THE ASSUMPTIONS, IN LIMITING FACTOR ANALYSIS ARE THAT A RESOURCE CONSTRAINT IS A SHORT-TERM PROBLEM AND THAT A BUSINESS SEEKS TO MAXIMISE TOTAL PROFIT WITH THE MANUFACTURING RESOURCES AVAILABLE. THIS FIRST ARTICLE ADDRESSES PROBLEM 1 – HOW TO DETERMINE THE PRODUCT MIX TO BEST UTILISE A LIMITING FACTOR.

LIMITING FACTOR

RELEVANT TO CAT PAPER 4

The CAT Paper 4 *Study Guide* includes limiting factor analysis within Section 17 Decision Making, covering situations where there is a shortage of a key resource that a business uses in the production of its components/products. Examples of a key resource that may be in short supply include a particular raw material, type of labour or machine capacity. The key resource in short supply becomes the limiting factor, ie it means that the business is unable to produce sufficiently to satisfy sales demand.

When a business has a limiting factor, caused by a resource constraint, a decision needs to be taken as to how the available resources can be best utilised. The assumptions, in limiting factor analysis relevant to CAT Paper 4, are that a resource constraint is a short-term problem and that a business seeks to maximise total profit with the manufacturing resources available.

Limiting factor problems

There are two distinct limiting factor problems, for a business with more than one product, in such a manufacturing environment:

1 How to maximise contribution when the availability of a key resource is insufficient to satisfy sales demand. This problem is solved by establishing the mix of products to manufacture and sell in order to best utilise the limited resource available, based on the contribution each product makes per unit of the scarce resource (limiting factor).
2 How to maximise contribution when the availability of a key resource is insufficient to satisfy sales demand but the resource limitation can be overcome by buying in components/products from another manufacturer. This problem is solved by minimising the incremental costs incurred in buying in, based on the difference in costs (bought-in versus in-house) per unit of the scarce resource (limiting factor) required in manufacture.

Problem 1 covers 17(c) in the CAT Paper 4 *Study Guide* – 'formulate and determine the optimal production solution when there is a single resource constraint'. Question 4 (Section B) in the June 2008 CAT Paper 4 exam is an illustration of this type of problem.

Problem 2 covers 17(d) in the CAT Paper 4 *Study Guide* – 'solve make/buy-in problems when there is a single resource constraint'. Question 1 (Section B) in the June 2009 CAT Paper 4 exam is an illustration of this type of problem.

Both of the above questions were poorly answered by candidates, indicating that those studying for CAT Paper 4 generally have an inadequate grasp of the topic. The purpose of this, and a subsequent article, is to cover each of the two types of limiting factor decision-making problem described above, using the June 2008 and June 2009 past questions respectively to illustrate the analysis required.

This first article addresses problem 1 – how to determine the product mix to best utilise a limiting factor.

Question 4, June 2008

A company manufactures three products (X, Y and Z). All direct operatives are the same grade and are paid at $11 per hour. It is anticipated that there will be a shortage of direct operatives in the following period, which will prevent the company from achieving the following sales targets:

Product X	3,600 units
Product Y	8,000 units
Product Z	5,700 units

Selling prices and costs are shown in **Table 1** opposite.

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ANALYSIS: PT 1

Required:
Determine the production plan that would maximise profit in the following period, if the available direct operatives' hours total 26,400.

Approach

As there is more than one product that uses the scarce labour resource, the approach to determining the optimal production plan is as follows:

1 Identify the scarce resource (limiting factor).
2 Establish the units of the scarce resource used by each product.
3 Calculate the contribution (sales less variable costs) per unit of each product.
NB As stated earlier, it is assumed that the allocation of available resources is a short-term decision with the objective of maximising total profit (also made clear in the question). As such, fixed costs can be assumed to be unaffected by the product mix and thus irrelevant to the decision (also made clear in the question scenario). The decision is based on contribution.
4 Calculate the contribution of each product per unit of the scarce resource consumed.
NB It can only be by prioritising the allocation of resources to those products that make the most contribution for every unit of the key resource consumed that total contribution, and thus total profit, will be maximised.
5 Establish production priority by ranking products according to the contribution per unit of the scarce resource.
6 Allocate the available scarce resource according to the ranking.

Solution

Question 4 from the June 2008 paper will be answered using the six stages outlined in the above approach:

TABLE 1: PRODUCT X, Y AND Z SELLING PRICES AND COSTS (QUESTION 4, JUNE 2008 PAPER 4 EXAM)

	Product X $ per unit	Product Y $ per unit	Product Z $ per unit
Selling prices	100.00	69.00	85.00
Variable costs:			
Production*	51.60	35.00	42.40
Non-production	5.00	3.95	4.25
Fixed costs:			
Production	27.20	19.80	21.00
Non-production	7.10	5.90	6.20
* includes the cost of direct operatives	24.20	16.50	17.60

The fixed costs per unit are based on achieving the sales targets. There would not be any savings in fixed costs if production and sales are at a lower level.

LIMITING FACTOR PROBLEMS IN THE JUNE 2008 AND JUNE 2009 EXAMS WERE POORLY ANSWERED BY CANDIDATES, INDICATING THAT THOSE STUDYING FOR CAT PAPER 4 GENERALLY HAVE AN INADEQUATE GRASP OF THE TOPIC.

