs. These costs include, amongst others, depreciation on buildings, property rates, interest on capital invested in warehouses, maintenance costs, costs of electricity, personnel costs and stock handling costs.

The last-mentioned cost item, namely handling costs, is often estimated at 2% of the average inventory value.

3.5.1.3 Obsolescence, depreciation, spoilage, theft and insurance costs (risk costs)
These costs are occasioned by business risks and increase as more stock is carried. Obsolescence and depreciation have a bearing on stock items which become old-fashioned, or on items for which substitutes become available, or on finished goods when new models appear on the market.

Spoilage represents a loss in value with regard to products which, with the passage of time, become unsuitable for processing or for sale - for example, fruit in the canning industry or milk in the dairy industry.

Theft is a further operating cost which may often reach astounding proportions. Insurance costs represent insurance premiums, which must be paid on policies which provide cover against theft, fire and other possible inventory losses.

Most of the abovementioned cost types are directly dependent upon the inventory size.

If all the abovementioned cost elements are taken into account, it is not surprising that a figure of between 15% and 40% of the value of the average stock is accepted as the yearly inventory carrying cost.

If a cost figure of 25% of the average stock value per annum is accepted, this means that if the firm carries R100 000 worth of stock, on average, the annual inventory carrying cost would be R25 000.

Think about it!

Put differently, it means that carrying an item in stock for four years would result in the carrying costs being approximately equal to the cost of the item itself.

1. Average stock = $\frac{Q}{2}$ (provided that the demand is constant and that replenishment takes place when the inventory decreases to zero.)
   Where Q = Order size
2. It is interesting to note that a figure of 20% of the average inventory value is used as the yearly inventory carrying cost in the Public Service Commission's stock system.

If it is assumed that the inventory carrying costs are a linear function of the average inventory size, the following relationship exists between the two factors:

Inventory carrying costs per annum $= \frac{Q}{2} \times P \times K$

Where Q = Order size

P = Percentage of the value of the average inventory as annual inventory carrying cost

K = The cost (price) per unit of the inventory item

To illustrate the relationship between the order size and the inventory carrying cost per annum, an example is chosen where order sizes vary from 100 to 1 000 units and where inventory carrying costs are estimated at 25% of the average inventory value.

The cost price of the particular item of stock is taken to be R1,00:

Order size (Q)	Average Inventory $\left(\frac{Q}{2}\right)$	Carrying costs $\left(\frac{Q}{2} \times P \times K\right)$ *per annum* (R)
100	50	12,50
200	100	25,00

300	150	37,50
400	200	50,00
500	250	62,50
600	300	75,00
700	350	87,50
800	400	100,00
900	450	112,50
1 000	500	125,00

Table 3.1 The relationship between order size and inventory carrying costs

From **Table 3.1** it may be deduced that the cost of holding inventory increases as the average stocks increase and that the average inventory held by the business should be as small as possible.

The last deduction is incorrect, however, since certain other inventory costs must be taken into account.

3.5.2 Order costs

Order costs are those costs which must be incurred in order to obtain inventory, including preparation and revision of purchasing orders, selection of suppliers, placement of orders, monitoring of orders, and costs related to reception, inspection, storage of and payment for goods.

Even when orders are placed for the internal production of items, order costs still arise, for example the issuing of orders, control of the progress of orders, inspection and storage of the goods, and adjustment of inventory records.

Order costs are usually fixed, irrespective of the order size. From this it may be deduced that the greater the order size, the less frequently need orders be placed and the lower the order cost will be.

The purchase price will also decrease if larger orders are placed, as a result of quantity discounts. From this it may again be deduced (incorrectly) that as few orders as possible should be placed.

Worked Example 3.1

If the order costs be estimated at R20 per order, and 1 000 units of the item concerned be required annually, calculate the order cost.

Solution:

Order cost per annum $= \frac{V}{Q} \times B$

Where V = The consumption in units per annum (1 000)

Q = The order size (?)

B = Order cost (fixed cost per order – R20)

The annual order cost of different order sizes will then be as follows:

When 100 units are ordered at a time:

Order cost per annum $= \frac{V}{Q} \times B$

$= \frac{1\ 000}{1\ 00} \times R20$

$= R200$

When 1 000 units are ordered at a time:

Order cost per annum $= \frac{V}{Q} \times B$

$= \frac{1\ 000}{1\ 000} \times R20$

$= R20$

Table 3.2 illustrates the relationship between different order sizes and the order cost.

Order size (Q)	Number of orders $\left(\frac{V}{Q}\right)$	Order costs $\left(\frac{V}{Q} \times B\right)$ *per annum* (*R*)
100	10,00	200,00
200	5,0	100,00
300	3,33	66,60
400	2,50	50,00
500	2,00	40,00
600	1,66	33,20
700	1,43	28,60
800	1,25	25,00
900	1,11	22,20
1 000	1,00	20,00

Table 3.2 Relationship between different order sizes and the order costs

3.6 Determination of economic order sizes

3.6.1 The basic inventory model

It is clear that as the order size increases, the annual inventory carrying costs increase and the order costs decrease. It may be deduced from this that the total annual costs (inventory carrying costs + order costs) will be high for very small, as well as very large order sizes.

Efficient inventory control seeks an equilibrium between the high total costs attached to very big and very small order sizes. The ideal is to seek sufficient stocks, but at the lowest possible annual costs.

It is possible to approximately determine the most economic order size by classifying and adding up the different costs relating to an inventory item. This is illustrated in **Table 3.3** with the aid of the same information as that used for **Table 3.1** and **Table 3.2**.

Q Order size	$\frac{Q}{2}$ Average inventory	$\frac{V}{Q}$ Number of orders	$\frac{Q}{2} \times P \times K$ Inventory carrying costs (R)	$\frac{V}{Q} \times B$ Order costs	$\frac{Q}{2} \times P \times K + \frac{V}{Q} \times B = E$ Total costs (R)
100	50	10,00	R 12,50	R200,00	R212,50
200	100	5,00	25,00	100,00	125,00
300	150	3,33	37,50	66,60	104,10
400	200	2,50	50,00	50,00	100,00 →
500	250	2,00	62,50	40,00	102,50
600	300	1,66	75,00	33,20	108,20
700	350	1,43	87,50	28,60	116,10
800	400	1,25	100,00	25,00	125,00
900	450	1,11	112,50	22,20	134,70
1 000	500	1,00	125,00	20,22	145,00

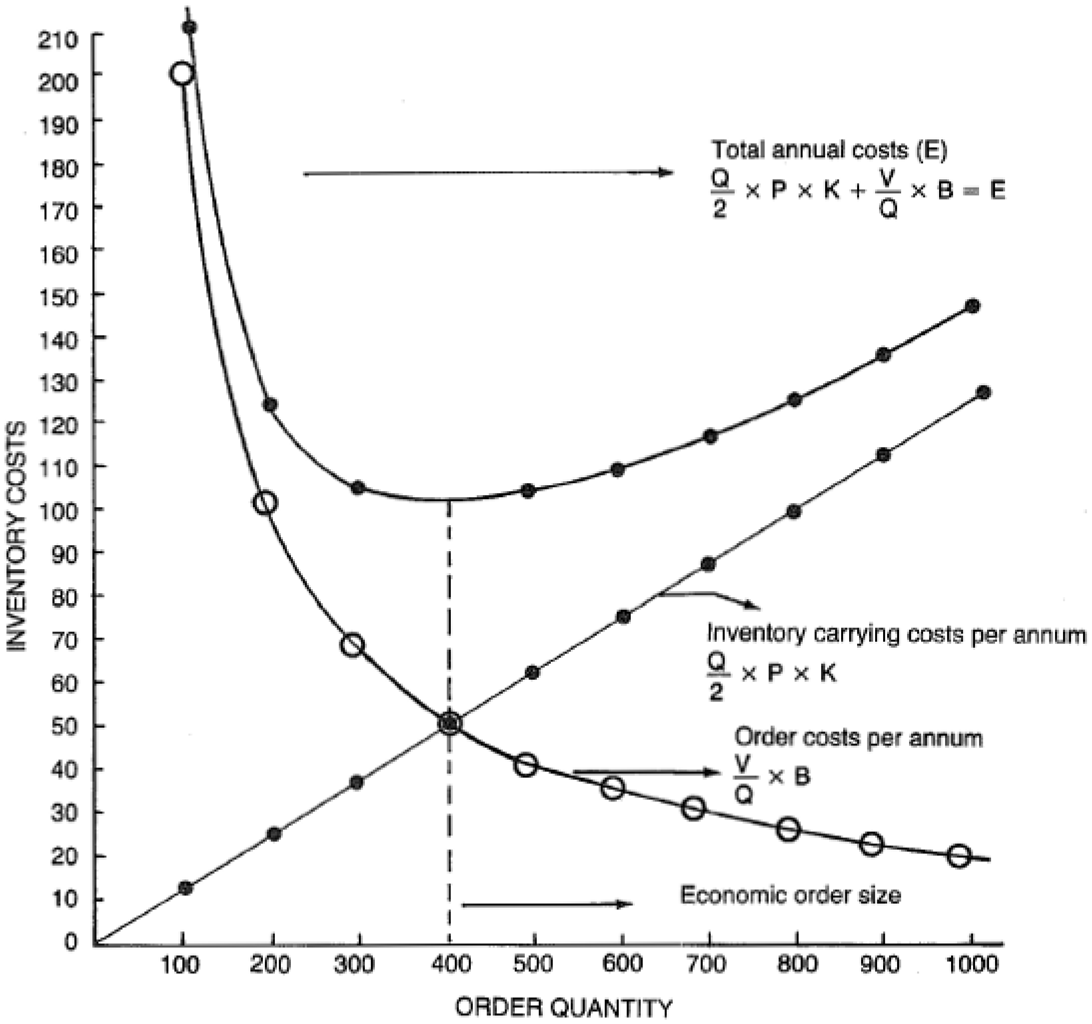
Table 3.3 The relationship between order size, the number of orders, the average inventory, the carrying costs, the order costs and the total annual costs

From **Table 3.3** it may be deduced that total annual inventory costs are minimised when the order size (0) amounts to 400 units. At this point, the inventory carrying costs equal the order costs.

Note:
This is a coincidental characteristic of this model and is therefore not applicable to all models.

One of the aims of inventory control is to determine an order size which will ensure the minimum total stock costs - the so-called economic order size.

Figure 3.6 (based on the information contained in **Figure 3.3**) illustrates the relationship between order size and inventory costs, and shows that the economic order size is reached at that point where inventory carrying costs and order costs are approximately equal.



E = Total annual inventory costs
Q = Order quantity (varying in the example from 100 to 1 000)
P = Percentage of the average stock value as annual inventory carrying costs (25%)
K = The cost (price) per unit of the inventory item R1,00)
V = The consumption in units per annum (1 000)
B = Order costs (fixed costs per order – R20)

Figure 3.6 Relationship between order quantity and inventory costs

From the preceding illustration of inventory cost information, it appears that roughly 400 units is the most economic order size. Considering that inventory- size intervals of 100 were used, the most economic order size cannot be precisely determined by this method.

This method can also be very time consuming - especially in cases where the order quantities of a variety of inventory items must be calculated.

From the total inventory cost formula $E = \frac{Q}{2} \times P \times K + \frac{V}{Q} \times B$, the following basic order size formula may be derived to determine the economic order size EQ easily and quickly:

$$EQ = \sqrt{\frac{2 \times V \times B}{P \times K}}$$

Where EQ = Economic order quantity (?)
V = The consumption in units per annum (1 000)
B = Order cost (fixed cost per order – R20)
P = Percentage of the average inventory value as Annual inventory carrying costs (25%)
K = The cost (price) per unit of the inventory item (R1,00)

$$\begin{aligned} EQ &= \sqrt{\frac{2 \times V \times B}{P \times K}} \\ &= \sqrt{\frac{2 \times 1\,000 \times 20}{0{,}25 \times 1}} \\ &= \sqrt{\frac{40\,000}{0{,}25}} \\ &= \sqrt{160\,000} \\ &= 400 \end{aligned}$$

Did you know?

By using differential calculus the following may be derived from the total incremental cost formula:

$$E = \frac{Q}{2} \times P \times K + \frac{V}{Q} \times B$$

$$\frac{dE}{dQ} = \frac{P \times K}{2} - \frac{V}{Q^2} \times B$$

$$\frac{P \times K}{2} - \frac{V}{Q^2} \times B = 0 \qquad \text{Minimum where } \frac{d^2E}{dQ^2} > 0$$

$$EQ = \sqrt{\frac{2 \times V \times B}{P \times K}}$$

From the above calculation it may be deduced that the standard order or economic order size must be 400 units, in other words 2½ orders per annum.

Other quantities (which necessitate more or fewer than 2½ orders per year) are not so advantageous.

The basic inventory model discussed was based on certain assumptions, namely that the annual consumption (in units) must be known, demand remains constant, total order quantity is delivered at one time, order costs remain constant regardless of the order quantity, purchase price does not fluctuate during the period under review, and there is sufficient space to store stocks and also sufficient funds to purchase the desired quantity.

Unfortunately many of these assumptions are not valid in practice, and the basic model has to be changed to suit circumstances. Two modifications will now be discussed, namely those applying when quantity discounts become relevant and when economic order sizes are not received at one point in time.

3.6.2 The influence of quantity discounts

Quantity discounts are often granted by suppliers in order to encourage larger orders. 'Large' orders, however, are coupled with high annual inventory costs.

The influence of quantity discounts can be assessed firstly by calculating the economic order size.

If the economic order size is smaller than the minimum quantity for which a quantity discount is received, the total annual inventory costs must be calculated for the point at which the quantity discount is received. The discount advantage must then be calculated.

The cost advantages or disadvantages of the alternative order sizes may then be determined. This procedure can be repeated for even larger order sizes with larger quantity discounts. **Table 3.4** illustrates the influence of quantity discounts on total inventory costs.

	Order size of 400 Price R1,00	**Order size of 800 Price R0,90**	**Order size of 1 000 Price R0,85**
Purchase costs per annum (1000 units)	1 000	900	850,00
Order costs (R20 per order)	50	25	20,00
Inventory carrying costs:			
Average stock x unit price x inventory carrying cost percentage (25%)	50	90	106,25
Total inventory costs	1 100	1 015	976,25

Table 3.4 The influence of quantity discounts on total inventory costs

The influence of quantity discounts on total inventory costs is illustrated in **Figure 3.7**.

Figure 3.7 The influence of quality discounts on total inventory costs

The savings that result from the purchase of large orders must now be weighed up against the risk of greater inventory.

3.6.3 The influence of the gradual receipt of orders

One of the assumptions made with respect to the basic order size formula was that the order must be received at one point in time. This assumption is not always valid in practice - especially in cases where it has been decided to manufacture the item within the plant and inventory becomes available for use as items are produced.

Figure 3.8a illustrates the case where the economic order size is received at one point in time, whereafter the inventory is consumed till the reordering level is reached, which must allow for sufficient stock during the lead time, so that the inventory supply is not exhausted before the next consignment is received.

Figure 3.8b illustrates the case where orders are received gradually over a period.

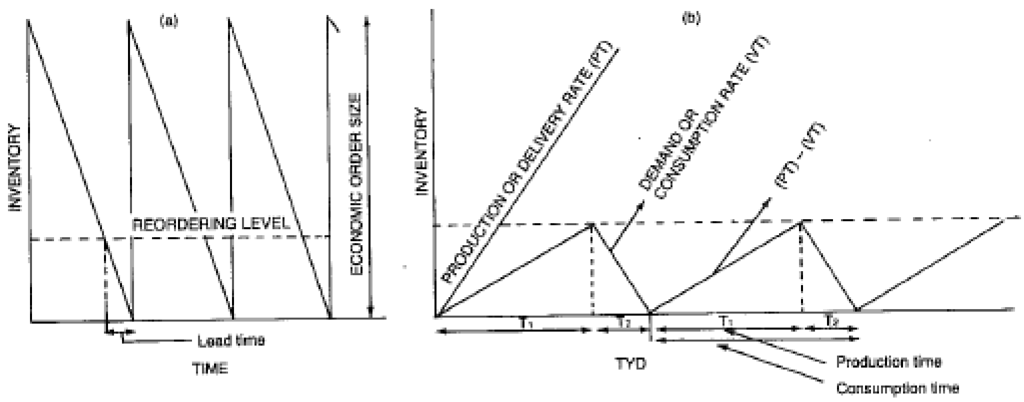


Figure 3.8 Illustration of simultaneous and gradual inventory receipts

	Definition: Lead time The time that elapses between the moment when the decision is taken to place an order till the consignment is received. Lead time also includes the time taken to prepare the buying order, for the order to be forwarded to the supplier, the preparation of the order by the supplier, the transport of the order, and lastly the unpacking, inspection and storing of the order.

When inventory is received gradually, the following formula is used to determine the economic order quantity (or the optimum production batch size):

$$EQ = \sqrt{\frac{2 \times V \times B}{P \times K\left(1 - \frac{VT}{PT}\right)}}$$

Where EQ = Economic order quantity (or optimum production Batch size)

V = Consumption in units per annum (1 000)
B = Ordering costs (fixed cost per order – R20)
P = Percentage of the average inventory value as annual inventory holding costs (25%)
K = The cost (price) per unit of the inventory item (R1,00)
VT = The demand rate (1 000 units per annum)
PT = The production rate (2 000 units per annum)

Therefore

$$EQ = \sqrt{\frac{2\times 1\,000\times 20}{0{,}25\times 1{,}00\left(1-\frac{1\,000}{2\,000}\right)}}$$
$$= \sqrt{\frac{40\,000}{0{,}25\times\frac{1}{2}}}$$
$$= \sqrt{\frac{40\,000}{0{,}125}}$$
$$= \sqrt{320\,000}$$
$$= 565{,}685$$

Note:
The formula may once again be derived with the aid of differential calculus from the total inventory costs formula.

In this case the economic order quantity is larger in comparison with the calculation according to the basic formula, since the average inventory size is smaller and the balance between order costs and inventory carrying costs is only achieved at a larger ordering quantity.

There are several other inventory models which have been developed to suit different business conditions, but these are not discussed here.

Note:
Fortunately the total annual cost is very often not particularly sensitive to calculations based on faulty estimates of the cost.

A few warnings must, however, be issued in regard to the use of inventory models, namely cost and other data used for the models are usually based on estimates and the result is only as accurate as those estimates, the business environment changes continuously and management must be sensitively geared to adapting the advance estimates to the changed circumstances; and lastly, care must be taken not to overlook the influence of opportunity costs, this influence being quantifiable with great difficulty.

3.7 Determination of the re-order point

After determining how much must be ordered (economic order size), management has the task of deciding when the order is to be placed. In the abovementioned EQ models the assumptions were made that demand is constant, that delivery times are constant, and that the rate of production is constant.

As has been pointed out, none of these suppositions is always valid in practice.

Although the annual demand may be 1 000 units, it is not necessarily true that the daily demand will be $\frac{1\,000}{250} = 4$ and the weekly demand 4 x 5 = 20 units.

It may also be impossible for the supplier to deliver the ordered goods in time - whether because of stock shortages, strikes, work delays or other contingencies.

To compensate for fluctuations in demand and supply, businesses are obliged to keep a safety stock on hand. The magnitude of the safety stock depends to a large extent on the stability of demand and supply and the amount of risk that management is prepared to run concerning a stock shortage.

If management only rarely wants to experience stock shortages, the planned safety stock must be 'large'. If the business activities are such that the stock shortages of a certain item will not cause great disturbances, or if a rush order is possible, a 'small' safety stock may be sufficient.

Note:
The determination of the safety stock depends to a large extent on the demand distribution during the lead time and the risk management is prepared to run in respect of a stock shortage.

Figure 3.9 illustrates the trend in the weekly demand regarding one specific inventory item by means of a distribution curve.

Assume that the demand over 11 weeks was as follows:
(For charting purposes the weekly demand was classified from small to large.)
10, 12, 15, 18, 19, 20, 21, 22, 25, 28 and 30

The average consumption per week is 20 units (which corresponds with the 50% on **Figure 3.9**). The total demand divided by the number of weeks: 220 ÷ 11 = 20.

If the average lead time is five weeks, and it is decided to be 100% certain that there will be no stock shortage, there must be 30 x 5 = 150 units still in stock when the order is placed.

The safety stock is then 150 - 100 (the average consumption during the average lead time) = 50.

If management decides to be less than 100% sure that no stock shortage owing to fluctuations in demand will occur during the five weeks of lead time, the probability function of demand may be determined for these five weeks.

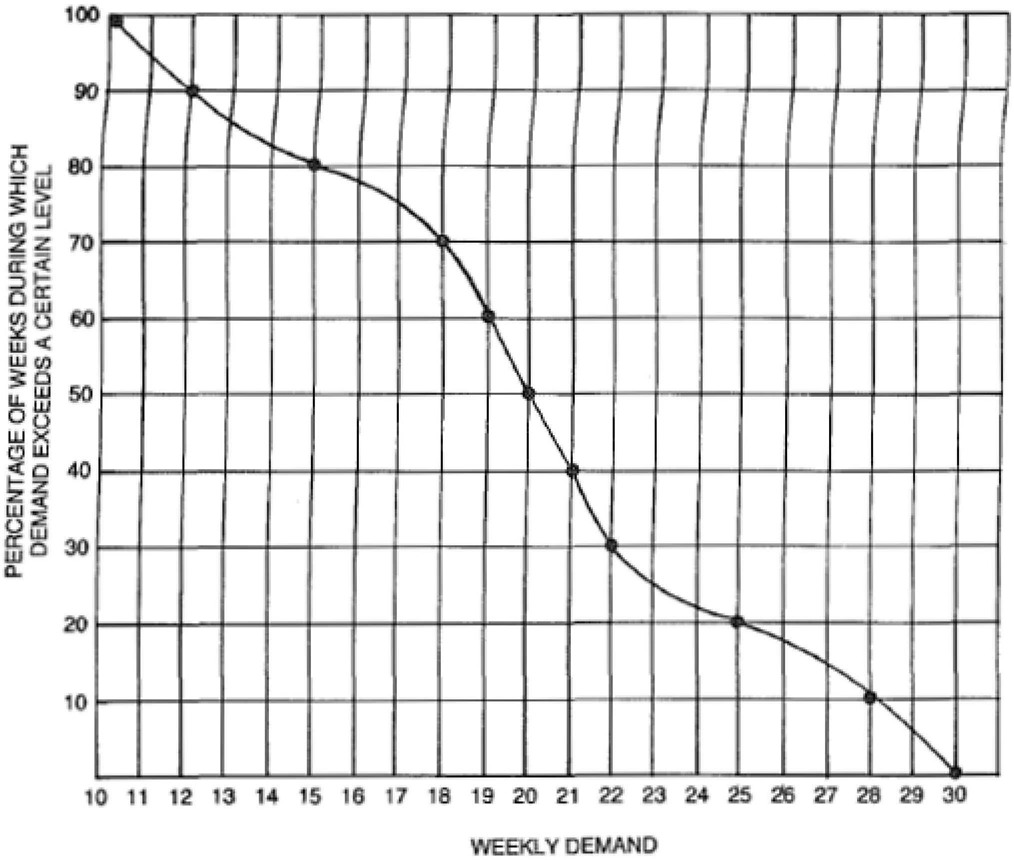


Figure 3.9 Distribution curve of the weekly demand regarding a specific inventory item

Suppose the demands for the different weeks are independent random variables with a distribution during each week as indicated in **Figure 3.9**. The distribution function of the demand over five weeks is illustrated in **Figure 3.10**.

From the graph it can be deduced that there is an approximate 100% chance that the demand for the five weeks will be greater or equal to 70, 50% that the demand will be greater or equal to 100, 20% that the demand will be greater or equal to 110 and 3% that the demand will be greater or equal to 125.

Note:
These values can also be obtained by using a normal approximation with an average of 100 and a standard deviation of $\sqrt{5} \times 5{,}94 =$ 13,28 (where 5,94 is the standard deviation of the demand for one week). To be 97% sure that there will be enough stock for five weeks, an order must be placed when the stock level has decreased to 100 + 1,89 x 13,28 = 125. (The factor 1,89 is obtained from tables for the area below the standard normal distribution.)

If management thus decides to be 97% sure that there will be no stock shortage owing to variation in demand, there should be 125 units in stock when an order is placed. In the latter case the safety stock will be 125 - 100 = 25.

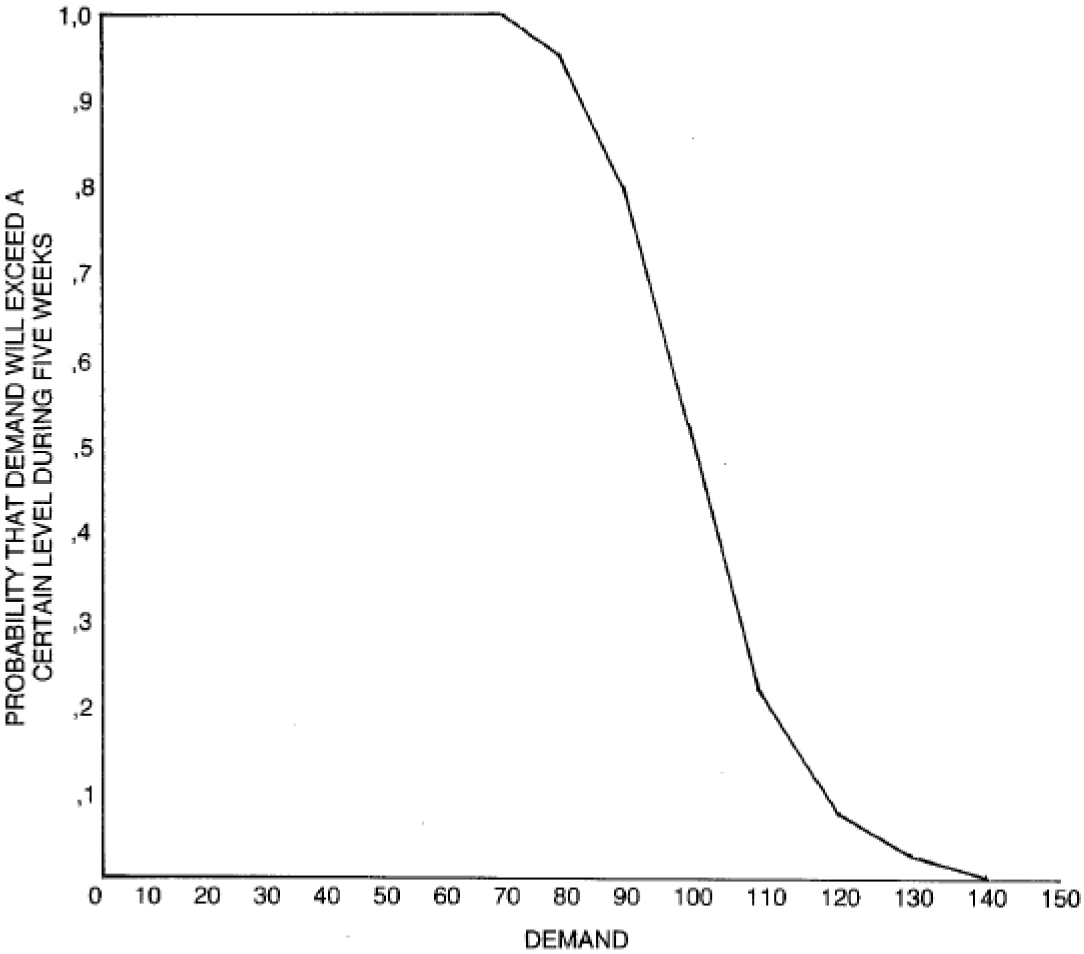


Figure 3.10 Distribution function of the demand for five weeks

Note:
No provision has as yet been made for delays in the lead time. To overcome this problem, the probability theory or the Monte Carlo Simulation Method may be used.

Assume that it is decided to be 97% sure of there being no stock shortage as a result of an increase in demand (for which 25 safety stock units have been allowed) and that provision for a delay of one week in lead time is made (for which a further 25 safety stock units are allowed).

The total safety stock will then amount to 50 units. The safety stock or normal minimum inventory may now be defined as that stock which must be carried to provide for a possible increase in consumption during the lead time and for delays in the lead time itself.

The normal maximum inventory is the largest stock that should normally be carried in the interests of the firm. The normal maximum stock level can be determined only after the economic order size has been calculated.

Should the economic order size be 400 units and the safety stock 50 units, then the normal maximum stock level would be 450 units.

The reordering level is that stock level selected by management for ordering new stock in order to minimise the risk of stock shortages occurring during the lead time or because of delays in the lead time itself.

Note:
The reordering level is equal to the average consumption during the average lead time plus the estimated safety stock: 20 X 5 + 50 = 150.

The determination of reordering points will now be explained with the aid of the data given above for different inventory control systems. The two best known systems are the fixed quantity system, also known as the maximum-minimum order system, and the periodic reorder system.

3.7.1 The fixed quantity system

According to this system a fixed quantity is ordered, but the time interval between orders differs in accordance with changes in consumption. Of cardinal importance with this method are the economic order quantity, the reordering level and the safety stock.

Assume	Economic order quantity	= 400
	Average consumption per week	= 20
	Average lead time	= 5 weeks
	Safety stock	= 50
	Reordering level	= ?

Assume also that there are 450 stock units at the beginning of a cycle, that the consumption during the first cycle is 20 units per week and that the lead time is five weeks.

Further assume that the consumption during the second cycle is 25 units per week and that the lead time is six weeks; and that consumption during the first ten weeks of the third cycle remains at 25, after which it decreases to ten units per week. The lead time is again five weeks.

Figure 3.11 illustrates the inventory levels and the reordering points when new stock must be ordered.

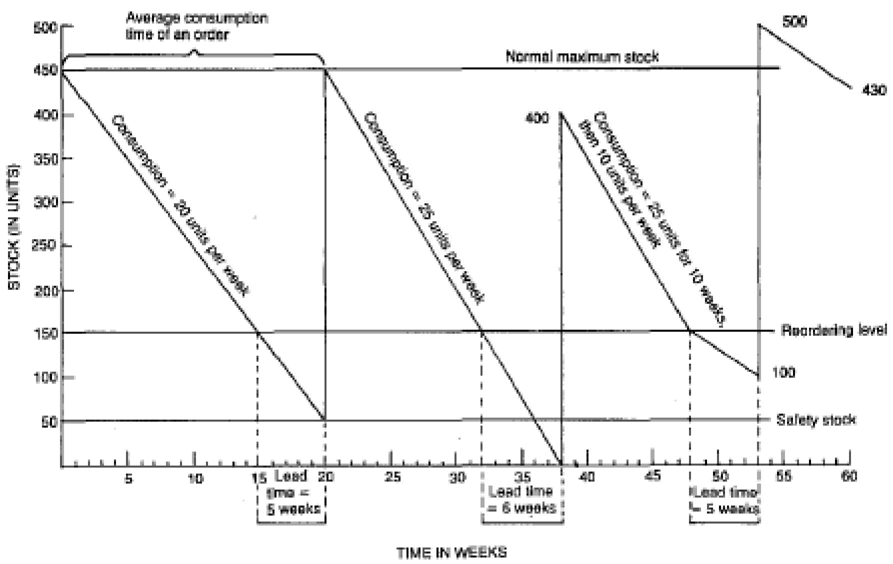


Figure 3.11 Illustration of the relationship between the economic order quantity, actual consumption, lead time, safety stock, reordering level and normal maximum stock in accordance with the fixed quantity system

In order to be fairly sure (97%) that the consumption will not exceed a certain limit and to provide for a possible delay in lead time (say one week), the reordering level is set at 150 units (25 x 5 + 25), and the economic order quantity is ordered when the stock has dropped to this level.

If the average consumption remains at 20 units per week, the reordering level is reached after 15 weeks: 450 - (20 X 15) = 150; if the average consumption during the lead time still remains at 20 units per week, there will be a stock of 50 units when the order arrives. This is the safety stock or normal minimum inventory.

When the order is received, the stock will rise to 450 units, which represents the normal maximum stock level. During the second cycle the consumption rises to 25 units per week and the reordering level is therefore reached after 12 weeks.

In this instance the total safety stock is depleted when the new order arrives. After receipt of the order the stock rises to 400 units. During the following ten weeks the consumption remains at 25 units per week. Consequently the reordering level is reached after ten weeks.

During the lead time of five weeks, the consumption is ten units per week. Therefore the stock level will be 100 units when new stock is received, whereafter it will rise to 500 units. Thus orders are placed after the 15th, 32nd and 48th weeks.

In practice several methods are used in applying the fixed quantity system, including the two-bin system and the bin-tag system. With the two-bin system, two bins or containers are used for each item.

The first bin contains enough stock to meet the demand during the lead time, while use is made of the stock in the second bin. As soon as the second bin is empty, the order is placed.

When the order is received, enough stock is put into the second bin to meet the needs during the next lead time, while the rest is placed into the first bin, after which the stock in the first bin is used.

The same result can be achieved by putting a warning tag at the reordering level of a container or shelf. The fixed quantity system is applied particularly when it is considered necessary to observe an inventory item continuously so that a new order can be placed as soon as the reordering level is reached.

3.7.2 The periodic reorder system

According to this system, orders are placed at regular intervals – either weekly, monthly or at any other interval. The size of the order varies according to the consumption since the previous order and the expected consumption during the lead time. This method is applied especially when a large variety of inventory items are ordered from the same supplier.

> **Note:**
> The most important difference between the fixed quantity system and the periodic reorder system lies in the fact that with the latter system ordering activities take place on a regular basis. Suppliers also prefer this method, as a fixed schedule for orders is available.

The periodic reorder system may be illustrated as follows:
Assume that the average consumption of a specific inventory item is 20 units per week (20 x 50 = 1 000 per annum), the ordering cost is R20,00, the inventory carrying costs are 25% of the average inventory value, and the price per unit R1,00.

With these data the economic order quantity (EQ) may be determined as being 400 units. Assume further that there are 50 working weeks in a year, that the average lead time is five weeks and that the safety stock is 150 units.

The ordering interval may be determined as follows:

Ordering interval $= \frac{economic\ order\ quantity}{annual\ demand} \times number\ of\ working\ weeks\ (or\ days)$

$= \frac{400}{1\ 000} \times 50$

$= 20\ weeks$

Average consumption during lead time $= 20 \times 5$

$= 100\ units$

The first reorder point $= average\ consumption\ during\ lead\ time + safety\ stock$
$= 100 + 150$
$= 250$

Assume (see **Figure 3.12**) that the stock for the first cycle (400 units) is received five weeks after the previous order was placed and that the stock level is 550 units (economic order quantity + safety stock).

Assume that the consumption for 60 weeks is as follows:
Weeks 1-20: 20 units per week
Weeks 21-48: 25 units per week
Weeks 49-60: 10 units per week

Assume the lead times are five, six and five weeks respectively.

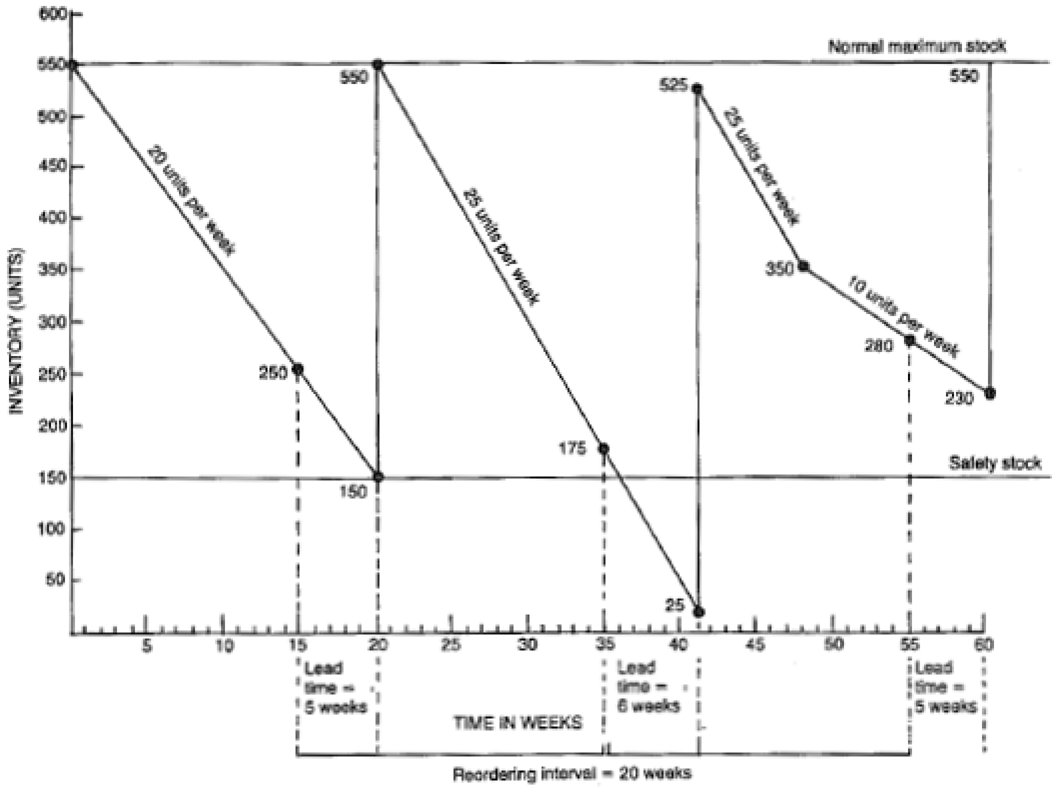


Figure 3.12 Illustration of the relationship between order size, actual consumption, lead time, safety stock, re-ordering level and time interval between orders in accordance with the period reorder system

The quantity of the order is equal to the difference between the stock on hand at the time of the order and the desired normal maximum inventory, plus the expected consumption during the lead time.

In other words:
Order quantity = (EQ - present stock) + expected consumption during the lead time + safety stock.

At the first reordering point (see **Figure 3.12**) the stock level stands at 250 units. It is accepted that the expected consumption will remain 20 units during the expected lead time (five weeks) - in other words, at 100 units.

Therefore (400 - 250) + 20 X 5 + 150 = 400 units are ordered. When the order is received, the stock level stands at 400 + 150 = 550 units. In this case the progress of the stock levels is identical with that under the fixed quantity system. During the second cycle the consumption rises to 25 units per week.

At the reordering point (end of the 35th week) the stock level is at 550 - (25 X 15) = 175 units. It is accepted that the consumption during the expected lead time (five weeks) will remain 25 units per week, in other words 25 x 5 = 125 units. In this case (400 - 175) + 25 X 5 + 150 = 500 units are ordered.

The lead time, however, in this case is six weeks and there are only 25 units in stock when the new consignment is received - after which the level of stock increases to 500 + 25 = 525. During the third cycle the consumption remains at 25 units per week for seven weeks, after which the stock level stands at 525 - (7 X 25) = 350.

Hereafter the consumption decreases to ten units per week. When the reorder point is reached, there are still350 - (10 x 7) = 280 units in stock. It is accepted that the expected consumption will remain ten units during the expected lead time (five weeks)- in other words, 50 units.

In this case (400 - 280) + 10 X 5 + 150 = 320 units are ordered. When the consignment is received the stock level again stands at 320 + 230 = 550 units.

One of the main disadvantages of the periodic reorder system is that the stock level can fluctuate sharply when management overcompensates for demand fluctuations. This occurs particularly if random deviations in demand are wrongly interpreted as permanent demand trends.

A larger safety stock must also be kept than in the case of the fixed quantity system, because, with the periodic reorder system, the safety stock must provide protection against fluctuations in demand during the total time span between orders and not only during the lead time.

Note:
An important advantage of the periodic reorder system is, however, that the activities of the inventory control department can be better planned and time can be used more efficiently because orders are placed at fixed points in time.

3.8 The ABC inventory classification method

Determining the economic order quantity and reorder points for all stock items is, in most cases, impractical and unnecessary. Strict inventory control requires continual attention and the costs involved in this are often higher than the savings derived from it.

In most cases inventory can be classified in different classes according to the annual consumption value, for example A items are those items with a high consumption value, B-items those with a medium consumption value and C-items those with a low consumption value.

A small percentage of the total inventory items often have a high consumption value, while a large percentage of the total stock items have a small consumption value. **Table 3.5** and **Figure 3.13** illustrate a typical ABC classification.

Classification	Number of inventory items consumed	% of inventory items consumed	Unit price (R)	Consumption value (R)	% of total consumption value
A	20	10	420	8 400	60
B	40	20	105	4 200	30
C	140	70	10	1 400	10

Table 3.5 Illustration of an ABC inventory classification

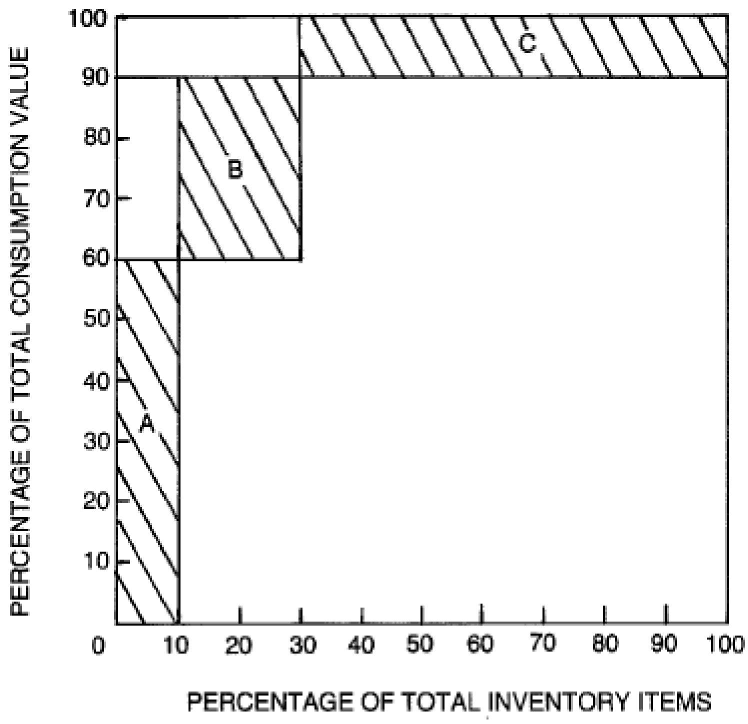


Figure 3.13 Illustration of an ABC inventory classification

More attention should be given to A-items, and order quantities must be scientifically determined, for example with the aid of the economic order quantity technique.

The purchasing of these stock types can take place on a small scale by tender. These stock items are usually few in number, and inventory control can consequently easily be carried out. B-items require good control and administration, as well as a safety stock.

Purchasing can also be carried out on a scientific basis, for example according to the periodic reorder system for a variety of B-items. C-items do not require continuous control, and a cheap and simple inventory control system may be applied.

Since the cost of these items is low, relatively large stocks can be kept. If a shortage arises with respect to C-items, this will normally not cause a production delay. Examples of these stock items are stationery and cleaning materials.

The ABC inventory classification is often encountered in manufacturing concerns. The classification of inventory in three categories is merely traditional, however, and there is no reason why inventory should not be classified into a larger number of groups.

Note:
This possibility could especially be exploited if a computer is available for inventory planning and inventory control purposes.

3.9 Inventory control in practice

The inventory control theory discussed so far, forms a useful guide for practice. Yet practical considerations such as the availability of capital, the necessary storage facilities and the advantage of combined orders, play a major role when the theoretical policy has to be applied in practice.

Since transport costs and quantity discounts play such an important role, the policy of ordering a few items must often be adapted to exploit the advantages of combined orders.

When the stock of a specific item reaches the reordering level, the inventory manager should thus consider all items which are ordered from the same supplier with a view to placing a combined order.

Think about it!
During the past two decades many businesses have switched from manual inventory control systems to computerised control systems.

The most important reasons for such a change are:

- inventory problems are solved more easily by a computer
- many businesses have in any case purchased computers for accounting purposes
- computer software is available for inventory control
- savings in inventory costs are possible
- the provision of stock can take place more efficiently
- better reporting on inventory levels can be achieved

Many established computer programmes are based on the fixed order quantity system and function in the same way as those discussed.

The computer can also be used to formalize demand forecasting - for example according to the exponential smoothing technique.

Thus, in practice, demand forecasting takes place as often as necessary for those stock items which are computer controlled.