1 Limiting factor
It is already clear from the question that the shortage of direct operatives is the limiting factor, ie the shortage will prevent the company from achieving the sales targets. To prove the fact (because such calculations may be required in answer to other such questions), and to provide some of the figures that will be used in subsequent stages below, the total direct operative hours required to achieve the sales targets are:

Product X	$24.20/unit ÷ $11/hr = 2.2 hrs per unit × 3,600 units =	7,920 hrs
Product Y	$16.50/unit ÷ $11/hr = 1.5 hrs per unit × 8,000 units =	12,000 hrs
Product Z	$17.60/unit ÷ $11/hr = 1.6 hrs per unit × 5,700 units =	9,120 hrs
		29,040 hrs

Direct labour hours available are 2,640 less (26,400 - 29,040) than those required to achieve the sales targets.

2 Units of the scarce resource used by each product
The amount of the scarce resource (in hrs) used by each product was calculated in stage 1 above (2.2, 1.5 and 1.6 hours per unit for Products X, Y and Z respectively). Alternatively, the amount of the scarce resource used by each product expressed in $, which was given in the question (ie $24.20, $16.50 and $17.60 for Products X, Y and Z respectively) could be used.

A HIGH NUMBER OF CANDIDATES SIMPLY ASSUMED THAT THE SALES TARGETS COULD BE ACHIEVED AND PROVIDED PROFIT STATEMENTS (AN ADDITIONAL REQUIREMENT NOT COVERED IN THIS ARTICLE) BASED ON THOSE. THESE CANDIDATES, THEREFORE, COMPLETELY FAILED TO IDENTIFY AND SOLVE THE LIMITING FACTOR PROBLEM.

3 Contribution per unit of product
Contribution is sales revenue less variable costs (both production and non-production). Thus:

Product X	$100.00 - $56.60 (51.60 + 5.00) = $43.40 per unit
Product Y	$69.00 - $38.95 (35.00 + 3.95) = $30.05 per unit
Product Z	$85.00 - $46.65 (42.40 + 4.25) = $38.35 per unit

4 Contribution per unit of scarce resource
The contribution per unit of scarce resource can be calculated either as a $ contribution per hour of direct operative time or as a $ contribution per $ cost of direct operatives. Thus:

Product X	$43.40/unit ÷ 2.2 hrs/unit = $19.73 per direct operative hour
Product Y	$30.05/unit ÷ 1.5 hrs/unit = $20.03 per direct operative hour
Product Z	$38.35/unit ÷ 1.6 hrs/unit = $23.97 per direct operative hour

or

Product X	$43.40/unit ÷ $24.20/unit = $1.793 per $ cost of direct operatives
Product Y	$30.05/unit ÷ $16.50/unit = $1.821 per $ cost of direct operatives
Product Z	$38.35/unit ÷ $17.60/unit = $2.179 per $ cost of direct operatives

5 Production priority
On the basis of the contribution per unit of the scarce resource, Product Z would be manufactured as the first priority ($23.97/hr or $2.179/$ cost), followed by Product Y ($20.03/hr or $1.821/$ cost) and finally Product X ($19.73/hr or $1.793/$ cost). The same conclusion would be reached whichever of the calculations in stage 4 was used because the basis is the same. The contribution per $ cost of the direct operatives multiplied by the hourly rate of pay will equal the contribution per direct operative hour. For example, for Product X $1.793 per $ cost × $11 per hour = $19.73 per hour.

AMONG THOSE CANDIDATES WHO MADE A BETTER EFFORT, MANY WERE UNABLE TO CALCULATE THE CONTRIBUTIONS PER UNIT OF PRODUCT CORRECTLY, AT TIMES NOT INCLUDING THE VARIABLE NON-PRODUCTION COSTS, DOUBLE-COUNTING LABOUR COSTS OR INCLUDING ALL COSTS AND THUS BASING THE ANALYSIS ON NET PROFIT PER UNIT.

It should be noted that the priority, in this example, is quite different from that indicated by using (incorrectly) the contribution per unit of product. This would have indicated priority of Product X ($43.40/unit), followed by Product Z ($38.35/unit) and finally Product Y ($30.05/unit). Although Product X has the highest contribution per unit, it requires disproportionately more direct operative hours to achieve it.

6 Allocate the scarce resource

The scarce resource of direct operative hours needs to be allocated according to the production priority established in stage 5 above. Product Z has first priority and so the direct operative hours will be allocated up to the limit required to achieve the sales target of 5,700 units. This was calculated in stage 1 to be 9,120 hours. The next priority is Product Y. The allocation of the 26,400 hours available can be set out as follows:

Product Z	9,120 hours	5,700 units
Product Y	12,000 hours	8,000 units
	21,120 hours	
Product X	5,280 hours	2,400 units
	(26,400 - 21,120)	(5,280 hours ÷ 2.2 hours/unit)
	26,400 hours	

It can be seen that demand for Products Z and Y can be fully satisfied leaving the balance of labour hours available to be used for Product X. Product X is restricted to 2,400 units with the remaining hours. This is the production plan that would maximise total contribution and total profit because it gives priority to those products that generate the greatest contribution per unit of the scarce resource.

Examiner's comments on candidates' performance

A high number of candidates simply assumed that the sales targets could be achieved and provided profit statements (an additional requirement of the exam question not covered in this article) based on those. These candidates, therefore, completely failed to identify and solve the limiting factor problem.

Where candidates did identify the problem, a number of them calculated the total profit of each product on the target sales and used this to establish priority. Among those candidates who made a better effort, many were unable to calculate the contributions per unit of product correctly, at times not including the variable non-production costs, double-counting labour costs or including all costs and thus basing the analysis on net profit per unit.

Some candidates did not get beyond the calculation of a contribution/profit per unit of product. Many others divided the contribution/profit per unit of product by the labour cost per hour rather than by the labour cost per unit of product or by the labour hours per unit of product. Finally, a number of candidates had difficulty establishing the production priority using their own figures and/or the production plan.

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