One of the greatest advantages of computerised inventory control is the variety of reports that can be prepared by the computer, for example:

- determining the inventory size - which is necessary for auditing tests
- determining the value of stock - which is convenient for financial management
- pointing out obsolete stock- which is essential for controlling the freshness of products
- indicating when stocks have reached the reorder level - which serves as a warning that new supplies should be ordered

Note:
At this stage there is not as yet a computerised inventory control system which completely eliminates the need for sound judgment and control on the part of management.

In this module the problems of materials control, stock keeping and inventory control have been investigated.

It is difficult to determine how much stock should be kept on hand and when stocks should be ordered.

This requires a compromise between the cost savings effected by mass production or mass purchases due to quantity discounts and hedging against inflation on the one hand, and the cost benefits derived from small orders or small batch sizes resulting in savings in the cost of holding stock, on the other hand.

	Note: The purchase price of an inventory item is consequently not as important as the cost of the item when it is consumed or sold.

No attention has been given to the costs attached to inadequate stocks, since these are almost impossible to determine and can only be estimated by management on the basis of its business judgment. Management should nevertheless bear this latent cost factor in mind.

3.10 Using Gantt charts for project planning

The critical issue when managing a project is to take corrective action when it becomes known that some tasks are not being completed on time. This requires a project plan with completion times for the different parts of the project.

A Gantt chart is a simple way of visually representing the tasks of a project, their duration, and their sequence of execution.

To draw up a Gantt chart of a project, you need to:

- Identify all the project tasks
- Establish how long each task will take
- Establish whether a task can be done independently of other tasks, or whether certain tasks have to be completed before other tasks can be started
- Establish whether tasks share the same resource and therefore cannot be done at the same time
- Establish in what sequence the tasks need to be executed

Let's take the basic steps in building a house as a simplified example of how to construct a Gantt chart. **Table 3.6** provides the necessary information in a precedence table. Each of the tasks is listed more or less in order of execution and has been allocated a task number.

	Note: The duration of the task, as well as the precedence of other tasks that have to be completed before a task can be started is important information for the project planning.

In this example, the walls have to be built (task 2) before the conduit pipes for the electrical wiring can be chased into the walls (task 3). Two tasks have to be completed before the electrical fittings can be installed: the wires have to be pulled into the pipes (task 5) and the pipes have to be plastered over (task 4).

Therefore, tasks 4 and 5 have to precede task 6.

Task no	Task name	Duration	Precedence

1	Lay foundations	1	
2	Build walls, install windows and doors	6	1
3	Chase electric pipes into walls	2	2
4	Plaster walls	5	2,3
5	Pull electric wires into pipes	2	3
6	Install electric fittings	2	4,5
7	Put roof on	4	2
8	Install carpets and cupboards	2	7
9	Painting and finishing	3	4,7

Table 3.6 Precedence table for a house-building project

From the precedence table, a Gantt chart can be drawn up, as illustrated in **Figure 3.14.** You can see how a task that relies on the completion of a previous task is drawn to start in line with the ending time of the previous task.

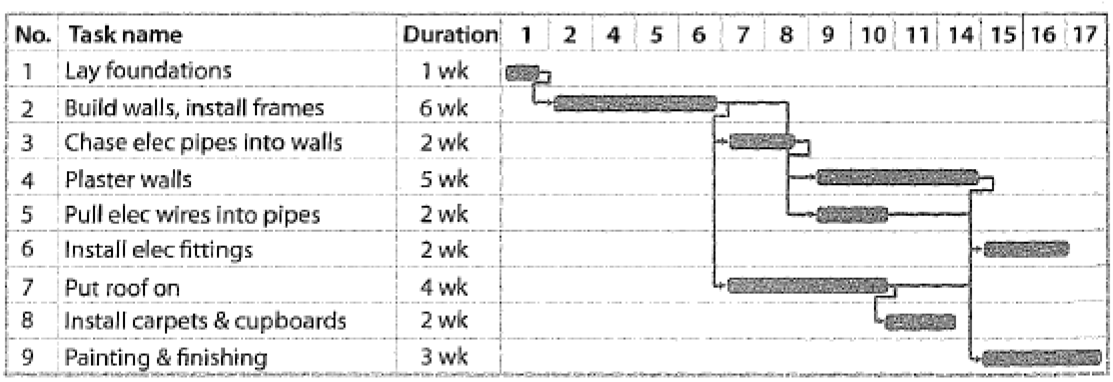


Figure 3.14 Gantt chart of house-building project

Gantt charts are useful as quick reference guides to how tasks in a project relate to one another because tasks are displayed as horizontal bars indicating the duration of the task.

In **Figure 3.14**, arrows indicate task precedence. Yet even in this relatively simple project, it is difficult to follow exactly which tasks must precede one another.

To plan a project with a large number of tasks or complicated precedence relationships between tasks, you need to draw up a network diagram and do critical paths analysis.

Activity 3.1

1. Write an essay on materials management and inventory control.
2. Write an essay on purchasing and material handling as components of materials management.
3. Write comprehensive notes on inventory costs.
4. Write an essay on the determination of economic order quantities.

5. Write an essay on the determination of the inventory reorder points.
6. Briefly outline (one or more of) the following material/inventory types: raw materials; components; semi-processed products; final products; and consumables.
7. List the most important duties of the purchasing department.
8. List the most important materials handling principles.
9. List the most important reasons for holding sufficient inventory.
10. Briefly discuss the most important objectives of inventory control.
11. Discuss (one or more of) the following inventory carrying cost items: cost of capital; space costs; risk costs.
12. Illustrate the relationship between the order quantity and inventory carrying costs.
13. Illustrate the relationship between the order quantity and order costs.
14. Give the formula used for calculating the economic order.
15. Give the formula for the calculation of the economic order quantity if stocks are received gradually.
16. Draw a graph to illustrate the relationship between the economic order size, the actual consumption, the lead time, the safety stock, the reordering level and the normal maximum stock under the fixed quantity system.
17. Draw a graph to illustrate the relationship between order size, the actual consumption, the lead time, the safety stock, the reordering level and the time interval between orders under the periodic reorder system.
18. Discuss and illustrate the ABC inventory classification method.

Activity 3.2

ANSWER THE FOLLOWING TRUE(T)/FALSE(F) QUESTIONS

1. Raw material stocks include all items which must be further processed before they become an identifiable part of the finished article.
2. The purchasing department usually initiates purchases and withdraws stock whenever the need arises.
3. The purchasing department has the authority to prescribe substitute materials for the production department.
4. Material handling is seen as a necessary operation in the production process because this activity increases the value of the product to a great extent.
5. One of the objectives of inventory control is to ensure sufficient raw material, components and consumables in order that the production department will not experience a shortage of stocks.
6. The two most important focal points of any inventory control system are the determination of the order quantity and the determination of the reordering points.
7. It is sometimes argued that inventory investment costs are determined by the opportunity costs of alternative investment possibilities.
8. Depreciation on buildings forms part of the risk costs in stock keeping.

9. The average stock is equal to the order quantity x 2.
10. Order costs are usually fixed, irrespective of the order quantity.
11. Inventory carrying costs will decrease and the order costs will increase as the order quantity increases.
12. The lead time is that time which elapses from the making of the decision to order till the following reordering point is reached.
13. The economic order quantity is smaller when stocks are gradually received than when stocks are received simultaneously.
14. The reordering level is equal to the estimated consumption during lead time plus provision for delays in the lead time.
15. The reordering level is equal to the average consumption during the average lead time plus an estimated safety stock.
16. In the periodic reordering system the size of the order varies in accordance with consumption from the time of the previous order and the expected consumption during the expected lead time.
17. A larger safety stock must be kept with the periodic reordering system compared to the fixed order quantity system, because with the periodic reordering system the safety stock must provide protection against consumption fluctuations during the total time interval between orders and not only for the lead time.
18. The determination of the economic order quantity and the reorder points for all inventory items is in most cases practical and necessary.
19. Inventory items are always classified in three categories: A-items, B-items and C-items.
20. The purchase price of an inventory item is not of as much importance as the cost of the item when it is consumed or sold.

Activity 3.3

ANSWER THE FOLLOWING MULTIPLE CHOICE QUESTIONS

1. The basic decision that must be taken with respect to inventory control is:
   (a) How and when orders must be placed
   (b) How and where orders must be placed
   (c) How much must be ordered and where
   (d) How much must be ordered and when
   (e) How much must be ordered and how to order
   (f) Where and when the orders must be placed
2. The time that elapses from the moment it is decided to place an order till the order is received is:
   (a) Stock out time
   (b) Lead time
   (c) Cycle time
   (d) Supplier's time
   (e) Purchaser's time
   (f) Lost time

3. The inventory control system where the quantity of the order varies in accordance with consumption from the previous order and the expected consumption during lead time, is:
   (a) The basic inventory control system
   (b) The fixed quantity system
   (c) The periodic reorder system
   (d) A deterministic inventory control system
   (e) A stochastic inventory control system
   (f) None of the above systems
4. All of the following, except one, are reasons why inventory is carried:
   (a) For protection against price decreases
   (b) To decouple operations
   (c) Because it is physically impossible to obtain the right stock item at the exact time it is needed
   (d) Because the consumer usually demands that his needs be met immediately
   (e) Because it assists manufacturing concerns in making production run smoothly
   (f) It serves as a buffer against uncertainties
5. In the case of the basic inventory model the average inventory is:
   (a) Half of the opening stock
   (b) Half of the order quantity
   (c) Half of the closing stock
   (d) Half of the opening and closing stock
   (e) The annual demand divided by the order quantity
   (f) The order quantity
6. In the case of gradual inventory receipts, the order quantity is larger in comparison with the calculation according to the basic formula, because:
   (a) The average inventory is larger and the balance between the order and stock holding costs is reached at a smaller order quantity.
   (b) The consumption rate is smaller than the manufacturing rate.
   (c) The average inventory is smaller and the balance between the order and inventory carrying costs is reached at a smaller order quantity.
   (d) The average stock is smaller and the balance between the order and stock carrying costs is reached at a larger order quantity.
   (e) (a) and (b)
   (f) (b) and (c).
7. In the graph where the influence of quantity discounts on total inventory costs is illustrated, the dotted lines indicate:
   (a) Possible cost/order quantity relationships
   (b) Impracticable costs/order quantity relationships
   (c) Economic order quantities
   (d) Optimal reordering points
   (e) Feasible and impracticable cost/order quantity relationships
   (f) None of the above alternatives.
8. The reordering level or reordering point is:
   (a) Equal to the buffer stock

(b) Equal to the expected consumption during lead time plus the economic order quantity
(c) Equal to the expected consumption during the following cycle
(d) Equal to the estimated consumption during lead time plus provision for delays in the lead time
(e) Equal to average consumption during the average lead time plus the estimated safety stock
(f) (d) and (e)

9. The safety stock is:
   (a) The normal minimum inventory
   (b) The stock which must be carried to provide for possible increases in consumption during lead time
   (c) The stock which must be held to provide for deviations in respect of lead time
   (d) The stock which must be held to provide for a possible increase in consumption during lead time and deviations in respect of the lead time itself
   (e) The reordering level
   (f) (a) and (d)
10. The ABC inventory classification shows that:
   (a) A small number of stock items are responsible for a high consumption value.
   (b) Stock items can be grouped into classes of which one class represents a large percentage of total stock items with a low consumption value.
   (c) C-items are those items with a low consumption value.
   (d) More attention must be given to A-items and order quantities must determined scientifically.
   (e) When a shortage of C-items arises, it will usually not cause production delays.
   (f) All the abovementioned alternatives are true.

Self-Check

I am able to:	**Yes**	**No**
• Describe the following inventory policies		
o order backlog		
o operating efficiency		
o customer service		
• Describe the following cost evaluation methods of inventory control		
o FIFO (First in first out)		
o LIFO (Last in first out)		
o weighted moving average		
o standard costing		

• Calculate weighted moving average given the following information		
o unit costs		
o total received		
o total issued		
• Compare the advantages and disadvantages of FIFO and LIFO systems		
• Describe the nature of the following types of stock items		
o raw material		
o finished goods		
o work in progress		
• Describe how each of the stock items listed has an impact on inventory level and its impact on other areas		
• Describe the process of managing inventory in terms of the following		
o lot sizes		
o lead times		
o batch sizes		
o shrinkage		
• Describe the inventory systems in terms of the following		
o re-order point		
o replenishment		
• Describe the process of distribution requirements planning in terms of the following		
o distribution network		
o forecasting		
o transportation		
• Calculate inventory levels given the following information:		
o scrap performance		
o lead times		
o stock levels		
• Describe each of the following inventory storage methods		
o dedicated storage		
o random storage		
o zone storage		
• Describe the advantages and disadvantages of each of the methods listed above		
• Describe four consequences of inaccurate record keeping of inventory		
• Describe the following pre-requisites necessary for inventory accuracy and the effect on inventory management		
o space		
o tools		
o training		
o incentive		

o accountability		
o creation of sub-stores		
o job description		
• Describe the following inventory calculation methods		
o annual inventory		
o cycle counting		
• Describe the advantages and disadvantages of each calculation method listed above.		
• Describe how an effective inventory management system achieves the following		
o optimal customer service		
o optimal inventory investment		
o optimal operational efficiency		
o optimal return on investment		
• Calculate annual carrying cost given the following		
o interest rate		
o unit costs		
o lot size		
• Calculate annual ordering cost, given the following information		
o cost per order placed		
o demand rate		
o lot size		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Module 4

Production costing

Learning Outcomes

On the completion of this module the student must be able to:

- Describe the purpose of process costing
- Describe with simple example the following elements
  - unit costs
  - man hours costs
  - machine run costs
  - overhead costs
- Describe how each of the inputs listed affect process costing
- Describe the steps involved in process costing
- Calculate the costing of a process given the following details
  - stock balances
  - unit cost
  - machine/man hours
  - overhead costs
- Define product costing
- Describe the elements that contribute to the cost of a product costing
  - material
  - overheads
  - labour
- Calculate the costing of a product given the following information
  - raw materials used
  - man hours
  - overhead costs
- Define budgeting
- Define cash flow projections
- Define variance control
- Describe each of the following types of variances
  - time variances
  - rate variances
  - material variances
- Describe the purpose of variance control
- Describe the cost of quality in terms of conformance and non-conformance to specifications
- Explain, using examples, the difference between operating budget and capital budget

- Describe three benefits of budgeting
- Calculate the efficiency variances of each of the following given the planned and actual information for each element
  - material
  - labour
  - machine hours
- Describe what is meant by standard costing
- Describe with simple examples how standard capacity is established in a manufacturing environment
- Calculate closing work in progress, given the following
  - opening work in progress
  - production data
  - unit cost

4.1 Introduction

The management function is the central overall function in any business, it enters into the activities of all the other functions, coordinating them towards a common goal. In order to achieve this goal, management should pay special attention to the planning and control functions.

The planning function may be seen as a decision-making process according to which the desired business targets are established; forecasts are made of the necessary raw material, labour, plant capacity and machine requirements in order to provide for the planned production and sales quantity; and an information system is set up to ensure efficient reporting on and control of the actual operating activities as against the set standards.

Note:
The control function relates to the management task of ensuring that the available means of production are combined to form a coordinated unit in order to achieve the set targets.

One of the most important links between the planning and control functions is the management-accounting information system which should ensure efficient communication, continuous feedback and responsible accounting to enable management to continuously adapt to changing circumstances.

Management accounting may be defined as a management instrument which uses the inputs and outputs of the financial and other business systems for the planning and control of business activities from a cost viewpoint.

Whereas financial accounting traditionally aims at reporting on historical events to external interested parties, such as the shareholders, creditors, the Receiver of Revenue, financial institutions, prospective investors and others, the aim of management accounting is to:

- use financial yardsticks according to the needs of the particular investigation
- provide insight into the present circumstances and to assist with future planning
- make financial analyses especially for decision-making and control purposes

Since the cost data which are required for financial-accounting purposes differ from those which are used for production decision-making purposes, the emphasis in this chapter falls on cost data for decision-making purposes.

The classification and flow of costs will therefore be explained in a manufacturing context.

Subsequently the cost concept will be analysed; then the classification of costs; the relationship between costs, volume of production and profit; the allocation of costs to cost centres and cost units; the various cost accounting methods; and the control of costs.

4.1.1 The cost concept

In theory as well as practice considerable confusion exists about the cost concept. The term cost is often used synonymously with expenditure.

Note:
The term cost is used for obtaining assets as well as for incurring current expenses.

In some cases cost refers to the sum of money which is or has to be paid for items of expenditure, whilst in other cases referring to the market value of goods or services which must be forfeited in exchange for goods or services received.

The term expenditure on the other hand, usually relates to the sacrifice made- that is, the value forfeited- during an income transaction.

Expenditure is consequently the measured monetary outflow of goods and/or services set off against income, in order to calculate the profit of a transaction, a period or a project.

To suit different circumstances and different requirements, various cost concepts have been developed by accountants, economists, business economists, engineers and various other relevant groups.

A few approaches to cost are discussed below:

- ***The traditional approach***. It has already been mentioned that accounting systems are traditionally based on the convention that transactions are recorded in terms of historical prices.

Accountants consequently measure the value of acquired production factors/goods/services in terms of the historical prices and refer to them as costs or actual costs.

Many business economists and cost accountants, however, have already abandoned this approach because in a dynamic economy, historical prices are irrelevant or of little value for decision-making purposes.

- The continental or normative approach. Many continental (and other) business economists approach costs in the light of expediently sacrificed values. It is argued that all expenses are sacrifices, but that only expedient sacrifices are costs. Inexpedient sacrifices are therefore classified as waste.

  In this case costs are defined as the expedient sacrifices, expressed in terms of replacement value, which must be made by the firm at the moment of exchange of goods and/or services. The replacement value is equated to what it will cost the firm to replace the sold goods at the moment of sale.

Note:
Although standard costs are also normative, they are not calculated in terms of replacement value, but rather by some or other scientific method.

According to this, costs are transferred to different departments or cost centres, where departmental managers or individuals are made responsible for cost deviations.

The differences between actual expenses and standard costs are known as cost variances, which are then further analysed into quantity and price variances. Standard costs will be further discussed later on.

From the above it is evident why many authors emphasise that different cost concepts are needed for different purposes. However, this broad approach to the cost concept necessitates a clear definition of the specific aim of the cost concept.

The following are some of the cost descriptions commonly encountered:
- Visible
- Direct
- Indirect
- Processing
- Fixed
- Variable
- Controllable
- Product
- Time
- Total

- Estimated
- Future
- Standard
- Replacement
- Historical
- Allocated
- Cash
- Absorption
- Differential
- Opportunity

Note:
Every one of these descriptive terms imply a specific approach to the calculation, measurement and application of the specific cost type.

Whereas the recorded historical costs are usually used in the preparation of final accounts, many of the other costing types are used in collecting cost data, for their allocation to costing centres and cost units, for the calculation of costs for tender purposes, for scientific planning and control of business activities at different levels, and for effective decision making.

Where appropriate the abovementioned costing terms will be defined and discussed in the text. From the above it is also evident that the production manager is dependent on money as a common yardstick of diverse production activities for decision-making, planning and control purposes.

4.1.2 Social costs

The context in which costs are discussed in this module is that of the individual business. A micro approach is therefore followed according to which cost data are analysed for the efficient planning and control of individual business activities.

To efficiently accommodate all industries in a country, it is essential that the authorities create an efficient infrastructure that must, amongst others, provide for transport, training, communication and information services.

The social costs resulting from infrastructural services can be analysed only by means of a macro analysis.

4.2 The classification of costs

The classification of costs is a prerequisite for the preparation of cost data for various purposes. **Figure 4.1** illustrates three criteria according to which costs can be classified into different categories.

CRITERION	COST CATEGORY
According to business activities	Total operating costs Manufacturing costs; Marketing and administrative costs Direct costs; Manufacturing overheads
According to cost behaviour	Fixed costs, variable costs, semi-variable costs
For decision-making purposes	Historical costs, standard costs, opportunity costs, incremental costs

Figure 4.1 Cost classification criteria and cost types

4.2.1 Cost classification according to business activities

The total operating costs of a manufacturing concern may be seen as the total costs or deductions from sales revenue, excluding tax. Total operating costs are usually classified into two main groups, namely manufacturing costs and marketing and administrative costs.

4.2.1.1 Manufacturing costs

Manufacturing costs, sometimes also referred to as production costs or factory costs, consist of the sum of the direct costs (direct material and direct labour) and the manufacturing overheads (indirect material, indirect labour and other indirect costs).

During the accounting period the cost of finished articles is posted to the finished goods account, while the cost of semi-finished articles is kept as a balance on the semi-finished goods account.

- ***Direct material***. Direct material relates to all material that specifically forms part of the finished goods and can directly be calculated as part of the costs of these products.

  Examples are the wood used in the manufacture of furniture, the steel used in motor vehicle manufacturing, and the crude oil used in fuel refining. The ease with which material can be allocated to the final product is an important criterion in distinguishing between direct and indirect material.

  Thus, for example, the nails and screws used in the furniture industry, which do admittedly form part of the final product, may nevertheless be classified as indirect material in the determination of the cost price.

  Direct material costs usually include freight costs. Many businesses also regard storage and handling costs as part of the direct material costs.

- ***Direct labour***. The second element of the manufacturing costs is made up of the direct labour costs, in other words those labour costs that are directly incurred in changing raw materials into final products.

  Direct labour costs may be defined as the wages and related costs of skilled and/or unskilled labour that can be identified specifically with the final product(s) or that vary in direct proportion to the number of finished product(s) so that a direct causal relationship exists between final product(s) and labour costs.

Definition: Prime cost
The sum of the direct material costs and the direct labour costs is known as the prime cost of the final product(s).

- ***Indirect material***. The third element in the manufacturing costs is made up of the indirect material costs, in other words those material costs that are necessary for the completion of the final product, but of which the consumption is either so relatively small or so difficult to account for that it is economically unjustifiable to classify them as direct material costs and to allocate them to the final product(s).

  Material that forms part of the final product, such as screws, nails, washers and adhesives, falls into this category, as well as factory consumables such as lubricating oil and detergents. These cost types constitute part of the overhead costs.

- ***Indirect labour***. The fourth element in the manufacturing costs and the second component of the manufacturing overheads is the indirect labour.

  Indirect labour costs, as opposed to direct labour costs, may be defined as those labour costs that are not directly expended on the production of (a) final product(s), but must be incurred for related services.

  These cost types include the costs related to factory superintendents, foremen, supervisors, maintenance staff, inspection staff, personnel who repair defective work, experimental labour costs and the costs of factory assistants whose work is not directly associated with physical production.

- ***Other indirect costs***. All other production costs that cannot be classified as indirect material or indirect labour, may be included under the collective term other indirect costs.

  They form the fifth element in the manufacturing costs and the third component of the manufacturing overheads.

  These include the following cost types: rent, insurance, local and state taxes, depreciation, maintenance and repair costs, power, lighting, tools and other sundry production overheads. We may now deduce that the manufacturing overheads include all production costs, except direct material and direct labour costs.

4.2.1.2 Marketing and administrative costs

- ***Marketing costs***. Marketing costs (sales or distribution costs) are those costs which are incurred in the promotion of sales, storage of the completed products and transportation of the finished goods to the consumers.

  These costs are incurred from the point at which manufacturing costs end, in other words from the point in time when production is concluded and the product is ready for sale.

  The following cost components form part of the marketing costs: salaries of and commission to sales personnel, advertising costs, the cost of free samples, entertainment expenses of sales personnel, travelling expenses, rent, telephone, stationery and postage expenses of the sales department, outward freight costs and sundry marketing expenses.

- ***Administrative costs***. Administrative costs include those expenses which are incurred in directing, administrating and controlling the operating unit.

  The salaries of executives and office personnel, research costs, development costs, rent, legal expenses, bad debts, telephone expenses, stationery, postage expenses, cost of public relations, donations and other sundry administrative expenses usually fall in the category of administrative costs.

  Some of these cost items - for example the salaries of executive officials- are often regarded as partially manufacturing costs and partially marketing costs and are allocated as such.

  The composition of the total operating costs and its relationship to income are illustrated in **Figure 4.2** and **Figure 4.3**.

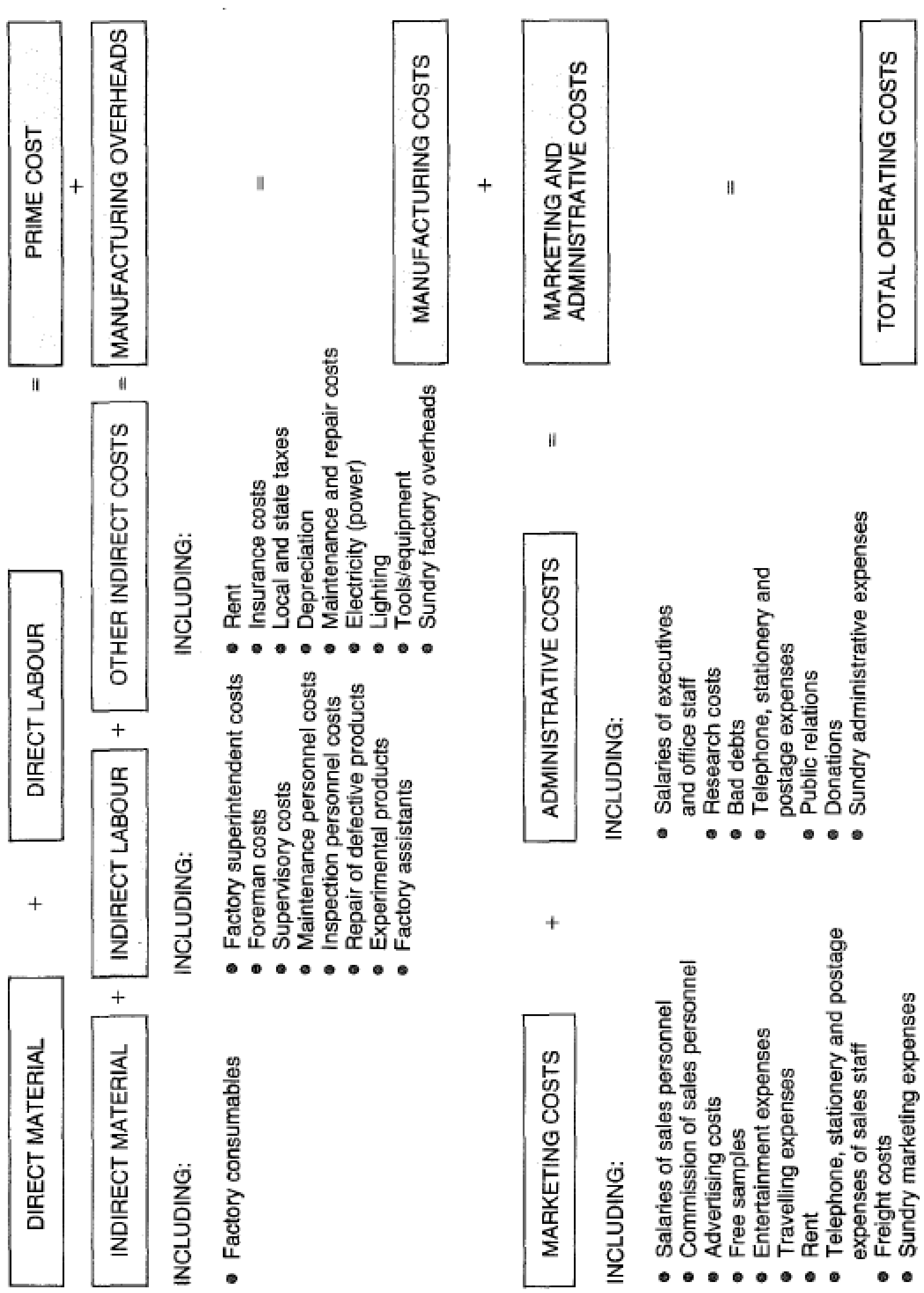


Figure 4.2 Composition of the total operating costs

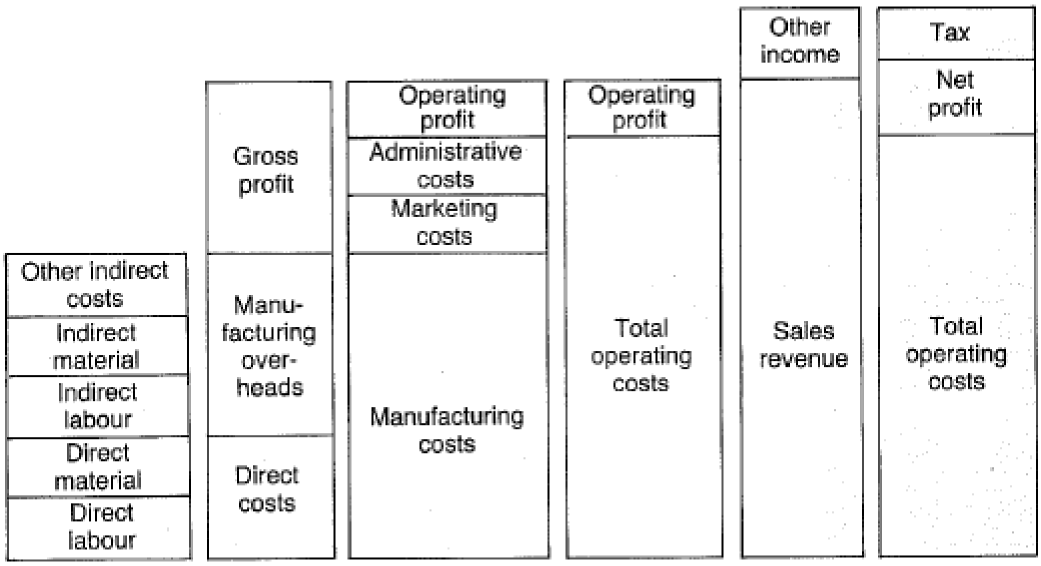


Figure 4.3 The relationship between total operating costs and income

4.2.2 Cost classification according to cost behaviour

In classifying operating costs according to behaviour, a distinction can be drawn between fixed, variable and semi-variable costs.

Those cost types which in totality tend to remain unchanged over the short term are known as fixed costs, while the cost types which in totality tend to change over the short term as the volume of production changes, are known as variable costs.

Semi-variable costs are an intermediate group that in totality tend to increase over the short term in a non-linear manner with increases in the volume of production.

Note:
The short term referred to, is that period during which the production volume is restricted by the available production capacity.

This condition is important, since all cost types usually tend to remain unchanged or fixed during a very short period (say one hour) and to vary during a very long period (say five years). The three cost types mentioned here and the total operating costs will be defined and graphically illustrated below.

4.2.2.1 Fixed costs

Fixed costs are costs that in totality tend to remain unchanged within certain limits regardless of an increase or decrease in the volume of production.

Examples of fixed costs are rent, rates on fixed property and insurance.

Figure 4.4a and **Figure 4.4b** illustrate total fixed costs and fixed costs per unit.

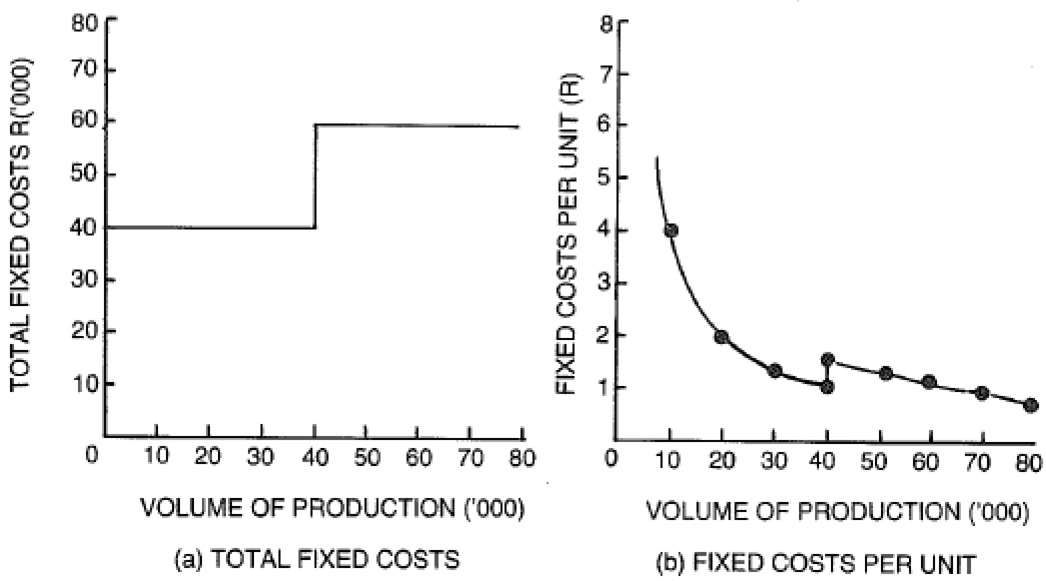


Figure 4.4 Total fixed costs and fixed costs per unit

Figure 4.4a shows that total fixed costs remain constant for a volume of production of 0 to 40 000. In the long term total fixed costs increase by a step of R20 000 to R60 000 for a volume of production of 40 000 to 80 000.

When total fixed costs amount to R40 000, the fixed cost of R4,00 per unit **Figure 4.4b** for a volume of production of 10 000 decreases to R1,00 per unit at a production volume of 40 000.

After fixed costs have risen to R60 000, the fixed cost per unit (for a production volume of 40 000 units) increases to R1,50 and then again decreases to 75c per unit at a production volume of 80 000.

It will now be clear why fixed costs are defined as costs which in totality tend to remain constant within certain limits. The fixed cost per unit (average fixed cost), however, decreases as the volume of production rises.

4.2.2.2 Variable costs

Variable costs are those cost types which in totality tend to increase proportionately over the short term as the volume of production increases.

Note:
Examples of variable costs are direct material and direct labour costs.

In general, variable costs have the following characteristics:

- Total variable costs often vary in direct proportion to changes in the volume of production.
- Variable costs per unit usually remain fairly constant in spite of changes in the volume of production.
- Variable costs can usually easily be allocated to a production department.

- A specific department head can usually be held responsible for variable costs.

Figure 4.5a and **Figure 4.5b** illustrate total variable costs and variable costs per unit.

Figure 4.5a shows that total variable costs increase in direct proportion to an increase in the volume of production if the average variable cost (variable cost per unit) (**Figure 4.5b**) remains constant.

The examples illustrate that if the average variable cost is kept constant at R1,00, the total variable costs will rise in direct proportion from 0 to R60 000 for a volume of production of from 0 to 60 000.

In practice, however, it is often found that total variable costs may increase in direct proportion or progressively or degressively, in respect of an increase in the volume of production.

4.2.2.3 Semi-variable costs

Semi-variable costs are those cost types which in totality increase over the short term in a non-linear manner as the volume of production increases.

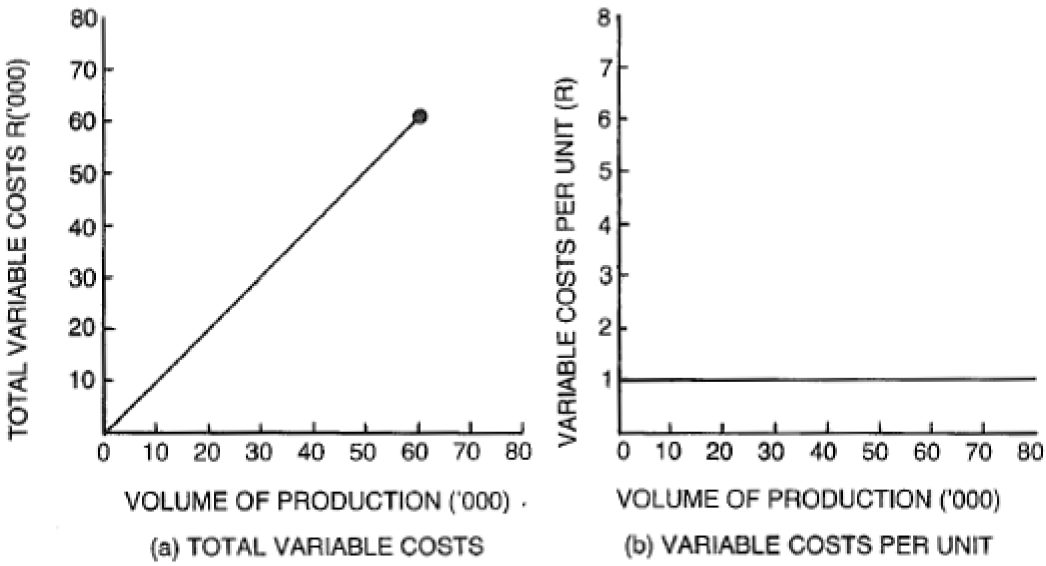


Figure 4.5 Total variable costs and variable costs per unit

Examples of semi-variable costs are indirect labour costs (supervision costs or costs of internal transport personnel), repair costs, the cost of consumables, protective clothing and tool costs. **Figure 4.6** illustrates the behaviour of semi-variable costs.

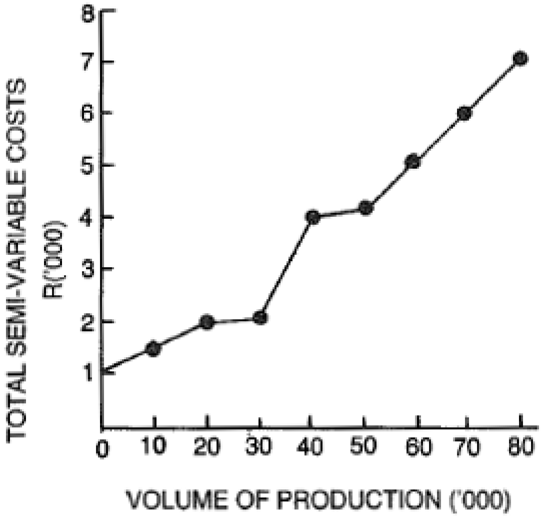


Figure 4.6 Semi-variable costs

4.2.2.4 Total costs

The total costs of a production unit's activities at a given volume of production are obtained by adding up the fixed, variable and semi-variable costs of the particular volume of production.

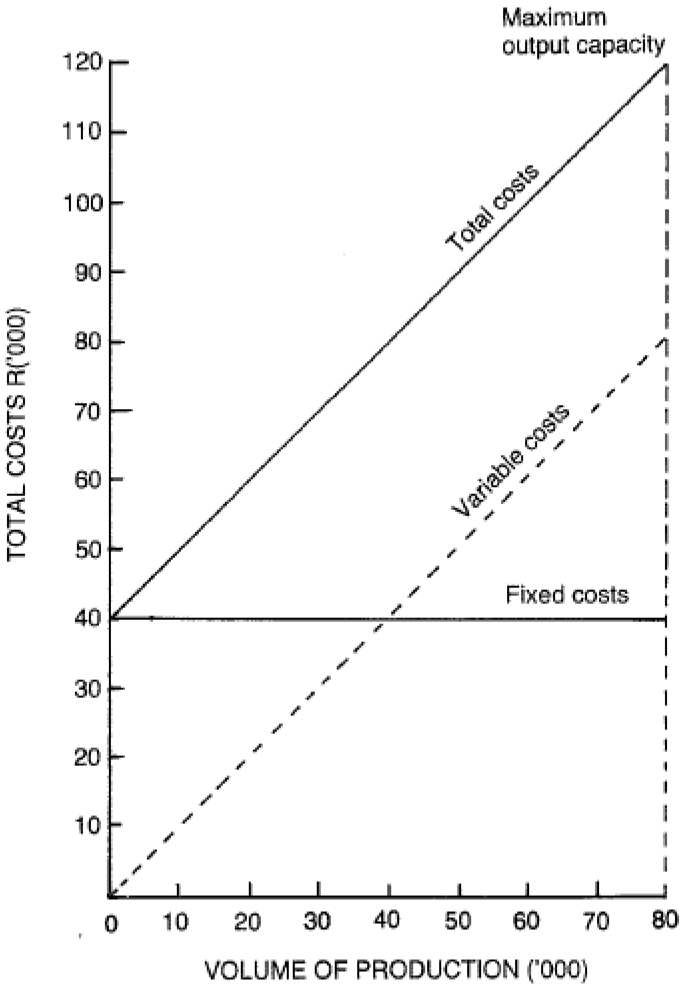


Figure 4.7 Composition of total costs

Figure 4.7 and **Figure 4.8** are graphical illustrations of (a) the composition of total costs and (b) the behaviour of average total costs or total cost per unit.

For the sake of clarity it has been assumed that semi-variable costs are divided into fixed and variable costs; that the total fixed costs amount to R40 000 at a production volume of 0 to 80 000; that the variable costs amount to R1,00 per unit; and that the total variable costs vary in direct proportion to an increase in the volume of production.

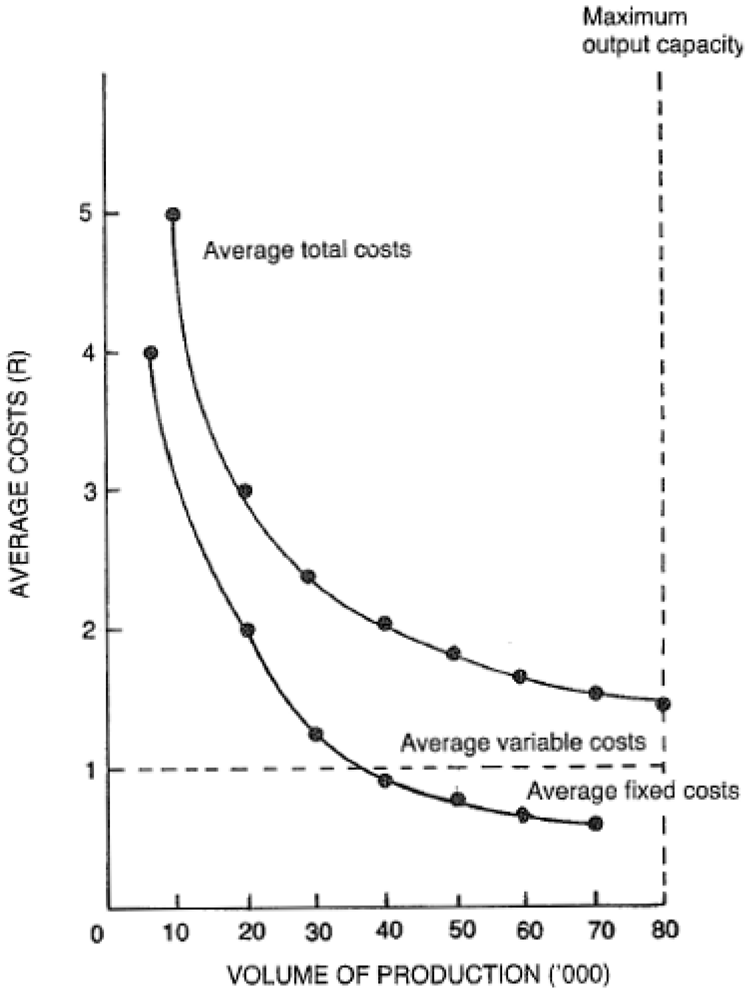


Figure 4.8 Behaviour of average total costs

4.2.3 Cost classification for decision-making purposes

When management has to make decisions with regard to future plans of action, it is essential that the costs (and the income) of the different alternatives should be taken into consideration.

For cost forecasting, management may either use historical cost information, suitably adapting it to the future, or with the aid of scientific methods make use of information within and outside the business to estimate future cost.

The latter technique is known as standard costing. Other decision-making aids are the opportunity and the incremental cost techniques. A brief discussion of historical, standard, opportunity and incremental costs follows.

4.2.3.1 Historical costs

By surveying the normal financial accounting of a firm it is a relatively simple matter to determine the historical costs, as well as their allocation.

A great danger in using historical cost data for decision-making purposes is, however, that they normally do not truly reflect the future behaviour of costs in a changing business environment.

Note:
Historical cost data should not be used per se as a norm for decision-making and planning purposes.

4.2.3.2 Standard costs

Since historical costs data become dated and therefore of little value for cost estimation purposes, business management ought to make use of more relevant cost data- by, for example, using some or other standard cost method.

Except in cases of long-term contractual agreements, the advance determination of standard costs is, however, only an approximate estimate of future business activities.

Thus the estimation of labour costs at R10 000 for a specific task for the following 18 months, requires a thorough knowledge of the future wage tariffs, future fringe benefits, future labour efficiency, future production volume and of the many other factors which are unknown at the time of decision making.

Note:
The determination of costs is of such great importance to business management that, in spite of inaccuracy, it must be performed.

According to the standard cost system, norms are predetermined according to the goals of the business. Sales goals are converted into production goals, namely how, what, where and when production must take place.

With the aid of work study, the labour and the machine time of tasks are scientifically calculated and the standard costs are estimated in advance. The use of standard cost data helps management to estimate future financial requirements and to prepare budgets accordingly.

Standard costs are, however, to a great extent dependent on the realism and accuracy of the various forecasts.

4.2.3.3 Opportunity costs

It would be incorrect to assert that only the 'visible costs' (including the historical cost price) represent the total cost of a product or service. Assume the cost of owning a vehicle must be calculated and the following data are applicable:

- cost price of the vehicle: R3 700,00 (including tax);
- annual depreciation: 20% if between 10 000 and 25 000 kilometres had been travelled and 30% if between 25 000 and 50 000 kilometres had been travelled;
- the expected distance that will be covered is 17 000 kilometres;
- insurance costs: R180,00;
- licence and registration fees: R25,00; deposit (say one-third of the purchase price): R1 233,00;
- monthly instalment: R100,00;
- cost of fuel: R923,00 (for the expected distance of 17 000 kilometres, and the expected fuel consumption of 10 litres/100 kilometres and the fuel costs of 54,30 cents per litre);
- tyre costs: R59,50 (,35 cents/kilometre for the expected 17 000 kilometres and with an expected tyre lifetime of 30 000 kilometres);
- expected maintenance costs: R275,00;
- expected sundry expenses (including traffic fines and parking expenses): R150,00.

When the above cost items are added up, they represent the total annual costs of the motor vehicle. To obtain the cost per kilometre, the total annual costs must be divided by the expected distance to be covered.

Note:
The monthly instalment cannot be deducted in full as a cost item, because part of it represents capital redemption and a part interest. The interest component in this case amounts to R188,00 per year.

Neither must the fact that a deposit of R1 233,00 was made, be forgotten.

When the owner of the vehicle decided to invest his savings in a motor vehicle, he utilised a scarce production factor -capital- in a specific way.

The owner could, however, have employed this scarce production factor in a number of different ways, for example to pay off the bond on his house, or to undertake an overseas trip, or as an interest earning investment.

When the motor vehicle owner decides to purchase the motor vehicle, he forfeits one or more of the other advantages he could have obtained from this capital. It is consequently logical and necessary that the cost of the forfeited advantages should be added to the visible costs of the vehicle.

If the owner had instead chosen an interest-earning investment and he could have earned 8% on his savings, the total annual costs of running the motor vehicle could be calculated as follows:

Fixed costs		
1 Depreciation	740,00	
2 Insurance	180,00	
3 Licence and registration	25,00	
4 Interest component of instalment	188,00	
5 Interest forfeited on deposit	98,64	
	R1 231,64	(7 ,245 cents/kilometre)
Variable costs		
6 Fuel costs	923,00	
7 Tyre costs	59,50	
8 Maintenance costs	275,00	
9 Sundry expenses1	50,00	
	R1 407,50	(8,279 cents/kilometre)
Total costs	R2 639,14	(15,524 cents/kilometre)

The interest component of the instalment (R188,00) and the interest forfeited on the fixed deposit (R98,64) together represent the opportunity costs which were lost on acquiring the motor vehicle (R286,64). This amount has to be added to the other visible costs to determine the total costs.

The production manager can in the same way determine the cost of installing a new machine.

In this instance the following factors may be taken into account:

- the purchase price
- expected lifetime
- resale value
- depreciation
- consumption of material
- labour requirements
- installation costs
- maintenance costs
- opportunity costs

The opportunity costs may in this case be determined according to the higher expected income if the machine had not been bought, and the capital had been used either to recruit more labourers or to increase inventory levels.

From the above it is now clear that the opportunity costs of a specific decision (or transaction) are equated to the cost of an alternative (or alternatives) forfeited in order to implement a specific decision.

Although the opportunity cost principle is an important management aid in decision making, it is in practice often difficult to know about all the possible alternatives and to express their advantages and disadvantages in monetary terms.

4.2.3.4 Incremental costs

In the classification of costs according to cost behaviour, it was indicated that the total costs of an undertaking's activities at a specific volume of production may be ascertained by adding up the fixed, variable and semi-variable costs for that particular volume of production.

It was also indicated that the average cost per unit can be determined by dividing the total costs of a certain volume of production by the actual production volume.

Note:
The calculation of average unit costs is of great value particularly in making decisions on production volume.

In addition to knowledge of the behaviour of average unit costs, it is essential that management should have knowledge of the incremental costs related to a particular decision.

Incremental costs may be defined as the additional (change in) total costs due to a particular decision. The expected change in total costs can thus be compared with the expected income related to the particular decision, for example the acceptance or refusal of an additional order at a certain price.

The incremental cost principle may also be applied in production decisions relating to capacity increases or in determining the level of mechanisation. In the latter case, for example, it is possible to judge whether the higher costs of more intensive mechanisation will be offset by the higher production output.

Incremental costs are also known as differential or additional costs and derive from the marginal cost concept of economic theory.

Now a few remarks on the marginal cost concept:

Marginal costs may be defined as the increase in cost that occurs when one additional unit is produced. The relationship between marginal costs, average fixed costs, average variable costs and average total costs is illustrated in **Figure 4.9**.

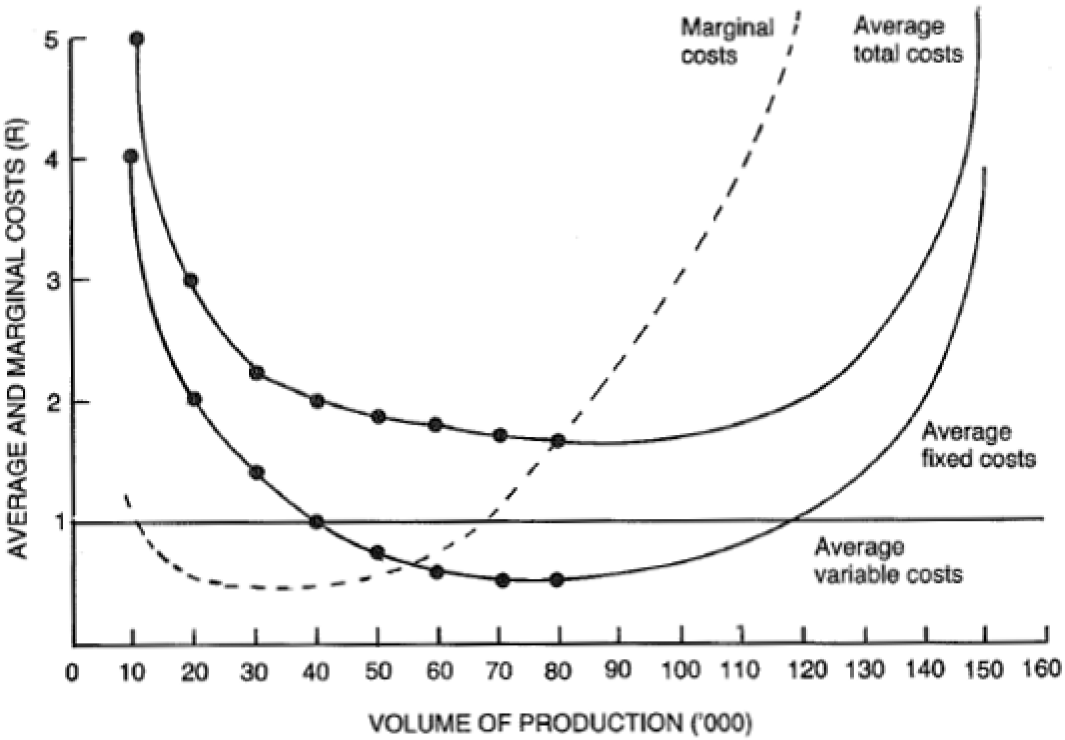


Figure 4.9 The relationship between marginal and average costs

In the above example the size of the production unit or production capacity, as determined by the fixed costs of durable production resources (land, buildings and machinery) remains unchanged, whilst the utilisation and costs of the variable production means (such as direct material and direct labour) change according to the production volume.

Since a variable production factor component is over the short term used in combination with a constant production factor component, the law of diminishing returns applies and both the marginal and the average output of the variable factor will first increase, but eventually again decline.

In contrast to this, the marginal cost, in other words the cost of every additional unit manufactured, will decline initially, but later rise quite rapidly.

The average total cost will also initially decline when the marginal cost is lower than the average total cost. The average total cost reaches its lowest point at a production volume of 80 000 units, where it equals the marginal cost, but again rises when the marginal cost is higher than the average total cost.

The point at which the average total cost is at its lowest, represents the most favourable relationship with regard to the fixed and variable costs for the relevant production capacity over the short term, and is known as the optimum scale of production or the short-term production optimum.

However, this short term production optimum is not necessarily the production volume which will yield the greatest profit, since profit also depends on the demand for and the price of the product being manufactured.

Where the optimum scale of production indicates the lowest unit cost in the short term and the size of the production unit (plant capacity) remains constant while the utilisation of other production means changes, the production capacity can, of course, be expanded over the long term.

In such a case, both the fixed and variable production factors will increase and consequently the law of diminishing returns cannot be used to determine the optimum size of the production unit or long-term production optimum.

When the existing production capacity is expanded over the long term, a U-shaped average production curve is once again obtained, as is shown in **Figure 4.10**.

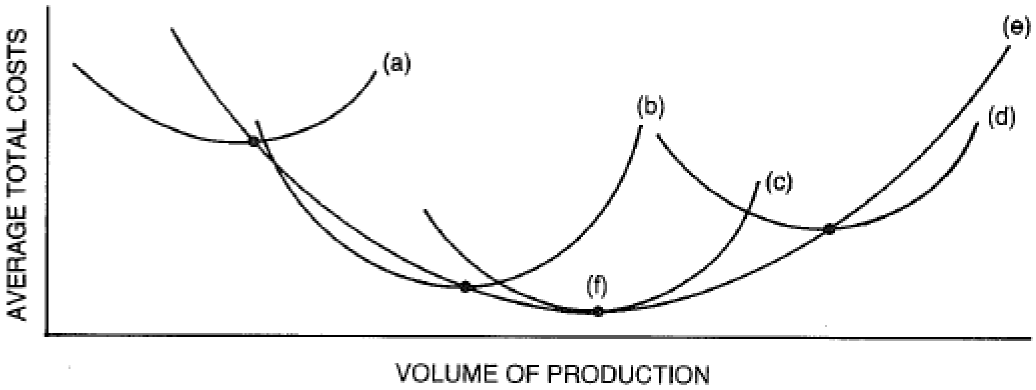


Figure 4.10 Average total costs and the long-term production optimum

Curves (a), (b), (c) and (d) are four short-term cost curves which indicate the behaviour of unit costs when the operating capacity is expanded over the long term.

Curve (e) (which passes through the lowest points of the short-term cost curves) is an indication of the trend in unit costs over the long term (long-term cost curve) and reaches its lowest point at point (f), which represents the optimum size of the production unit or long-term production optimum.

The declining section of the long-term cost curve may be ascribed, in particular, to more efficient technology, more efficient research, the obtaining of relatively cheaper capital, greater managerial efficiency, relatively cheaper purchases and marketing, and more efficient manufacturing.

Note:
Capacity savings cannot continue ad infinitum, however, and soon a point is reached where coordination problems in particular are responsible for an increase in average total costs.

The optimum size of the production unit as well as the optimum scale of production are two optima which merely indicate the lowest unit cost over the long and short terms.

The greatest profit, however, is made at the optimum size of the business unit.

Assume that a firm is forced to operate at a certain capacity (for instance, a capacity represented by the short-term cost curve (b) in **Figure 4.10**) and that a given price is received for finished products.

Figure 4.11 then shows the average total costs, marginal costs, average income, marginal income and optimum size of the business unit in a situation of perfect competition.

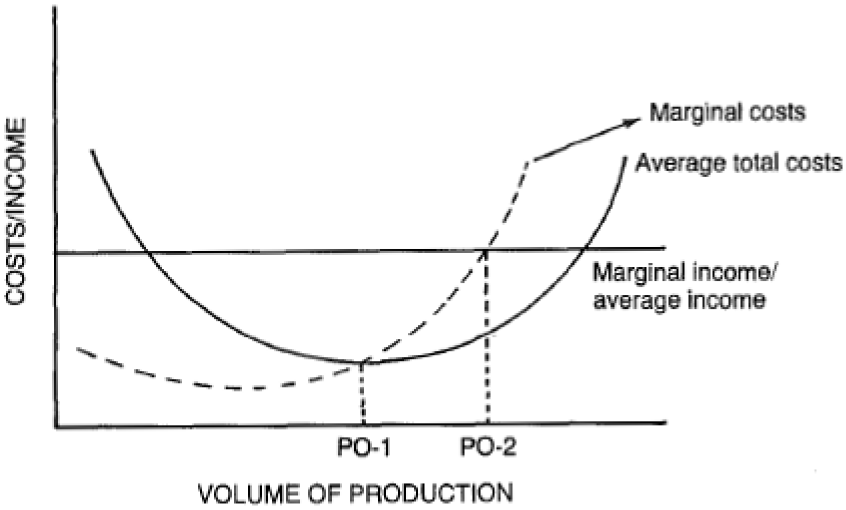


Figure 4.11 Determination of the optimum size of a business unit in a situation of perfect competition

In the above example the average income is identical to the marginal income because the same price is received for the product throughout. The average total cost reaches its lowest point at PO-1 (where the marginal costs is identical to the average total costs).

This point represents the optimum scale of production and although the difference between average total income and average total costs is greatest at this point, the largest profit is not realised here.

Every additional production unit after point PO-1 still yields a greater income than the costs associated with it, until point PO-2 is reached where the marginal income is equal to the marginal cost.

Note:
This volume of production yields the maximum profit and is known as the profitability optimum or optimum size of the business unit.

Whereas marginal cost indicates the increase in costs when only one additional unit is manufactured, incremental costs are an indication of the increase in total costs resulting from a specific decision.

Definition: Incremental costs
Incremental costs may thus be defined as those costs which must be incurred as a result of a specific decision, but which need not be incurred if the decision is not taken.

In this case, too, the expected increase in income should be compared with the expected increase in costs (including the increase in opportunity costs) before the decision can be taken.

Assume that the fixed costs for a production volume of 80 000 amount to R40 000, that the variable costs is R1,00 per unit and is directly proportional to the volume of production, 1 and that the selling price is R2,00 per article.

The profit may then be calculated as follows for a production volume of 80 000 units:

	R	R
Income from sales at R2 per unit		160 000
Fixed costs	40 000	
Total variable costs	80 000	120 000
Profit		R40 000

If a further 20 000 units can be sold and the fixed costs remain unchanged (this need not necessarily be the case), the differential or incremental costs of the 20 000 units is equal to the increase in variable costs, namely R20 000 in total or R1,00 per unit.

This additional costs due to an increase in production, is known as the differential cost price. When the total cost of the total production quantity (100 000 units) is calculated, it amounts to R40 000 plus R100 000 = R140 000 or R1,40 per unit.

This price is known as the integral cost price. The question now arises whether the differential cost price or the integral cost price should be used as a basis for the selling price of the additional 20 000 units.

The motorcar owner is confronted with the same problem when he has to decide, for instance, whether to make use of an aircraft or his motorcar to visit a certain place.

Assume that the place to be visited is situated 1 000 kilometres away from the car owner's home and that the air ticket costs R170,00.

The fixed costs of the car amount to 7,245 cents/kilometre and the variable costs to 8,279 cents/kilometre. If he argues that he already owns the car (in other words, the fixed costs remain constant), the increase in costs for the trip will amount to only 2 000 x 8,279 cents = R165,58.

If he however calculates the costs according to the integral method, they will amount to (7 ,245 + 8,279) + 2 000 = R310,48.

Did you know?
In theory as well as in practice much difference of opinion exists between the supporters of the differential cost price and the supporters of the integral cost price methods.

4.3 Uses of cost data

4.3.1 General

The most important uses of cost data may be summarised as follows:

- ***Preparation of final accounts***. Traditionally, cost and income data are recorded, classified and summarised in accordance with a set of prescribed accounting principles. The main aim of financial accounting is to reflect the financial position of an undertaking in such a way that various interest groups (shareholders, financial institutions, managers, the Receiver of Revenue, etc.) can assess the financial results for a certain period (income statement), as well as the position regarding assets and liabilities and the shareholder's interest (balance sheet).
- ***Profit planning***. Planning for the profit in a subsequent period demands a knowledge of the relationship between costs, volume and profit, as well as an insight into the way in which income will contribute towards fixed costs and profit. Accurate accounting is required for this.
- ***Inventory valuation***. The enterprise's financial position depens to a large extent on the relationship between assets and liabilities. The value of the goods in process and finished products must be determined accurately, as this can constitute a large component of the enterprise's assets. The manager must therefore use a cost system which will reflect the true value of the inventory.
- ***Cost control***. Cost control comprises the comparison of the actual achievement with some predetermined yardstick. A business budget is a valuable management instrument which can be used to compare the actual costs and income with the budgeted amounts. Any deviations from the expected standard should be carefully analysed. A budgeting system requires an orderly cost collecting system whereby costs can be grouped according to department or cost centre, and whereby the relevant department head or supervisor can be called upon to answer for any deviations.
- ***The determination of selling prices***. Successfully realising additional sales depends to a large extent on management's ability to predict costs and to base selling prices on this information. Although the availability of historical cost data is often essential in determining selling prices, the modern view holds that standard costs should be used for this purpose. Standard costs are predetermined costs based on experience, work study, expected future

material prices, expected manufacturing costs or on some combination of these factors. Standard cost calculations necessitate the determination of expedient sacrifices, as the undertaking cannot expect the consumer to pay for wastage.

- ***Production decisions***. Cost data aid management particularly in choosing between possible alternatives. It is, for example, essential that management should be informed about the behaviour of different cost types (fixed, variable, incremental and opportunity costs), in order to decide to what extent mechanisation should take place and to determine the optimum lot size, inventory size and ordering quantity. In all these cases management will look for the alternative with the lowest cost. In the following sections three important applications of cost data will be discussed more fully, namely break-even analysis, the allocation of costs to cost centres and cost units, and production budgets.

4.3.2 The determination of the connection between production volume, costs, income and profit

4.3.2.1 Break-even analysis

Break-even analysis is a graphic or algebraic representation of the relationship between the production volume, costs, income and profit in an organisation.

Note:
The break-even point is reached at that production volume where the income from sales equals total costs and no profit or loss is made (if it is assumed that all manufactured goods are sold).

Break-even analysis is a valuable instrument in the hands of business management and provides, amongst others, the following information:

- The influence on profit if the business raises or lowers its prices.
- To what extent profit will increase with an increase in the volume of production and sales.
- The influence of an increase in fixed costs (for instance, an expansion in capacity) on profit.
- An indication of the break-even volume - in other words the break-even point- and the safety margin with a larger production volume.
- The sales volume and the production capacity necessary for the 'planned profit'. Such planning will be done in cooperation with the marketing department, because the expected sales at a particular price depend on good market forecasting.

Break-even analysis is usually carried out with the aid of a break-even chart as represented by **Figure 4.12** and **Figure 4.13**. The horizontal axis represents the volume of production and sales in units, while the vertical axis indicates the cost and income in monetary values.

When the firm's future activities are planned in the short run, it is first necessary to classify the expected total costs according to fixed costs (assume they amount to R40 000 for a maximum production volume of 80 000 units) and variable costs (assume they amount to R1,00 per unit and increase in direct proportion to increases in the production volume).

If the volume of production is nil, the total costs will be R40 000 (the fixed cost component). With a larger volume of production, the total costs will consist of both the fixed and variable components up to a maximum of R40 000 + R80 000 at a production volume of 80 000 units.

Further information required is the firm's income from sales. Here too, realistic forecasts must be used. Assume that the firm consistently receives R2,00 per unit and that the total production is sold each time. The income from sales therefore also varies in direct proportion to the volume of production.

Note:
The relationship between the volume of production, costs, income and profit may now be either graphically illustrated, or expressed algebraically.

The break-even chart is illustrated in two different ways in **Figure 4.12** and **Figure 4.13**.

Figure 4.12, however, clearly indicates the extent to which a higher volume of sales will contribute to fixed costs and profit. In the first instance the desirability of a production-increase decision is usually assessed by whether the expected increase in income will cover the variable costs and, in the second instance, by the contribution that the income will make to the fixed costs and profit.

It should not be forgotten that break-even analysis is based on various assumptions, such as the following:

- The price at which a unit of the output is sold must remain constant regardless of the volume of production (volume of sales). This is why the total income curve is linear.
- Variable unit costs remain constant throughout. Consequently, the total variable costs vary in direct proportion to the volume of production and this curve is thus linear too.
- If more than one product is produced and sold, the ratio of the different products to the total output must consistently remain constant at the different volumes of production.
- It must be possible to distinguish between fixed and variable costs and the relationship between fixed and variable costs must remain constant throughout.
- The productivity performance must remain constant throughout.
- The total output must be sold.

In the short run (with a maximum production capacity of 80 000 units in the above example), the break-even chart is a simple yet efficient projection of the firm's total income, total costs, and profit and loss expectations at different volumes of production.

The following observations may also be made:
- Up to a volume of production of 40 000 units, costs exceed income and a loss is projected.
- At a production volume of 40 000 units, costs equal income and no profit is made, but neither is any loss incurred. This point is known as the breakeven point (break-even sales volume).
- At a volume of production of more than 40 000 units, a profit is made. Since the fixed cost component serves as leverage, income rises more than proportionately as the volume of production increases (operating leverage).

Instead of a graphical break-even analysis, the break-even point (according to volume of production or to sales value) or the projected profit or loss for different volumes of sales, may also be calculated algebraically.

To calculate the profit or loss made at different sales volumes, the fixed and variable costs are subtracted from the total income at the relevant volume of production.

The following equation is applicable:

P/L = SR - (FC + VC)

Where SR = Sales revenue - This is the number of units produced and sold, multiplied by the selling price

FC = Fixed costs

VC = Variable costs - This is the number of units produced and sold, multiplied by the variable cost per unit

P/L = Profit or loss

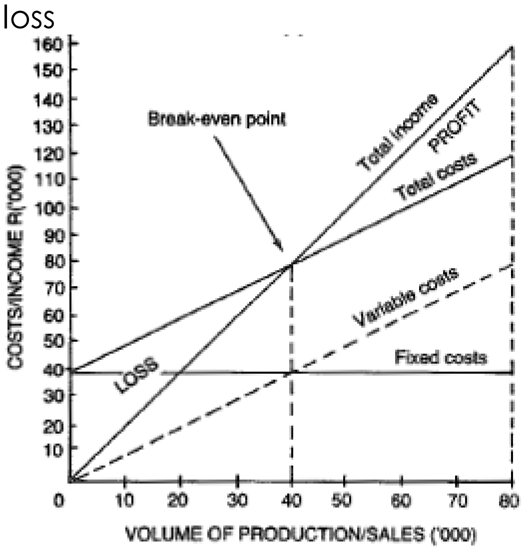


Figure 4.12 Break even chart

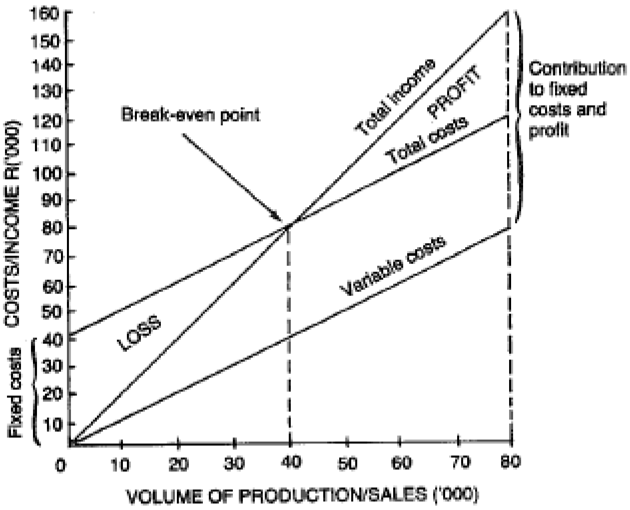


Figure 4.13 Break even chart

Should management want to determine the profit at a production volume of 60 000 units, this will be calculated as follows:

P/L = SR - (FC + VC)
= (60 000 X R2,00 per unit) - (R40 000 + (60 000 X R1,00 per unit)]
= R120 000 - (R40 000 + R60 000)
= R120 000 – R100 000
= R20 000 (profit)

If the break-even point is to be calculated, the following equation is applicable:

$$BEP = \frac{FC}{RPU - VCU}$$

Where BEP = Break-even point
FC = Fixed costs
RPU = Revenue per unit
VCU = Variable costs per unit

The break-even point for the above example is therefore:

$$BEP = \frac{FC}{RPU - VCU}$$

$$= \frac{R40\ 000}{R2/init - R1/unit}$$

$$BEP = \frac{R40\ 000}{R1/unit}$$

= 40 000 units

To calculate the monetary value of the break-even point, the break-even volume of production (40 000 units) need merely be multiplied by the selling price per unit (R2,00). For the above example the monetary value of the break-even point thus amounts to R80 000.

4.3.2.2 The advantages and shortcomings of break-even analysis

The most significant advantages of break-even analysis are that the calculations are quickly and easily done and that the interpretation of the results for production and profit-planning purposes is simple.

It must, however, be borne in mind that the technique has various shortcomings:

- The analysis is only as accurate as the data upon which it is based.
- Information may, for example, be obsolete, over-optimistic or over-pessimistic.
- The analysis is based on the assumption that any one of the variables (volume of production, costs or sales revenue) can change and that the remaining variables will react in direct proportion to the change. In practice, however, a linear correlation between these variables seldom exists.
- Since it is assumed that everything produced will be sold, it is accepted that there will be no change in inventory levels. The profit projection will therefore differ completely from that reflected by the income statement because the latter takes different inventory values into consideration.
- The analysis assumes static business circumstances. Actual practice is characterised by dynamic conditions with seasonal and cyclical changes.
- Since constant prices are assumed, the influence of a larger sales volume on the selling price is totally ignored. On the other hand, the price that is paid for the production factors (for example, stock) will also depend on the ordering quantity.
- It is often very difficult to classify costs into watertight fixed or variable components.

Note:
In spite of these serious shortcomings, break-even analysis is a valuable management aid - especially if its limitations are recognised and are taken into consideration.

Management may now also extrapolate different assumptions from the original to predict future results.

For this purpose a linear relationship or - if more applicable - non-linear relationships between the variables may be presupposed.

The following variables may influence the break-even point in different ways, for example:

- **Figure 4.14a** shows the influence of a higher selling price. A new sales revenue line (dotted line) with a steeper slope is obtained. If the costs remain unchanged, the break-even point will be reached at a smaller volume of production.

- **Figure 4.14b** shows the influence of an increase in fixed costs on the break-even point, for example when the production capacity is increased.

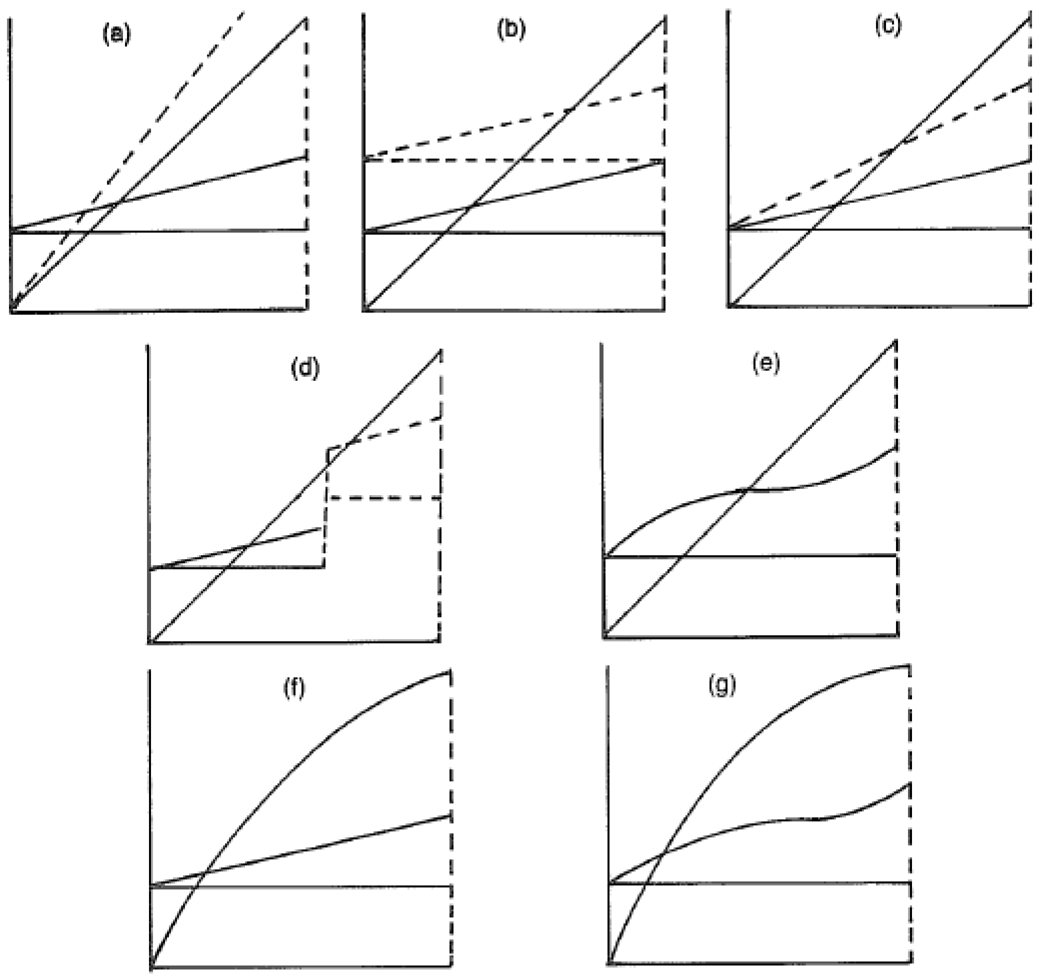


Figure 4.14 Influence of variables on the break-even point

- **Figure 4.14c** illustrates the influence of an increase in variable costs, for example, higher direct labour costs.

- If fixed costs have to be incurred after a certain volume of production has been reached, when an extra machine must for example be purchased, fixed costs may increase step-wise. This is illustrated in **Figure 4.14d**.

- **Figure 4.14e** illustrates a case where the variable costs increase progressively. This can happen when, for example, direct labour costs rise as a result of higher rates for overtime work.

- The case where a business can sell a greater quantity only if the selling price is lowered, is indicated by **Figure 4.14f.**

- **Figure 4.14g** shows a progressive increase in variable costs and a degressive increase in sales revenue.

4.3.3 Allocation of costs

Management must have knowledge of the relationship between the volume of production, costs and income in order to plan profit in advance.

Apart from planning the total profit, management will also want to accurately determine the cost and selling price of individual products, to accurately assess their profitability and to maintain efficient control over the cost of manufacturing the product.

The three most important objectives of cost accounting are to:

- determine the cost price of the finished products
- determine their profitability
- exercise control over their costs

In practice, however, it is in most cases impossible to accurately calculate the unit cost (and therefore the profit) in advance- except in the case of a sole proprietor manufacturing a single product under static business conditions- the reason being that the behaviour of costs is difficult to predict and their allocation is arbitrary.

Cost allocation is a concept used to describe the methods and techniques of allotting the costs of consumed production means to cost centres (departments or even individual machines) and cost units (final or completed products).

A variety of cost allocation techniques may be applied. Thus the cost allocation technique of a plant with a mass production structure would for example differ from that of an enterprise employing a piecework system.

Some cost allocation techniques are based on the principle that all costs must be allotted to finished products (absorption costing system), whereas in other systems the view is taken that only variable costs must be allotted to cost units, whilst the total fixed costs must be transferred to the income statement of the appropriate accounting period (marginal costing system).

4.3.3.1 The allocation of costs to cost centres and units

A cost centre is a place or centre in a business where costs originate as a result of the decisions of the person responsible for that cost centre (eg a foreman). Three types of cost centres are normally distinguished, namely auxiliary, service and major cost centres.

Did you know?
A cost centre which is controlled by a responsible person, is known as a responsibility centre. Cost centres are generally the same as responsibility centres. It may, however, happen that a cost centre is designed only for the administrative allocation of costs and then such a cost centre cannot be classified as a responsibility centre.

- An auxiliary cost centre may be regarded as an administrative cost centre, for it cannot be identified as a tangible department, and is merely used to simplify the allocation of costs. In a manufacturing industry, the accommodation space (whether manufacturing or office space) is classified as an auxiliary cost centre, in which costs such as rent, depreciation of the building and wages for the cleaning of the building are added up before being transferred to cost units.
- A service cost centre is a department which does not directly participate in the manufacturing process, but which renders services to the departments directly concerned with the manufacture of the product. Examples of service cost centres are the production planning and production control department, the work study department and the maintenance department.
- A major cost centre is a department or workshop which participates directly in the manufacture of finished products. These departments are usually under the control of the person responsible for the costs of the production means used/consumed there. In the printing industry, for example, the setting, printing and binding departments may be classified as major cost centres. A single machine may at times be classified as a major cost centre - for example, when a newspaper printing works employs two printing presses, each printing press may be regarded as a cost centre.

Administratively the allocation of costs to cost centres and cost units takes place step by step:

(a) With the main budget as starting point, the total costs are classified as follows:
  - Direct material costs
  - Direct labour costs
  - Indirect material costs
  - Indirect labour costs
  - Other indirect overheads
  - Administrative costs
  - Marketing costs.

(b) The direct material costs and direct labour costs are allocated directly to cost units.
(c) The indirect material costs, indirect labour costs and other indirect overheads are apportioned to the relevant auxiliary, service and major cost centres.
(d) The administrative costs are then apportioned to the appropriate auxiliary, service and major cost centres according to some particular apportioning key.
(e) The marketing costs are usually allocated to a separate major cost centre.

Note:
The administrative and marketing costs are often transferred directly to the income statement. Another method entails classifying the

	administrative costs into 'other indirect manufacturing costs' and 'marketing costs'. In this case only the marketing costs are transferred directly to the income statement.

(f) The total allocated cost of the various auxiliary and service cost centres are apportioned to the various major cost centres according to a particular apportioning key.
(g) After the total auxiliary and service costs have been apportioned to the appropriate major cost centres, the totals of the major cost centres are individually transferred to the cost units. In most cases the apportioning key used takes into account the relationship between costs and cost units. Manufacturing costs can, for example, be distributed to cost units according to one of the following criteria: material costs, material units, labour costs, labour hours, machine hours, product units or manufacturing space used. Marketing costs can be allotted according to sales volume (in money or in units), the number of sales representatives acting for the specific cost unit, the size of the sales area, the number of sales points, etc.

Assume a business has the following cost centres: an auxiliary cost centre, a service cost centre, and three major cost centres, namely two manufacturing cost centres (A and B) and a marketing cost centre (C). Assume further that two products are manufactured (cost units M and N). The allocation of costs to cost units is illustrated in **Figure 4.16**.

4.3.3.2 Cost accounting systems

A cost accounting system is a formal system whereby costs are accumulated and recorded in accordance with the purpose for which the cost information is needed.

Depending on the production structure of the business, a distinction is normally drawn between two cost accounting systems, namely a job costing system (when discrete products are manufactured) and a process costing system (when flow production takes place).

Figure 4.15 illustrates how either of these two systems can be applied according to either the absorption costing technique or marginal costing technique.

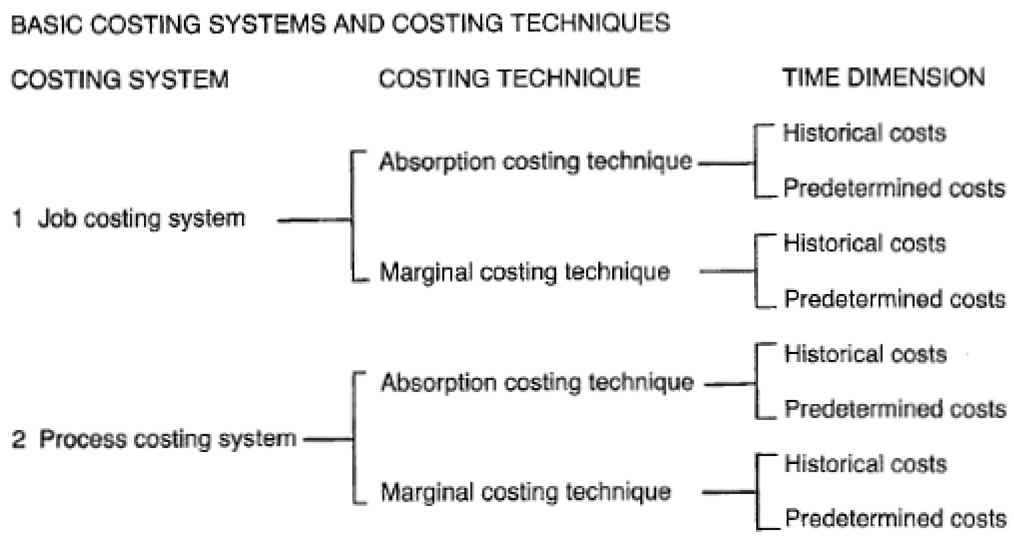


Figure 4.15 Basic costing systems and costing techniques

(a) Job costing system. A job costing system is applied particularly in a production unit where the work differs from task to task according to the requirements of the purchaser. Each task is therefore a 'cost subject' which must carry its rightful share of the total costs. Special characteristics of a job costing system are the large amount of administrative work involved in gathering the information on each task and the phenomenon that the flow of costs does not follow a fixed pattern, but varies from task to task. This system is used particularly by building contractors, civil engineers, foundry works, furniture manufacturers, motor repair shops, etc.

(b) Process costing system. In cases where large quantities of the same product are manufactured over a relatively long period and where it is impossible, as in the case of a job costing system, to identify each individual task or product, a process costing system can be used. Examples of such production units are soap, toothpaste and shoe manufacturing, beer breweries, chemical industries, oil refineries, etc.

Because of administrative advantages and for the sake of uniform price determination, it is necessary to determine the cost per successive process in these production units.

The costs of raw materials, labour and overheads are thus collected chronologically for each process/section/department and allotted on the basis of the quantity of products processed by each department.

The products are then carried over to the next process at a specific unit cost until they have been completed and the total unit costs of the final product have been determined.

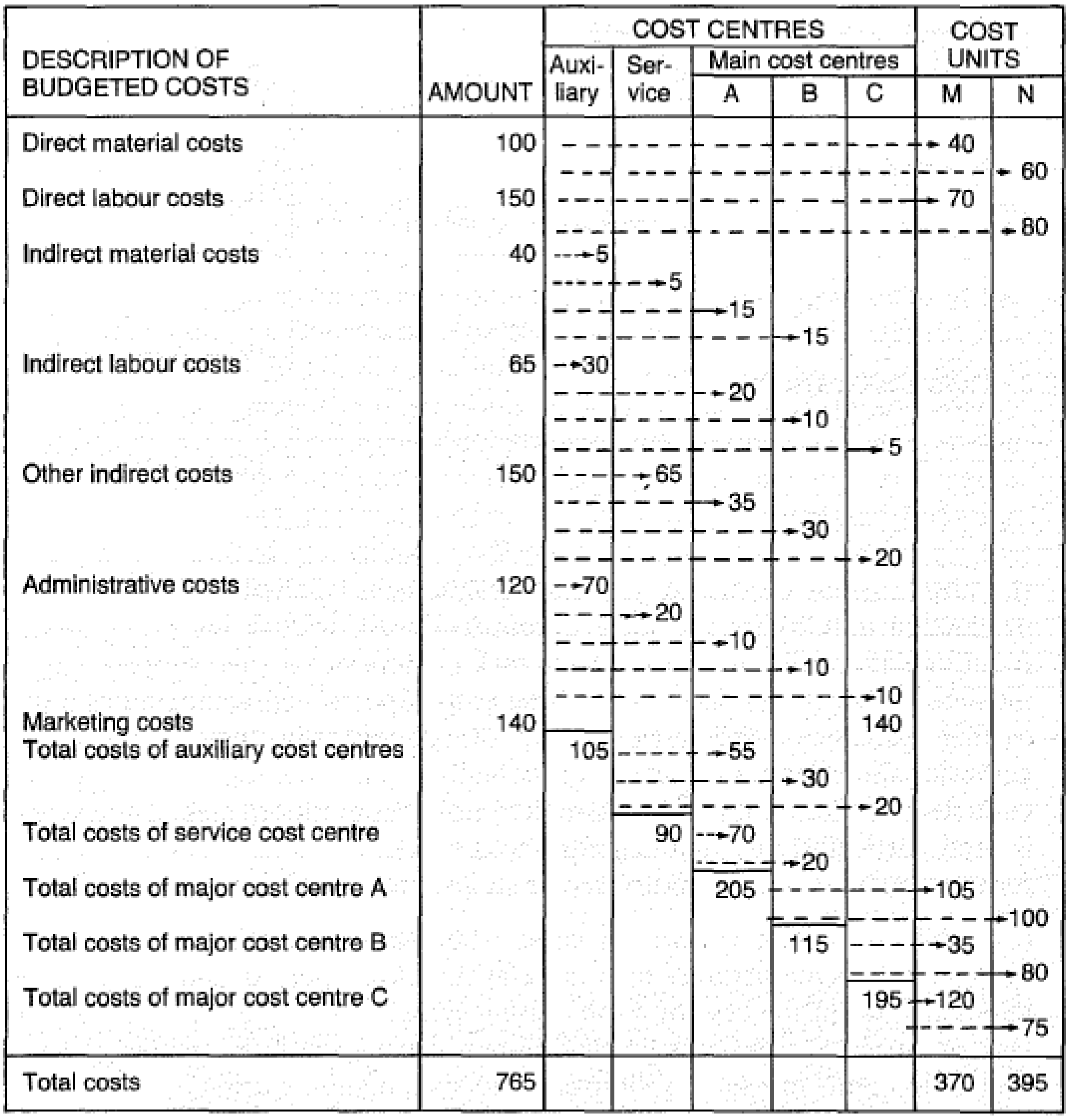


Figure 4.16 Sample cost allocation sheet

4.3.3.3 Absorption and marginal costing techniques

(a) Absorption costing. If all costs (fixed and variable) are allotted to cost centres and cost units (as illustrated in the example of cost allocation), it is referred to as absorption or integral costing. The basic point of departure here is that the finished products must absorb their rightful share of all costs incurred in their manufacture. A characteristic feature of an absorption system is consequently that the unit costs change in inverse proportion to the volume of production.

The most important disadvantages of absorption costing are that:

- the danger exists that too many or too few costs may be absorbed over a certain period, depending on the differences that might exist between the planned operating capacity and the actual production; and

- the causal relationship between fixed costs and cost units is in many cases difficult to determine. The arbitrary allotment of fixed costs to cost centres and cost units may lead to incorrect business decisions.

(b) Marginal costing. According to the marginal or differential costing ·technique, the fixed and the variable costs are determined separately. Only the variable costs are charged to cost units, while the fixed costs are written off in full (in the income statement) against the income of the accounting period during which they had been incurred. Strictly speaking, marginal costing is not a costing method, but rather a method for evaluating the desirability of a transaction. The cost price is in this instance merely a partial cost price (consisting of only the variable costs), as opposed to the integral cost price used in the absorption costing system.

The most important disadvantages of this system are the following:

- It confuses the capital, asset and profit situation because fixed costs are not included in the inventory valuation.
- When selling prices are compared with the marginal costs, only the contribution of units sold to the fixed costs and profits is shown and not what the real transaction profit is. This may lead to a defective price policy.
- The classification of costs as fixed and variable demands a considerable amount of administrative effort.

The most important advantages of marginal costing as compared with absorption costing may be summarised as follows:

- The technique is easy to apply, as fixed costs are taken into account per period instead of per cost unit.
- The system is easily understood at all levels of management.
- Since the fixed costs are calculated in total, the over or under recovery of fixed costs is eliminated.
- It is a very useful technique in evaluating incidental sales transactions, make-or-buy decisions, calculating the optimum batch size, determining the optimum inventory size, etc.
- The profit of a period is determined by the sales and not by production.

(c) Illustration of absorption and marginal costing. Before the absorption and marginal costing techniques can be illustrated by the use of a numerical example, it is necessary to briefly discuss the concept of normal production capacity (normal plant capacity). If the fixed costs for a certain production capacity amount to R20 000, the variable costs per unit are R6,00 and 5 000 units are manufactured, it can be assumed that the total unit costs would be R10. If the demand for a product in a following phase declines and only 4 000 units are produced, it can be reasoned (wrongly) that the total unit costs consist of R5,00 in fixed costs and R6,00 in variable costs- in other words a total of R11. In this case there was, however, an under utilisation loss which does, of course, not constitute part of the product cost. It is therefore essential that management should be familiar with the normal production capacity in order to separate costs from under utilisation losses. The normal production capacity is that production capacity which can normally be attained by the plant, although it is usually smaller than the maximum production capacity because allowance has to be made for contingencies.

Assume the normal production capacity of a plant is estimated at 5 000 units per annum. Assume further that the variable costs per unit are made up of material R3,00; direct labour R2,00; and indirect costs (factory overheads)

		First year	Second year	Third year
Sales	(R20 per unit)	R40 000	R100 000	R160 000
Direct material	(R3 per unit)	12 000	18 000	15 000
Direct labour	(R2 per unit)	8 000	12 000	10 000
Factory overheads	(R1 per unit)	4 000	6 000	5 000
Fixed factory overheads	(R4 per unit)	16 000	24 000	20 000
Cost of manufactured goods		40 000	60 000	50 000
Opening stock	(R10 per unit)	—	20 000	30 000
Cost of goods available for sale		40 000	80 000	80 000
Closing stock	(R10 per unit)	20 000	30 000	—
Cost of goods sold		20 000	50 000	80 000
Under/over absorption of fixed factory overheads		4 000	(4 000)	—
Actual costs of goods sold		24 000	46 000	80 000
Gross profit/loss on sales		16 000	54 000	80 000
Marketing and administrative costs		5 000	5 000	5 000
NET PROFIT/LOSS FOR PERIOD		11 000	49 000	75 000

Figure 4.17 Illustration of the absorption costing technique

R1,00 - thus a total of R6,00. 1 The fixed costs at normal production capacity amount to R20 000 or R4,00 per unit. The number of units produced per period is used in the allotment of fixed costs. The selling price per unit is R20,00, and marketing and administrative costs amount to R5 000 a year.

The actual production, sales and stock position for three successive years was as follows:

	First year	Second year	Third year
Opening stock (units)	-	2 000	3 000
Production (units)	4 000	6 000	5 000
Sales (units)	2 000	5 000	8 000
Closing stock (units)	2 000	3 000	-

Note:
It should be mentioned that in the example no distinction is made between standard and actual labour, material and overhead costs. It is therefore assumed that no wastage occurred. If wastage does occur, all losses should be transferred directly to the income statement. This remark applies to both the absorption and the marginal costing systems.

		First year	Second year	Third year
Sales	(R20 per unit)	R40 000	R100 000	R160 000
Direct material	(R3 per unit)	12 000	18 000	15 000
Direct labour	(R2 per unit)	8 000	12 000	10 000
Factory overheads	(R1 per unit)	4 000	6 000	5 000
Variable costs of manufactured goods		24 000	36 000	30 000
Opening stock	(R6 per unit)	—	12 000	18 000
Variable costs of goods available for sale		24 000	48 000	48 000
Closing stock	(R6 per unit)	12 000	18 000	—
Variable cost of goods sold		12 000	30 000	48 000
Gross marginal contribution		28 000	70 000	112 000
Less: Fixed factory overheads (per annum)		20 000	20 000	20 000
Less: Marketing and administrative costs		5 000	5 000	5 000
Total fixed costs		25 000	25 000	25 000
TOTAL PROFIT/LOSS FOR PERIOD		3 000	45 000	87 000

Figure 4.18 Illustration of the marginal costing technique

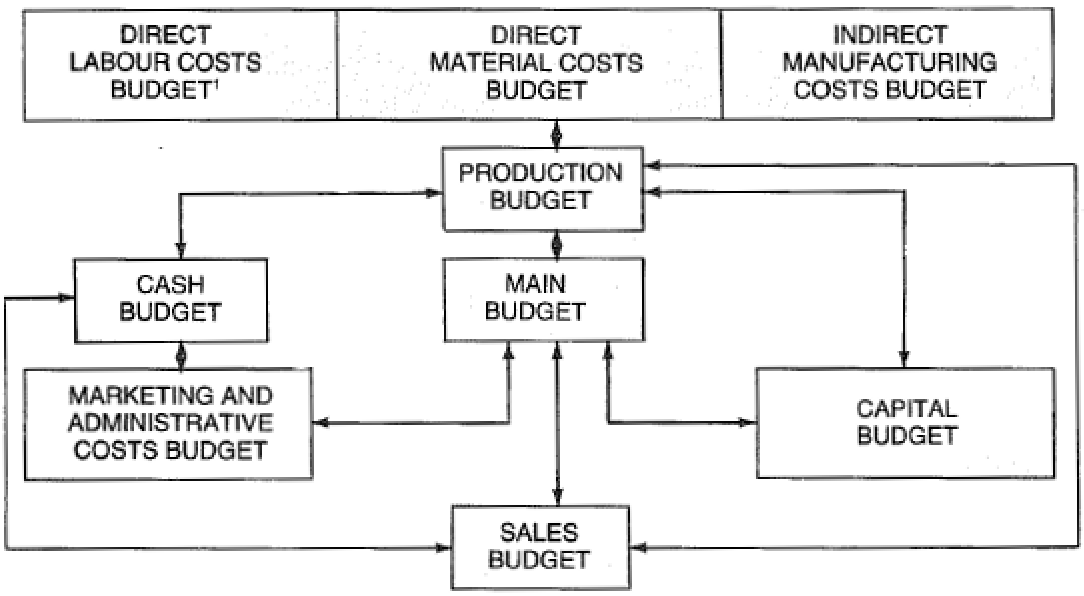


Figure 4.19 Composition of the main budget

4.3.4 Cost control

The aim of cost control is to compare actual performance with some predetermined criterion. One of the most important instruments which management uses to plan costs in advance and exercise control over them, is the business budget.

The main budget is normally compiled from a number of subsidiary budgets, using the sales budget as a starting point in the process:

- The production budget is based on the sales budget which in turn is based on the sales forecast.
- The direct labour, direct material and indirect manufacturing cost budgets are prepared according to one of the standard costing techniques. With the aid of work study, the standard labour time and the standard material consumption are determined beforehand, whilst the indirect manufacturing costs are budgeted for according to adapted historical cost data and the expected level of business activity.

Note:
Although it is common practice in many businesses to refer to the labour costs budget, it would be scientifically more correct to speak of the labour expense budget, in order to show that the budget also provides for expected wastage (which is always present). This remark is also applicable to the material costs, the indirect manufacturing costs, the marketing costs and the administrative costs budgets.

- The marketing and administrative cost budgets are prepared by the heads of the marketing and administrative departments respectively. The expected level of business activity and sales volume will influence these budgets to a large extent.
- The cash (or liquidity) and capital budgets are the responsibility of the financial department. The former plans the incoming and outgoing cash flow during the budget period, whilst in the capital budget the acquisition and application of long-term capital funds are predicted.

The different subsidiary budgets are then combined in the main budget by a responsible official. A budget that remains unchanged, is known as a fixed budget, whilst a variable budget estimates the position in changing circumstances.

Budgeting is of great value not only because it involves persons at various business levels (from top management to supervisory level) in business planning, coordination of activities, realisation of business goals and control of activities, but also because it encourages them to meet or even to exceed predetermined standards.

Control takes place in consecutive stages, namely:

- the compilation of standards
- collecting of data
- comparison of data with set standards
- critical analysis of performance and deviations
- adoption of corrective measures

Activity 4.1

1. Write an essay on cost data for production decision-making purposes.
2. Write comprehensive notes on the different ways in which costs can be classified.
3. Discuss why it is so important that management determine the relationship between volume of production, cost, income and profit.
4. Explain in detail how costs are allocated to cost centres and cost units. Illustrate your answer with an appropriate diagram.
5. Discuss the cost concept and the different cost approaches.
6. Discuss the classification of costs according to business activities.
7. Discuss the classification of costs according to the behaviour of costs.
8. Write notes on historical and standard costs.
9. What do you understand by the concept of opportunity costs? Illustrate your answer with an appropriate example.
10. Discuss (one or more of) the following concepts: marginal cost, optimum scale of production, the optimum size of a production unit, the optimum size of a business unit and incremental cost.
11. Write brief notes on the different uses of cost data.
12. Briefly discuss the different cost accounting systems and support your answer with an appropriate diagram.
13. Discuss the differences between the absorption and the marginal costing systems.
14. Write notes on cost control.
15. Answer the true/false questions on: Cost data for production decision making purposes.
16. Draw the various diagrams/graphs appearing in the text.

Activity 4.2

ANSWER THE FOLLOWING TRUE (T)/FALSE (F) QUESTIONS

1. Whereas financial accounting traditionally seeks to report on historical events, one of the most important aims of management accounting is to analyse financial data for decision-making and control purposes.
2. With the normative approach all sacrifices are regarded as costs, but only expedient costs are sacrifices.
3. Materials which form part of the final product, such as screws, nails, washers and adhesives, are usually classified as direct material.

4. Manufacturing overheads consist of indirect material, indirect labour and other indirect costs.
5. Average fixed costs usually decline as the volume of production increases.
6. Variable unit costs usually remain relatively constant despite fluctuations in production volume.
7. Examples of semi-variable costs are indirect labour costs, the costs of repairs and the costs of consumable goods.
8. Historical costs can usually be used as a norm for decision-making and planning purposes.
9. The opportunity costs of a specific decision (or transaction) are equated to the cost of (an) alternative(s) sacrificed in order to implement a decision.
10. Incremental costs may be defined as the additional (change in) fixed costs due to a particular decision.
11. Marginal costs may be defined as the increase in costs if more than one additional unit is produced.
12. The point where the average total costs is the lowest, represents the most favourable relationship in respect of the fixed and variable costs for the specific production capacity in the short term and is known as the optimum size of the production unit.
13. The break-even point is that production volume where income is equal to fixed costs and where no profit or loss is made.
14. The desirability of a production-increase decision is, in the first place, usually assessed by whether the expected increase in income will cover the variable costs and secondly by the contribution of income to fixed costs and profit.
15. It is possible that a cost centre may be created merely for the administrative allocation of costs. In such a case the centre cannot be classified as a responsibility centre.
16. A service cost centre is a department that participates directly in the manufacturing process.
17. Marketing costs are usually allocated to a separate cost centre.
18. When all costs (fixed and variable) are allocated to cost centres and cost units, it is referred to as marginal costing.
19. According to the absorption or marginal costing technique, fixed and variable costs are calculated separately. Only variable costs are used in calculating the cost price, while total fixed costs are subtracted from the income.
20. The sales budget is usually based on the production budget.

Self-Check

I am able to:	Yes	No
• Describe the purpose of process costing		
• Describe with simple example the following elements		
o unit costs		

o man hours costs		
o machine run costs		
o overhead costs		
• Describe how each of the inputs listed affect process costing		
• Describe the steps involved in process costing		
• Calculate the costing of a process given the following details		
o stock balances		
o unit cost		
o machine/man hours		
o overhead costs		
• Define product costing		
• Describe the elements that contribute to the cost of a product costing		
o material		
o overheads		
o labour		
• Calculate the costing of a product given the following information		
o raw materials used		
o man hours		
o overhead costs		
• Define budgeting		
• Define cash flow projections		
• Define variance control		
• Describe each of the following types of variances		
o time variances		
o rate variances		
o material variances		
• Describe the purpose of variance control		
• Describe the cost of quality in terms of conformance and non-conformance to specifications		
• Explain, using examples, the difference between operating budget and capital budget		
• Describe three benefits of budgeting		
• Calculate the efficiency variances of each of the following given the planned and actual information for each element		
o material		
o labour		
o machine hours		
• Describe what is meant by standard costing		
• Describe with simple examples how standard capacity is established in a manufacturing environment		
• Calculate closing work in progress, given the following		
o opening work in progress		
o production data		

o unit cost		
If you have answered 'no' to any of the outcomes listed above, then speak to your facilitator for guidance and further development.		

Past Examination Papers

higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

November 2014

NATIONAL CERTIFICATE

PRODUCTION AND QUALITY CONTROL N5

(8140055)

25 November (Y-Paper)
13:00 – 16:00

This question paper consists of 7 pages.

TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Calculations must be clearly shown and be rounded off to TWO decimal places.
5. RULE OFF on completion of each question.
6. Write neatly and legibly

QUESTION 1

Various options are given as possible answers to the following questions. Choose the answer and write only the letter (A-D) next to the question number (1.1-1.14) in the ANSWER BOOK.

1.1 The resource requirements plan is to the production plan what the rough cut capacity plan is to the ...

A master production schedule.
B material requirements plan.
C shop floor control.
D capacity requirements plan.

1.2 Which ONE of the following is a medium-term capacity plan?

A Rough cut capacity plan
B Capacity requirements plan
C Input output control
D Resource requirements plan

1.3 Having insufficient capacity is most likely to result in …

A higher work-in progress
B lower customer service
C frustrated workers
D All of the above mentioned

1.4 Productivity can be defined as ...
A production rate
B throughput
C output over input
D efficiency and effectiveness

1.5 If the utilisation and efficiency of a department are both 85%, the productivity of the department ...

A will also be 85%
B will be more than 85%
C will be less than 85%
D cannot be calculated without having more information

1.6 Assume that during a 10 hour shift, a work centre is idle for TWO hours and during the other EIGHT hours completes an operation which has a standard time of SEVEN hours.

The utilisation of that work centre is ...

A 20%
B 80%

C 70%
D 87,5%

1.7 The capacity of a manufacturing factory is 100 car tyres per hour. If the monthly production plan is for 40 000 car tyres and the manufacturing waste factor is 5%, the load on the factory for the month will be …. Hours.

A 400
B 420
C 440
D 460

1.8 An advantage of a make-to-order manufacturing policy is ...

A better quality
B greater stakeholder satisfaction
C faster delivery to customers
D lower inventory costs

1.9 A work centre has an actual input of 70 hours per week over a four week period. The actual outputs over this period were 65, 67, 71 and 73 hours. The work-in-progress (WIP) at the end of the four week period is ... hours.

A 2
B 4
C 6
D 3

1.10 Which ONE of the following provides the primary input to production activity control?

A Customer orders
B The production schedule
C Manufacturing orders
D The master production schedule

1.11 The time taken to get a machine ready for production is known as …. time.

A set up time
B run time
C lead time
D external

1.12 The main purpose of the ABC inventory classification system is to …

A list stock items alphabetically
B focus attention on the most valuable stock items
C release the most expensive stock items first
D prioritise the ordering of stock

1.13 A point-of-use storage system would probably have the advantage of ...

A improving quality
B reducing lead times
C reducing stock losses
D lowering manufacturing costs

1.14 The term expediting is used to describe ...
A speeding up production to meet delivery dates
B slowing down production to prevent bottlenecks
C returning damaged raw materials to a supplier
D re-routing jobs to avoid bottlenecks

(14 x 2) **[28]**

QUESTION 2

2.1 A work centre operates for 15 hours per day, SIX days a week with a utilisation of 80%. On average, the work centre takes 6% longer to complete orders than the standard time. (5)

What is the rated capacity of the work centre?

2.2 Complete the following capacity report for a work centre (show details in brackets) (10)

	WEEK 1	**WEEK 2**	**WEEK 3**	**WEEK 4**
Standard hours required	102	95	92	90
Available hours	96	96	96	88
Daily excess (deficit) in hours				
Cumulative excess (deficit) in hours				

Is this work centre balanced over the FOUR weeks?
Explain your answer.

2.3 Describe the FIVE ways in which capacity and load can be balanced. (10)
Also, state whether each is a capacity response or a load response

[25]

QUESTION 3

3.1 List FOUR elements of lead time that are found within manufacturing companies. (4)

3.2 Explain what is meant by a make-to-order manufacturing policy. (4)
Give ONE advantage and ONE disadvantage of this approach.

3.3 A project is planned as follows: (10)

Prepare a Gantt Chart to determine the overall length of the project.

3.4 Name THREE performance measurements that are important to ensure control on the factory floor. (6)

In each case, describe a consequence of not meeting performance standards

[24]

QUESTION 4

4.1 Assume that the annual demand for a component is 5 000 units. The ordering cost is R27 per unit, the inventory holding cost is 30% and the unit costs is R1 000. (5)

Calculate the economic order quantity (EOQ) using the following formula:
$EOQ = \sqrt{2DS/IC})$

4.2 Describe any FIVE precautions that can be taken to ensure the physical control of inventory. (5)

4.3 Name the FIVE aspects of a business that inventory management seeks to optimise. (5)

4.4 Discuss the difference between the LIFO and FIFO methods of evaluating inventory and state ONE advantage of each approach. (8)

[23]

TOTAL: 100

Marking Guidelines

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NOVEMBER 2014

NATIONAL CERTIFICATE

N5

(8140055)

QUESTION 1

1.1 A

1.2 B

1.3 D

1.4 C

1.5 C

1.6 B

1.7 B

1.8 D

1.9 B

1.10 C

1.11 A

1.12 B

1.13 B

1.14 A

(14 x 2) **[28]**

QUESTION 2

2.1 Takes 6% longer, therefore efficiency is 94% (5)

Rated capacity = hours per day x days per week x utilisation x efficiency
= 15 hours/day x 6 days/week x 0,8 x 0,94
= 67,68 hours per week

2.2 (10)

	WEEK 1	**WEEK 2**	**WEEK 3**	**WEEK 4**
Standard hours required	102	95	92	90
Available hours	96	96	96	88
Daily excess (deficit) in hours	(6)	1	4	(2)
Cumulative excess (deficit) in hours	(6)	(5)	(1)	(3)

1 mark for each answer in TABLE (8 X 1 = 8)
No, the centre is not balanced (1 mark)

Since the load exceeds the available capacity (1 mark)

2.3
- Work overtime - capacity response (10)
- Sub-contract some work - capacity response
- Focus on improving output of bottlenecks - capacity response
- Re-route some jobs to other work centres - load response
- Reschedule some orders - load response

[25]

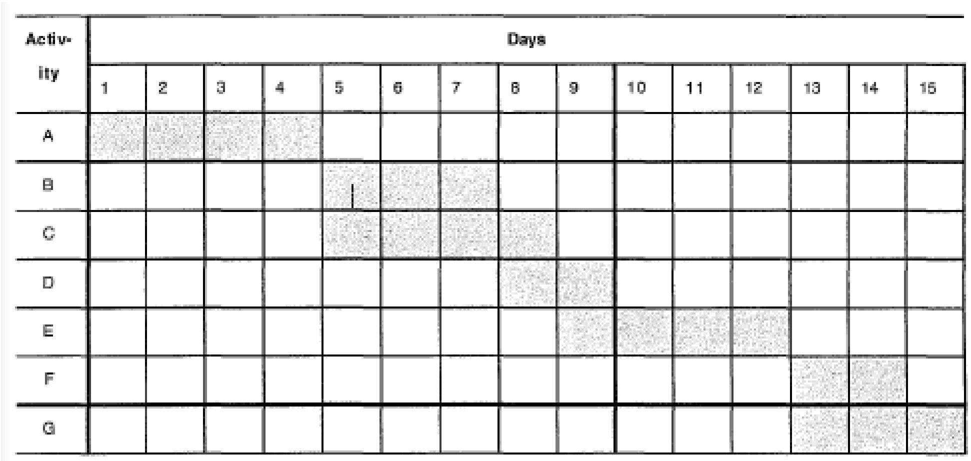
QUESTION 3

3.1
- Set-up time (4)
- Move time
- Queue time
- Run time
- Wait time

3.2 Under a make-to-order policy, products are only manufactured when specifically ordered by customers (1 mark). No finished goods stock is carried (1 mark). (4)

Advantage: the cost of carrying inventory is reduced (1 mark).
Disadvantage: the customer needs to wait for his product (1 mark)

3.3 (10)



Overall length of project= 15 days (1 mark)

3.4
- Manufacturing lead times. If targets are not met, inventory levels can rise and delivery dates may be missed. (6)
- Customer service. If customer service targets are not met, customers may look for alternative suppliers and leave.
- Work in progress levels. If WIP levels are higher than the targets set, bottlenecks may result with a reduction in customer service.
- Schedule performance. Slippage may cause delivery dates to be missed.
- Product quality. If specifications are not met, cost of poor quality will rise and sub-standard product may reach the customer.
- Efficiency of work centres. Inefficiency will result in an increase in WIP and longer lead times.

- Reprocessing and scrap. If these are too high, costs rise and bottlenecks may result as a result of the reprocessing of products. (Any 3 x 2)

[24]

QUESTION 4

4.1 EOQ = $\sqrt{2DS/IC}$ (5)

= $\sqrt{2 \times 5\,000 \times 2/0{,}3 \times 1\,000}$

= $\sqrt{900}$

= 30 units

4.2 (5)

- Provide a secure storage place
- Limit access to the storage area
- Use formal locations within this area to store inventory
- Have authorised receipt and issue procedures
- Undertake systematic stock taking on a periodic basis
- Clearly identify/label inventory items (Any 5 x 1)

4.3 (5)

- Customer service
- Inventory investment
- Manufacturing, purchasing and distribution
- Profitability
- Return on investment

4.4 LIFO stands for 'last in first out' i.e. it assumes that the most recently received stock will be issued first (1 mark). The issues are therefore valued at the cost of the remaining latest receipts. (1 mark) (8)

LIFO advantage=: Increases cash flow. (1 mark)

LIFO disadvantage:
Increases cost of goods
Decreases profits
Complicated and difficult to manage
(Any ONE; 1 x 1)

The FIFO method, on the other hand, stands for 'first in first out' and assumes that the items that are received first are issued last (1 mark).
The issues are therefore valued at the cost of the oldest stock (1 mark)

FIFO advantage:
Decreases cost of goods sold
Increases profits (Any ONE; 1 x 1)

FIFO disadvantages:
Decreases cash flow
Complicated and difficult to manage (Any ONE; 1 x 1)

[23]

TOTAL: 100

Past Examination Papers

higher education
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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

August 2014

NATIONAL CERTIFICATE

PRODUCTION AND QUALITY CONTROL N5

(8140055)

4 August (Y-Paper)
13:00 – 16:00

This question paper consists of 8 pages.

TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Number the answers according to the numbering system used in this question paper.
3. Any calculations must be clearly shown and the answers given to TWO decimal places.
4. Rule off across the page on completion of each section.
5. Write neatly and legibly

SECTION A

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A-D) next to the question number (1-15) in the ANSWER BOOK.

1 Rough cut capacity planning should ...

A determine the feasibility of the master production schedule.
B manage work in progress on the shop floor.
C highlight potential bottlenecks.
D achieve all of the above mentioned

2 Controlling the sequence of work on the shop floor and maintaining low stock levels are key objectives of ...

A production planning.
B production activity control.
C material requirements planning.
D inventory management.

3 The volume of manufacturing orders scheduled for a work centre is known as that work centre's ...

A load.
B capacity.
C productivity.
D utilisation

4 A work centre has the capacity to produce 5 pumps per hour. If the monthly production plan is for 1 000 pumps and the waste factor during production is 2%, the monthly load on the work centre will be ... hours.

A 196
B 200
c 202
D 204

5 An example of a load response to balancing load and capacity is ...

A rescheduling.
B sub-contracting.
C bottleneck management.
D working overtime.

6 If the standard time for a work centre to produce one unit is 12 minutes, and the daily demand is 40 units, then that work centre ...

A has excess capacity if it works 8 hours per day.
B is overloaded if it works 8 hours per day.
C is balanced if it works 8 hours per day.
D None of the above mentioned

7 Assume that a work centre takes 7 hours to complete an operation which has a standard time of 8 hours. The efficiency of that work centre is ... %
A 12.5
B 70
C 80
D 87.5

8 The capacity of a department can be defined as ...

A the amount of orders scheduled for that department.
B the output that the department is capable of producing.
C output minus input.
D the sum of rated capacity and demonstrated capacity.

9 A work centre has an actual input of 50 hours per week over a three week period. The actual outputs over this period were 47, 52 and 48 hours. The work-in-progress (WIP) at the end of the three week period is ... hours.

A 0
B 1
C 3
D 6

10 Which of the following is an example of a project scheduling technique?

A Flow control scheduling
B Forward loading
C Backward loading
D Critical path method

11 A system under which manufacturing orders are pulled from one work centre to the next is known as ...

A continuous production.
B batch manufacturing.
C Kanban.
D Kaizen.

12 The process of checking whether products conform to specifications is known as ...

A quality control.
B quality planning.
C quantity planning.
D quality assurance.

13 Forward loading and backward loading are examples of ...

A operations scheduling techniques.
B bottleneck management.
C project scheduling techniques.
D production activity control.

14 If 1 0% of finished goods are unavailable when requested by customers, it means that ...

A 1 0% of customers are dissatisfied.
B the fill rate is 10%.
C the fill rate is 90%.
D throughput is 90%.

15 A point-of-use storage system would probably have the advantage of ...

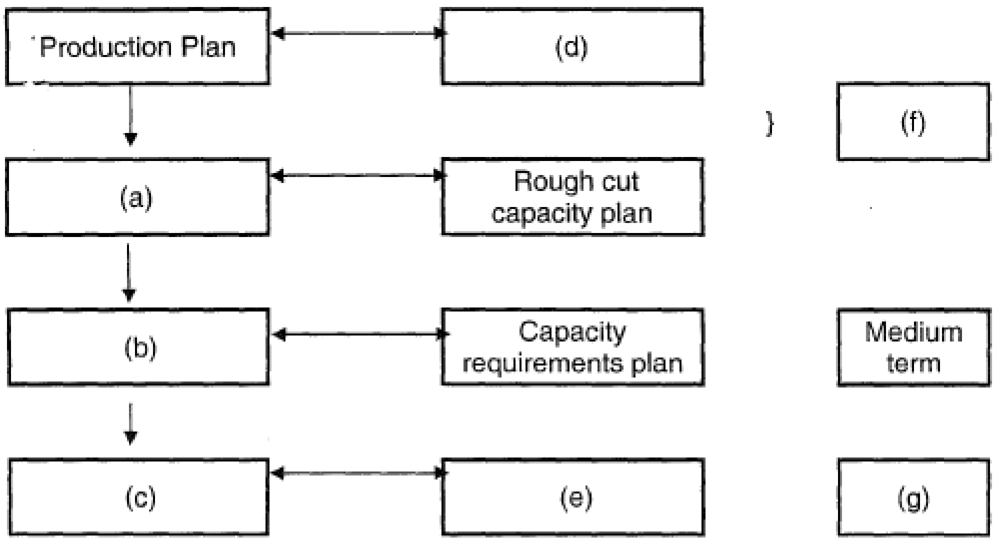
A improving quality.
B reducing lead times.
C lowering costs.
D increasing profit.

(15 x 2) **[30]**

TOTAL SECTION A: 30

SECTION B

1 Complete this diagramme showing the capacity management hierarchy. Write only the word(s) next to the letters (a-g) in the ANSWER BOOK. (7)



2 The sales forecast that a particular machine needs to meet over a four month period is given below. (8)

Redraw the table in your ANSWER BOOK and complete the table by showing the production plan and load for this machine, based on a waste factor of 5% and a load profile of 6 units per hour.

	Feb	Mar	Apr	May
Sales forecast (units)	1 060	1 120	1 240	1 380
Production plan (units)				
Load (hours)				

3 Explain what is meant by a bottleneck and describe how companies should manage such centers to minimise delays. (6)

4 Explain what is meant by the term 'productivity', and give three common reasons for low productivity. (5)

[26]

TOTAL SECTION B: 26

SECTION C

1 Explain what is meant by a make-to-stock manufacturing policy. (4)

Give ONE advantage and ONE disadvantage of this approach.

2 Describe what is meant by Just-in-time (JIT) manufacturing and list FOUR benefits of this manufacturing strategy. (6)

3 A project is planned as follows: (10)

Activity	Duration	Details
A	3 days	
B	4 days	depends on A
C	6 days	depends on A
D	2 days	depends on B
E	3 days	depends on C
F	2 days	depends on E
G	3 days	depends on E

Prepare a Gannt chart to determine the overall length of the project.

4 Describe briefly how customer - supplier relationships are changing as companies strive to become more competitive. (4)

[24]

TOTAL SECTION C: 24

SECTION D

1	Name the FIVE aspects of a business that inventory management seeks to optimise.	(5)
2	Assume that a company experiences the following stock movements over a five day period: Day 1 : Receipt of 500 units at R21 per unit Day 2 : Receipt of 1 000 units at R18 per unit Day 5 : Issue of 500 units Calculate the value of stock at the end of day 5 using the following methods of inventory evaluation: (a) the FIFO method (b) the LIFO method (c) the weighted average method	(10)
3	Give any FIVE advantages of *distribution requirements planning*	(5)
		[20]
	TOTAL SECTION D:	**20**
	GRAND TOTAL:	**100**

Marking Guidelines

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

AUGUST 2014

PRODUCTION AND QUALITY CONTROL N5

(8140055)

4 August (Y-Paper)
13:00 – 16:00

SECTION A

1	D
2	B
3	A
4	D
5	A
6	C
7	D
8	B
9	C
10	D
11	C
12	A
13	A
14	C
15	B

(15 x 2) **[30]**

TOTAL SECTION A: 30

SECTION B

1 a) Master production schedule (7)
b) Material requirements plan
c) Shop floor control
d) Resource requirements plan
e) Input output control
f) Long term
g) Short term

2 (8)

	Feb	Mar	Apr	May
Sales forecast (units)	1 060	1 120	1 240	1 380
Production plan (units)	1 113 *(1)*	1 176 *(1)*	1302 *(1)*	1 449 *(1)*
Load (hours)	185.5 *(1)*	196 *(1)*	217 *(1)*	241.5 *(1)*

3 A bottleneck is a work centre that is always overloaded (1 mark) ie its output determines the output of the entire organisation (1 mark). The entire organisation should focus on (any four of, 1 mark each: (6)

- ensuring the work centre never stops - work shifts and stagger lunch breaks
- ensuring that compulsory stoppages are minimised
- treating any breakdowns in the bottleneck centre as top priority
- maximising processing speeds in the work centre
- performing as much preparation as possible before the next job starts
- investigating re-routing to other work centres

4 Productivity is defined as efficiency multiplied by utilisation (1 mark). Also output over input (1 mark) (5)
Causes of poor productivity : Any three valid reasons such as poorly trained staff, old machinery, low utilisation, poor quality requiring rework, machine breakdowns, poor factory layout (1 mark each).

[26]

TOTAL SECTION B: 26

SECTION C

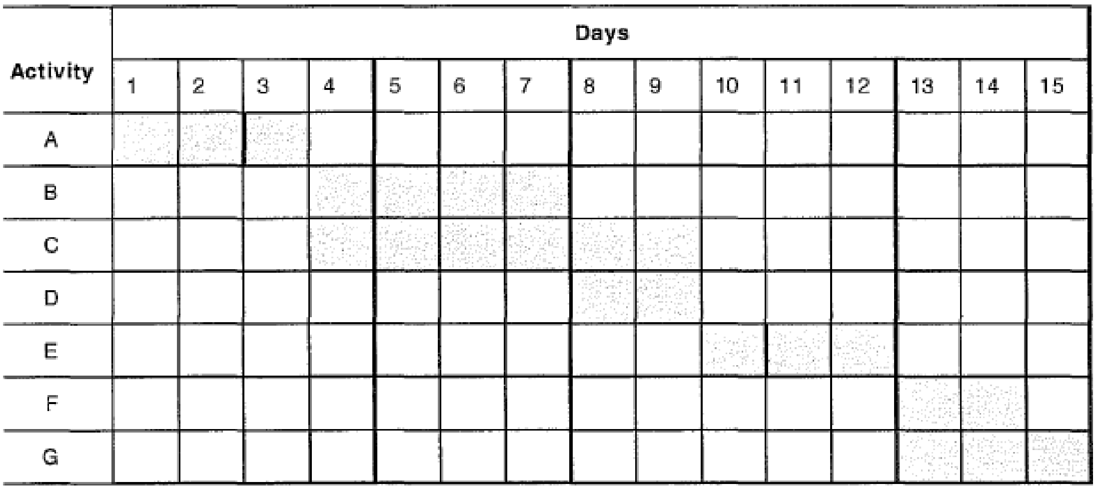
1 Under a <u>make-to-stock</u> policy, products are manufactured based on forecasts of demand *(1 mark).* They are then put into finished goods stock until sold *(1 mark).* (4)
<u>Advantage</u> : Capacity management is easier *I* capacity can be better utilised, lowering production costs *(1 mark).*
<u>Disadvantage</u> : Inventory costs are high or inventory can get damaged(1 *mark)*

2 Just-in-time (JIT) is a manufacturing strategy in which jobs are planned to arrive at a work centre just in time for processing *(1 mark).* It is also concerned with the continuous elimination of waste *(1 mark).* Benefits *(1 mark each):* (6)

- Reductions in lead times
- Reductions in stocks I inventory
- Smaller batches are produced
- Responsibility for quality is introduced at each work centre

3 One mark for correct layout (1 mark) (10)
One mark for correct axis headings (1 mark)
One mark for correctly showing each activity duration i.e. start and end day

(7 marks)



Overall length of project = 15 days *(1 mark)*

4 • Companies are striving to develop long term relationships with their suppliers addressing quality, delivery, cost and overall customer service. (4)
• JIT deliveries based on Kanban releases are replacing predefined deliver schedules.
• Incoming inspection by the customer is being replaced by quality at source i.e. suppliers are taking greater responsibility tor the quality of their goods.
• Companies are also reducing their numbers of suppliers - best suppliers are identified and more work is being given to them.
• Companies are thus able to spend more time with their suppliers.

[24]

TOTAL SECTION C: 24

QUESTION 4

1 • customer service (5)
• inventory investment
• manufacturing, purchasing and distribution
• profitability
• return on investment

2 a) <u>FIFO method</u> (10)

Under FIFO (first-in-first-out) the 500 units issued are assumed to be from the first receipt i.e. from day 1 *(1 mark).* Therefore, the value of the remaining stock is:
(500-500m) at R21 + 1000m at R18 = **R18 000** *(2 marks)*

b) <u>LIFO method</u>
Under LIFO (last-in-first-out) the 500 units issued are assumed to be from the most recent receipt i.e. from day 2 *(1 mark).* Therefore, the value of the remaining stock is:

500m at R21 + (1000- 500m) at R18 = R10 500 + R R9000 = **R 19 500** *(2 marks)*

c) <u>Weighted average method</u>
Total stock receipts= 1500 units
Weighted value of stock received on day 1 = 500/1500 X R21 = R7 per m *(1 mark)*
Weighted value of stock received on day 2 = 1000/1500 X R18 = R12 per m *(1 mark)*

Therefore, total weighted average value of stock= R7 + R12 = R19 perm

The value of the remaining stock is (1500- 500) X R19 = **R19 000** *(2 marks)*

3 (5)

- improved customer service
- improved inventory management
- improved distribution
- reduction in inventories
- reduction in obsolete inventories
- improved financial planning and control
- improved communication and market information (Any 5 x 1)

[20]

TOTAL SECTION D: 20

GRAND TOTAL: 100

Past Examination Papers

higher education & training

Department: Higher Education and Training
REPUBLIC OF SOUTH AFRICA

April 2014

NATIONAL CERTIFICATE

PRODUCTION AND QUALITY CONTROL N5

(8140055)

7 April (Y-Paper)
13:00 – 16:00

This question paper consists of 7 pages.

TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Any calculations must be clearly shown and the answers given to TWO decimal places.
5. RULE OFF across the page on completion of each section.
6. Write neatly and legibly

QUESTION 1

Various options are given as possible answers to the following questions. Choose the answer and write only the letter (A-D) next to the question number (1.1-1.14) in the ANSWER BOOK.

1.1 The primary input for resource requirements planning is ...

A the production plan.
B the material requirements plan.
C shop floor control.
D the master production schedule

1.2 Medium term capacity planning is known as …

A input output control
B rough cut capacity planning
C resource requirements planning
D capacity requirements planning

1.3 An example of a capacity response to balancing load and capacity is …

A rescheduling
B alternate routing
C working overtime
D None of the above mentioned

1.4 The volume of manufacturing orders scheduled for a work centre is known as that work centre's …

A utilization
B capacity
C productivity
D load

1.5 If the standard time for a work centre is to produce one unit every 6 minutes, and the daily demand is for 120 units, then that work centre …

A has insufficient capacity if it works 12 hours per day
B has excess capacity if it works 12 hours per day
C is balanced if it works 12 hours per day
D is a bottleneck centre if it works 12 hours per day

1.6 If the output of a machine varies between 10 and 13 units per hour, with an average output of 11.8 units per hour, then the demonstrated capacity of that machine is ... units per hour.

A 10
B 13

C 11,5
D None of the above mentioned

1.7 A work centre has an actual input of 120 units per week over a four week period. The actual outputs over this period were 114, 119, 123 and 122 units per week respectively. The cumulated work-in-progress (WIP) at the end of the four week period is ... units.

A 0
B 2
C 4
D 10

1.8 If a production department has an efficiency of 90% and utilisation of 80%, the productivity of that department is ... %

A 90
B 85
C 80
D 72

1.9 Electricity generation is an example of …

A continuous production.
B jobbing
C batch manufacturing
D project manufacturing

1.10 The LIFO method of evaluating stock is characterised by ...

A higher profits, but weaker cash flow.
B stronger cash flow, but lower profits.
C weaker cash flow and higher cost of manufacturing.
D high profits and strong cash flow.

1.11 Ensuring that work input and output are balanced is the function of ...

A information technology
B input output control
C shop floor control
D production leveling

1.12 Gantt charts are used for ...

A production control.
B project scheduling.
C counting inventory.
D quality control.

1.13 The scheduling technique that is based primarily on setting and meeting production rates is known as ...

A mixed model production scheduling.
B the critical path method.
C flow control scheduling.
D None of the above mentioned

1.14 If a company has annual sales of R90 million and an average inventory of R 15 million, then its inventory turnover is ...

A 6 times.
B R75 million.
C R90 million.
D 25%.

(14 x 2) **[28]**

QUESTION 2

2.1 The sales forecast that a particular department needs to meet over a four week period is given below. (8)

Complete the TABLE below to show the production plan and load for this machine, based on a waste factor of 5% and a load profile of 2 units per hour.

	WEEK 1	WEEK 2	WEEK 3	WEEK 4
Sales forecast (units)	100	120	140	160
Production plan (units)				
Load (hours)				

2.2 Describe fully any FOUR elements of lead time. Also provide TWO advantages of reducing lead times. (10)

2.3 Describe what is meant by the term rated capacity and list the factors that should be considered when calculating it. (6)

[24]

QUESTION 3

3.1 Explain the difference between a *make-to-order* and a *make-to-stock* manufacturing policy. Give ONE advantage of each. (6)

3.2 Describe what is meant by plant layout according to work cells and give THREE advantages of this approach. (2 +3) (5)

3.3 Assume that a work centre has a demonstrated capacity of 500 unnits per day and receives the following manufacturing orders: (10)

Day:	1	2	3	4	5
Order	400	600	300	700	300

Prepare a TABLE showing the manufacturing schedule based on the following:

3.1.1 The backward loading technique

3.1.2 The forward loading technique

3.4 Name any FOUR performance measurements that are important for ensuring control on the factory floor. (4)

[25]

QUESTION 4

4.1 Give any FOUR objectives of Distribution Requirements Planning (ORP). (4)

4.2 The annual demand for a chemical is 800 kg; the ordering cost is R20 per order; the inventory holding cost is 20% per year, and the unit cost is R100 per kg. (5)

Calculate the Economic Order Quantity, EOQ= √ (2DS/IC).

4.3 Describe the THREE types of inventory typically faun~~. iri(i;fJlanufact~[rlng companies. (6)

4.4 Assume that a company experiences the following stock movements, over a five day period: (8)

Day 1 : Receipt of 50 units at R210 per unit
Day 2 : Receipt of 100 units at R180 per unit
Day 5 : Issue of 50 units

Calculate the value of stock at the end of Day 5, using the following methods of inventory evaluation:

4.4.1 FIFO method

4.4.2 LIFO method

[23]

TOTAL: 100

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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

PRODUCTION AND QUALITY CONTROL N5

(8140055)

7 April (Y-Paper)
13:00 – 16:00

QUESTION 1

1.1 A

1.2 D

1.3 C

1.4 D

1.5 C

1.6 D

1.7 B

1.8 D

1.9 A

1.10 B

1.11 D

1.12 B

1.13 C

1.14 A

(14 x 2) **[28]**

QUESTION 2

2.1 (8)

	Week 1	Week 2	Week 3	Week 4
Sales forecast (units)	100	120	140	160
Production plan (units)	105 *(1)*	126 *(1)*	147 *(1)*	168 *(1)*
Load (hours)	52.5 *(1)*	63 *(1)*	73.5 *(1)*	84 *(1)*

2.2 (10)

- Set-up time is the time taken to set up a machine or work centre for production
- Move time is the time taken to transport or move a job/product from one work centre to the next.
- Queue time is the time that a job waits in a work centre before it is processed.
- Run time is the time taken to perform the work on a task/job/assignment.

- Wait time is the time taken while a job is waiting to be transported to the next work centre.
  (Any FOUR of the above; 1 mark for the name, 1 mark for the description).

ADVANTAGES OF REDUCING:

- Improves throughput
- Reduces WIP
- Reduces waste
- Reduces manufacturing costs
  (Any TWO or something similar- *1 mark each)*

2.3
- The work center's efficiency (6)
- The work center's utilisation
- The number of shifts worked
- The scrap/rework rate
- The amount of overtime worked

Rated capacity is the theoretical capacity of a work centre that can be calculated *(1 mark).* It is calculated from *(1 mark for each of):*

[24]

QUESTION 3

3.1 Under a make-to-order policy, products are only manufactured when specifically ordered by customers *(1 mark).* No finished goods stock is carried *(1 mark).* (6)
ADVANTAGE: the cost of carrying inventory is reduced *(1 mark).*

Under a make-to-stock policy, products are manufactured based on forecasts of demand *(1 mark)* They are then put into finished goods stock until sold *(1 mark).*
ADVANTAGE: Capacity management is easier/capacity can be better utilised, lowering production costs *(1 mark).*

3.2 Work cells are usually used when a Just-in-time production strategy is followed *(1 mark).* This form of plant layout involves grouping together operations or work centres that produce a particular product *(1 mark).* (5)

Work cells have the following advantages: *(Any 3 x 1, 1 mark each):*
- Reduced lead times
- Reduced queues in front of machines
- Reduces WIP stocks
- High visibility of problem areas
- Improved quality
- Improved teamwork

3.3 (10)

Day:	1	2	3	4	5
Order	400	600	300	700	300
Backward	500 *(1)*	500 *(1)*	500 *(1)*	500 *(1)*	300 *(1)*
Forward	400 *(1)*	500 *(1)*	400 *(1)*	500 *(1)*	500 *(1)*

3.4 (4)
- Manufacturing lead times
- Customer service
- Work in progress levels
- Schedule performance
- Product quality
- Efficiency of work centres
- Reprocessing and scrap (Any 4 x 1)

[25]

QUESTION 4

4.1 (4)
- Improved customer service
- Improved inventory management
- Improved distribution
- Reduction in inventories
- Reduction in obsolete inventories
- Improved communication and market information
- Improved financial planning and control (Any 4 x 1)

4.2 (5)

EOQ = √ 2DS/IC
= √2 x 800 x 20 / 0,2 x 100 *(2 marks)*
= √32 000 / 20 *(1 mark)*
= √1 600
= 40 kg *(2 marks)*

4.3 (6)

Raw material (1 mark): all material to be used in the manufacture of a finished product (1 mark)
Work-in-progress (1 mark): inventory on the factory floor in various stages of production (1 mark)
Finished goods (1 mark): completed (fully produced) goods which are available for sale (1 mark)

4.4 (8)

4.4.1 FIFO method
Under FIFO (first-in-first-out) the 50 units issued are assumed to be from the first receipt i.e. from day 1 *(1 mark).*
Therefore, the value of the remaining stock is:
(50- 50) units at R21 0 + 100 units at R180 *(1 mark)*
= R18 000 *(2 marks)*

4.4.2 LIFO method
Under LIFO (last-in-first-out) the 50 units issued are assumed to be from the most recent receipt, i.e. from Day TWO (*1 mark).*

Therefore, the value of the remaining stock is:
50 units at R210 + (100- 50) units at R180 = R10 500 + R9 000
(1 mark)
= R19 500 *(2 marks).* (2 x 4)

[23]

TOTAL: 100

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